Designing Frameworks to Deliver Unknown Information to Support MBIs

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Abstract

This paper reports on a Catchment Modelling Framework (CMF) designed to support an Australian pilot of an auction for multiple environmental outcomes – EcoTender. The CMF is used to estimate *multiple* environmental outcomes including carbon, terrestrial biodiversity, aquatic function (water quality and quantity) and saline land area. This information was previously unavailable for application to environmental markets. This is the first time a market-based policy has been fully integrated from desk to field with a Catchment Modelling Framework for the purchase of multiple outcomes.

This framework solves the *unknown information* problem of linking paddock scale landuse and management to catchment-scale environmental outcomes. The framework provides the Victorian government with a replicable transparent evidence-based approach to the procurement of environment outcomes.

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1 Introduction

In Australia over the past five years, the use of market-based approaches has received considerable attention from both state and federal government agencies. Most notably there has been an allocation of funds to pilot Market Based Instruments (MBI) for the environment by the National Action Plan for Salinity and Water Quality, funded by both the state and federal governments. The National MBI Pilots Program seeks to increase Australia's capacity to use MBIs in managing natural resource issues, in particular to address the problems of salinity and water quality.

MBIs attempt to produce relatively more efficient outcomes than traditional instruments such as grants and fixed price schemes for the provision of environmental services (NMBIWG 2005). They do this by increasing the environmental outcomes attainable for a given budget or maintaining a given level of pollution at minimum cost.

One of the key features of MBIs is their ability to deal with asymmetric information problems. MBIs such as auctions and cap and trade allow government to implement environmental policies where these asymmetric information problems exist. These approaches provide incentives for those participating in the environmental market to truthfully reveal costs and actions they can undertake to provide environmental outcomes cost effectively.

The implementation of new instruments in the national pilot program highlighted the need for new and often missing information linking actions in the landscape to environmental outcomes (NMBIWG 2005). There needs to be very good biophysical modelling at the farm or paddock level to capture the spatial and temporal nature of the problems (Grafton 2005). For example, determining the impact of revegetation by a landholder on river flows and saline land area in the catchment. This problem is particularly acute for non-point environmental problems, which made up the bulk of the pilots that were funded under the national MBI program.

The Department of Primary Industries, Victoria received funding from the national MBI program to pilot an auction (EcoTender) to procure multiple environmental outcomes (Eigenraam *et al* 2006). The project developed an auction for environmental goods and a spatial modelling framework, which were successfully applied to two sub-catchments in Victoria.

In this paper we examine the EcoTender pilot auction for multiple environmental outcomes – saline land, carbon sequestration, terrestrial biodiversity and aquatic function. The pilot was run in two sub-catchments in Victoria, namely the Avon Richardson (371,000ha) and Cornella (47,000ha), see Figure 1 below.

Figure 1. Pilot areas

Catchment selection was based on data availability, the areal extent of any proposed land use change, the type of management considered by land managers and a requirement that the focus catchment be a priority region as identified by the appropriate state and regional authorities.

EcoTender is a multi-outcome extension of BushTender that focused on one environmental outcome, terrestrial biodiversity (Stoneham *et al* 2003). The basic rationale for including several goods in the auction mechanism is twofold. First, environmental goods may be 'jointly supplied'. For example if a landholder plants trees, this may simultaneously affect carbon sequestration, saline land and aquatic function. Second, since auctions for environmental goods involve site visits, it may be more economical to visit each landholder only once in relation to all goods, rather than visiting them separately for each good.

The EcoTender pilot provides several new economic and scientific challenges. Whilst EcoTender's predecessor, BushTender dealt with the asymmetric information problem via an auction, the fact that it was a single good meant it was relatively easy to implement. The procurement of multiple environmental goods raises several additional economic issues, particularly in terms of the revelation of preferences when an agency is buying multiple environmental goods and they are jointly produced.

Scientifically, EcoTender is a more sophisticated policy response than BushTender. It requires the estimation of an 'environmental production function' to express landholder actions in terms of environmental goods. This raises issues on how to estimate this function and the cost of doing so. The science is further complicated because it needs to connect with the increased economic demands for expressing preferences. In Section 2 we examine conceptual issues that arise when procuring multiple environmental outcomes, specifically joint production and agency preferences. This is followed by a discussion of methods to represent and implement an environmental production function in Section 3. Finally, we detail how EcoTender was implemented in Section 4 and provide results and concluding comments in Sections 5 and 6.

2 Conceptual Issues

Auctions have been used in the past to distribute environmental funds. BushTender, demonstrated significant cost savings could be achieved when compared to other grant based approaches (Stoneham *et al*. 2003). If correctly applied auctions can help to overcome common problems involving *asymmetric information* – where landholders have information about the cost of undertaking an action but this information is hidden from the agency that is providing the funds. The agency needs both cost information from landholders and information linking landholder actions to environmental outcomes (*missing information*), to allocate funds cost effectively. In general, auctions aim to provide private landholders with the incentive to truthfully reveal their cost of undertaking specified actions that produce environmental outcomes.

2.1 Single environmental good

The BushTender pilot focused on the procurement of terrestrial biodiversity benefits, for which the "*habitat hectare*" approach was applied along with other biodiversity-related information to help solve the missing scientific information problem (Parkes *et al*. 2003). BushTender allocated contracts to the lowest cost bids until the budget was exhausted. Figure 2 below depicts a supply curve for terrestrial biodiversity based on the habitat hectare approach (x-axis).

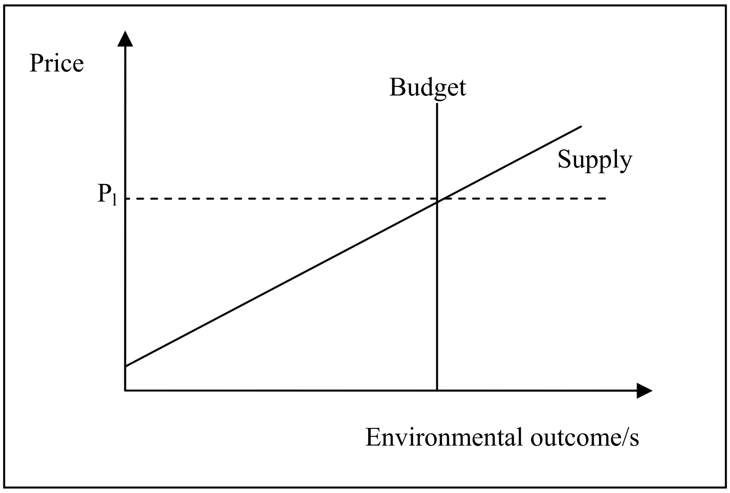

Figure 2. Supply and Demand of Environmental Outcomes

In the context of environmental problems, this suggests that markets for some environmental goods and services might be created if relevant information is discovered and shared between demanders and suppliers of these goods and services.

On the demand-side of BushTender the need to express preferences was made simpler because there was only one good on offer. Further, in order to reduce auction transaction costs the metric 'habitat hectare' contained preferences determined by technical specialists aware of such things as scarcity and extent of current biodiversity[1]. During the selection of bids BushTender assumed the willingness to pay was greater than the price of the last unit purchased (P_l in Figure 2).

2.2 Multiple environmental goods

2.2.1 Joint production

There is a growing recognition that environmental outcomes are correlated – benefits are jointly produced by the same action. For instance, revegetation may jointly produce carbon, improvements to water quality and wildlife benefits. Wu and Bogess (1999) refer to this as an ecosystem-based approach that recognises the interaction between alternative environmental benefits. They show that an efficient fund allocation must account for both physical production relationships between environmental outcomes and the value of those outcomes. Further, Wu and Skelton-Groth (2002) developed an empirical model to demonstrate the extent of fund misallocation when jointly produced environmental benefits are ignored.

Inter-linkages in the landscape mean that an action that affects one environmental good also has other environmental outcomes which may be positive (in the sense that another environmental good is also produced) or negative (another environmental good may be depleted). In this case environmental goods are said to be 'jointly supplied' such that one action, which has one lump sum cost, produces multiple outcomes.

Where environmental goods are not interlinked in the landscape and can be provided separately, an auction for multiple outcomes may still be beneficial to reduce the transaction costs of running a number of auctions. Where goods are not jointly supplied we could make separate or isolated decisions about how much of each good to procure. We may allocate an amount that we are willing to spend on procuring each type of outcome (separate budgets for each good) and then spend each budget on the actions that provide the good for which that particular budget is allocated most cost effectively. This process could be continued for each budget in turn until all budgets are exhausted. With no jointness in supply each budget would be spent on procuring actions that provide only the good for which the budget was allocated.

Multiple environmental outcomes contribute to the difficulty of addressing the demand side problems which cannot be dealt with by assigning a separate budget for each type of public good. Where joint supply exists, an auction to procure an environmental outcome must take account of all jointly supplied environmental outcomes in order to maximise the benefits of the bids accepted in the auction, and to avoid unnecessarily creating negative environmental benefits. Preferences for each of the environmental goods need to be revealed in order to determine the quantum of each good to be procured.

2.2.2 Preferences

For a given budget Figure 3 below shows the consumption possibilities frontier for two environmental goods, terrestrial biodiversity and aquatic function denoted as T and A, respectively. Moving along the frontier from left to right decreases the amount

[1] See Stoneham *et al* 2003 for discussion of demand side preferences and transaction costs.

of terrestrial biodiversity and increase the amount of aquatic function. The frontier represents all possible combinations of bids that can be chosen within the available budget. It is analogous to a production possibilities frontier but in this case the agency has a budget at its disposal and must select from a set of bids to purchase a combination of T and A. Consider points Z_1 and Z_2, two alternative combinations of bids not on the frontier. Z_1 is inefficient because the agency could increase the amounts of T and A it procures by moving out to the frontier and remaining within budget. Whereas Z_2 is outside the frontier and contains more bids than the budget allows, unless the budget were increased.

Each selection of bids (landholders) is budget constrained and results in different input combinations of land and water to achieve the terrestrial and aquatic outcomes. For instance, consider two points on the curve where the agency has $500 budget.

X – 15 bids – produce T_X units of terrestrial biodiversity and A_X units of aquatic function from – 20 units of land, 30 units of water – at a cost of $500

Y – 11 bids – produce T_Y units of terrestrial biodiversity and A_Y units of aquatic function from – 23 units of land, 27 units of water – at a cost of $500

Moving from point X to point Y on the frontier results in less T and more A, and a different selection of bids.

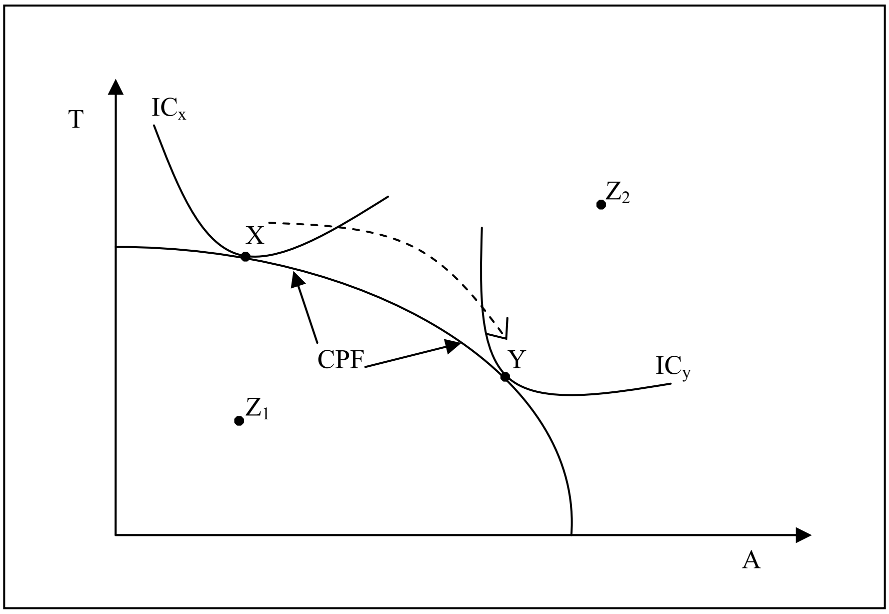

Figure 3. Environmental production possibilities frontier

It now becomes important for the agency to explicitly determine its relative preference for each good. In Figure 3 indifference curves IC_x and IC_y reflect two possible sets of preferences for terrestrial biodiversity and aquatic function. The indifference curves contain different weightings for each of the goods. In order to choose bids the agency will have to make decisions such as deciding whether it is better to accept a bid that delivers more terrestrial biodiversity and less aquatic function or a bid that offers less terrestrial biodiversity and more aquatic function. In making this decision the agency must, either explicitly or implicitly, express a relative preference or 'weighting' between the two goods.

For example, consider three bids received in a procurement auction for two environmental outcomes, terrestrial biodiversity and aquatic function, bids A, B and C as described in Table 1. The procuring agency has a positive willingness to pay for both these environmental outcomes. Bid A is for $15 and has a score of 15 for terrestrial biodiversity and a score of 30 for aquatic function. Bid B is for $15 and has a score of 20 for terrestrial biodiversity and 20 for aquatic function, and bid C is for $15 and has a score of 15 for terrestrial biodiversity and 32 for aquatic function.

Table 1. Three Hypothetical Bids Received in An Auction for Two Goods

	Bid A	Bid B	Bid C
Units of Terrestrial Biodiversity (Hha x BSS)	15	20	15
Units of Aquatic Function (T/ha x mm/ha)	30	20	32
Bid Cost ($)	15	15	15

Comparing the three bids, it is possible to conclude that an agency, whatever it's preferences between the goods and given sufficient budget, would choose to accept bid C over bid A. Doing so enables it to, for the same cost, obtain the same amount of terrestrial biodiversity but more aquatic function. However, when deciding whether it will accept bid A or bid B, the choice is not as clear because it is not possible to incur no additional cost and get more of one good without getting less of another. Bid A has a score of 10 more than bid B for aquatic function, but has a score of 5 less for terrestrial biodiversity for the same price. To determine which bid an agency is better off accepting it must decide whether it is willing to trade 5 units of terrestrial biodiversity for 10 units of aquatic function. If an agency chooses to accept bid A over bid B, it is willing to trade 1 unit of biodiversity in exchange for 2 units of aquatic function. To choose which bid it would prefer to accept an agency must determine how much of one good it is willing to trade for another.

One way an agency may choose to express its preference between the goods to simplify the process of ranking bids in order of preference or value for money is to apply weights to the scores for each different outcome. For example, an agency could determine that it was willing to trade 1 unit of biodiversity for a minimum of 2.5 units of aquatic function. The agency could simplify the process of choosing between the three bids in line with this preference by putting the scores for both goods in terms of one of the goods. Given a unit of biodiversity is worth 2.5 units of aquatic function to the agency, the agency could multiply biodiversity scores by 2.5, this product would be the biodiversity score in terms of equivalent aquatic function units given the agency's preference, thus comparable to the raw aquatic function scores. The relative sizes of the sums of the product of biodiversity score by 2.5 and the aquatic function scores can be used to rank the bids in order of value for money to the agency, as shown in Table 2.

Table 2. Weights Representing Willingness to Trade One Good for Another

	Bid A	Bid B	Bid C
	Weighted Scores	Weighted Scores	Weighted Scores
Terrestrial Biodiversity	15 x 2.5 =37.5	20 x 2.5 = 50	15 x 2.5 = 37.5
Aquatic Function	30	20	32
Total Weighted Benefits in equivalent terms*	67.5	70	69.5
Cost	15	15	15
Value for Money (total benefits per dollar)	4.5	4.67	4.63
Bid Ranking	3	1	2

If an agency has preferences that lead to a weight of 2.5 being applied to biodiversity and a weight of 1 to aquatic function, bid B provides the most value for money, followed by bid C, and then bid A. In EcoTender this problem is made more complex as there are three public goods and each bid may have a different cost.

To further complicate the joint production issue and the need for preferences is the production of market goods with public goods. Revegetation for environmental outcomes also results in sequestration of carbon from the atmosphere, which in some circumstances is a market good. For instance if there were an emissions trading system for carbon as suggested by the Emissions Trading Working Group carbon would have market value (IETWG 2005). For the purposes of this pilot it was assumed there is a market for carbon and the clearing price for carbon is $12. From the agency's point of view it does not need to consider the tradeoffs between public goods and market goods, it simply passes the market goods it obtains on to the market for the clearing price. There are efficiency gains to be made in environmental markets when there is joint production of both public and private goods – the agency will pay less for environmental outcomes when landholders own the right to mitigation of carbon (Strappazzon *et al* 2003). However, those bidding in the auction will need to take into account the impact of producing carbon will have on the amount they need to bid assuming they are willing to sell their carbon into the market. The agency can possibly count on receiving lower bids for the provision of the public goods given landholders who are undertaking revegetation will also be receiving money for carbon sequestration.

3 The Environmental Production Function

Implicit in the above discussion is the fact that the agency can obtain information about the way that landholder actions convert to environmental outcomes. In other words, the agency has at its disposal a 'production function' for environmental goods. Consequences of not knowing the non-point production function include:

- only the costs of prospective environmental policies can be determined
- because any two policies differ with respect to environmental outcomes as well as cost, no conclusions are possible regarding the relative merits of alternative policies

- it is impossible to calculate a set of management practices or management incentives which are truly "best" in terms of the costs of achieving any given level of pollution abatement.
- non-point incentives and non-point standards are not realistic policy alternatives because emissions cannot be monitored or estimated

The essential feature of a non-point production function is that is allows market based instruments to be based upon those factors which determine pollution rather that the pollutant itself (Griffin and Bromely 1982).

The EcoTender pilot required a non-point production function that explained landholder actions in terms of environmental outcomes. The environmental outcomes needed to be estimated at the catchment-scale and incorporate both their temporal and spatial characteristics. Equation (i) below shows the general form of a non-point production function which can include inputs such as land, water, labour, landuse, soil type location, slope, rainfall etc.

$$EBI = \sum_{i}^{N} EO(a_i, b_i, c_i, \ldots) = f(land, water, labour, technology, SA_i) \qquad \text{(i)}$$

where EBI – environmental benefit index, for sites i = 1 to N

EO – environmental outcomes a_i, b_i, c_i,…. for site i.

SA – site specific spatial attributes which may include soil type, slope, aspect.

The production function needs to have the ability to be applied on any of the sites that bid in the auction which are generally at the paddock scale within a farming system. There are a number of modelling approaches that can be used to represent and implement the production function. These include

- Statistical models that require the collection of data at the farm scale (including, soil, management, stocking rate, slope, landuse, etc) and relate it to observed environmental outcomes. For instance, in a specific area best management practices may have been adopted over a period of years and data collected on the level of pollution being produced by that area. It may be possible to develop a mathematical relationship reflecting the transformation of a change in farm practice (adoption of BMP) to a change in pollution. This relationship could be used to generalise across other farms within the area to determine the change in pollution if additional farms adopted the BMPs. Increasing the number of observations increases the explanatory power of the resulting equation however it is difficult to find sites that have sufficient data to develop a relationship for both changes on site and the environmental outcomes.
- Economic models that are generally linear programming models that contain an economic objective function (profit maximisation) and equations that reflect the transformation of inputs to outputs. In some cases these models include environmental impacts such as nutrient runoff, recharge etc which are based on generalised equations for farms in the area of interest. Economic models are generally used to determine how input and output pricing policies influence environmental outcomes. Alternatively economic models can have the environmental outputs constrained to determine the shadow price of each unit reduced – and thus the cost of reducing/abating pollution.

- Simulation models that are a collection of equations that explain how biophysical factors of the environment interact with one another. Generally simulation models explain plant and animal interactions for a given point in space with weather data as a temporal input. These models can vary in their complexity from aggregate (catchment) to micro (farm, paddock) level approaches. Simulation models generally rely on equations that have either been conceptually derived or statistically determined by respective scientific specialisations which can be found in published literature. For instance, the "bucket model' or the "richards equation" to explain the movement of water through the soil profile (Broughton 1994, Ross 1990).

An important factor influencing the choice of modelling approach is the level of disaggregation required to implement the policy. For instance, the policy may be operating at the farm, catchment or state (county) scale. Generally more disaggregation means better information and policy efficiency but it may also be more costly in terms of data requirements, computing, calibration and validation.

Numerous economic studies (Braden *et al* 1989, Babcock *et al* 1997, Just and Antle 1990, Babcock *et al* 1996) suggest that targeting or refining spatial information increases the economic efficiency of environmental programs. Holding budget constant and using information to target areas that have a higher impact result in greater environmental outcomes. Alternatively, if technologies and management solutions can be identified in high impact areas then the overall cost of achieving a given pollution target is lower. However, spatial models that focus on either cost or benefits alone will result in efficiency losses – it is the ratio of costs to benefits that is important (Babcock *et al* 1997, Capentier *et al* 1998). In order to maximise environmental outcomes it is important to model the interaction between agricultural and environmental policies at a highly disaggregate level - to capture the heterogenous nature of the physical environment and the economic behaviour of farmers (Just and Antle 1990).

The EcoTender project assessed changes in environmental outcomes as a result of farmers changing land use or management at the paddock scale within their farming system. The project did not require an assessment of tradeoffs (optimisation) or any economic information because the auction mechanism revealed the price needed to procure the outcomes.

EcoTender required a non-point production function that took inputs at the paddock scale and converted them into outputs at both the paddock and catchment scale. In many cases the production functions role is limited to the paddock scale and sophisticated numerical techniques are used to aggregate the paddock data to the catchment scale. For instance, surface water flows from contributing paddocks need to be aggregated to determine the rate of water flow within a stream, but the production function is operating at the paddock scale.

Statistical approaches are resource intensive and are generally only applicable to the area in which the data is collected are cannot be used to differentiate process complexities. Further it is very difficult to source data that includes paddock level management, economic information, spatial characteristics and environmental outcomes. Under limited circumstances this approach is useful to support conceptual modelling but is of little use for implementation in the field.

Carpentier *et al* 1998 reported an extensive study combining statistical sampling of farm management and economic characteristics that were used to parameterise a linear programming model SUSFARM (farm level economic model). Their analysis suggested the use of spatial information with adequate technologies and institutions can reduce the cost of controlling non-point source pollution. However, they acknowledge the approach lacked infra-farm spatial variability, for instance differing soil type across a farm and assumes rational profit maximising farmers. Their methodology is useful to compare and contrast regulatory approaches and quantify the costs of alternative regulatory standards. Their approach demonstrates the importance of spatial information to capture the heterogenous nature of non-point pollution but the optimisation process is not suitable for linking with market based instruments.

Simulation models have the ability to operate at a spatial resolution as defined by the user. However, they need to be designed with the users needs in mind. For instance there are numerous simulation models that operate at a relatively high level of disaggregation which are useful for policies that operate at a high level (Vertessy and Bessard, 1999, Zhang *et al*., 2001, Zhang *et al*., 2002). For instance highly aggregated simulation models can indicate that one third of the land within a catchment (watershed) needs to be converted to an alternate use to achieve a catchment scale environmental objective, however they cannot differentiate at the paddock scale which paddock it is best to undertake the actions on. More detailed simulation models enable a higher spatial resolution and provide spatially and temporally explicit estimates of catchment dynamics in sufficient detail to assess the trade-off between land management strategies and off-site biophysical impacts (Beverly *et al* 2005).

4 The EcoTender Approach

EcoTender is a reverse price auction approach to allocating conservation contracts. The EcoTender auction has the following design features[2]:

- First price
- Sealed Bid
- Single round
- Information about Metric Revealed

The following sections outline how the EcoTender project dealt with the non-point production function, how it was used to provide metrics for the environmental outcomes and finally how preferences were expressed.

4.1 The Catchment Modelling Framework

A key innovation of EcoTender was the development of a non-point production function used to score multiple environmental outcomes. In order to achieve this the Catchment Modelling Framework (CMF) was developed to estimate multiple environmental outcomes and to spatially represent these to potential bidders (landholders) and the purchaser (Victorian Government) of these services.

[2] See Eigenraam *et al* 2006 for full details on contract design, supply and demand side preferences etc.

The CMF models landholder actions at the scale in which they occur – farm/paddock – explicitly accounting for the heterogenous nature of the environmental outcomes. This allows the Department to explicitly measure and account for the heterogeneous nature of environmental outcomes. As heterogeneity between landholders and sites exists it is possible to get more environmental outcomes for a given environmental budget as apposed to paying a flat rate and assuming equal environmental benefit.

This approach also offers the prospect of improving the cost-effectiveness over the single dimension auction by maximising the total of environmental benefits per dollar spent. It also reduces the costs of providing information about the impact of land-use change, thereby reducing transaction costs associated with procuring environmental outcomes. For instance rather than running several programs for each environmental element (salinity, water quality, etc) a single program can be run purchasing bundles saving on contact time with landholders and information gathering to determine the relative environmental merit of each site.

The catchment modelling framework presented here focuses on providing the *missing information* linking on and off-site environmental outcomes with on-site actions on private land. The framework has been designed to explicitly model and report the joint production of environmental outcomes which links effectively with policy to efficiently allocate conservation funds.

Past modelling approaches have adopted large homogenous land areas assuming the environmental outcomes within an area are the same for all landholders. Aggregated approaches are not suitable for application to the auction and do not allow for a comparison of environmental outcomes at the farm scale (Beverly *et al* 2005).

The CMF incorporates a suite of one-dimensional farming systems models into a catchment scale framework with modification to account for lateral flow/recharge partitioning (see Eigenraam *et al* 2006, Appendix I for detailed description). The CMF consists of an interface and a simulation environment. The interface is used to assemble time-series and spatial data sets for use by simulation models, visualisation and interpretation of data, and the analysis of simulation outputs. The interface was designed to assist in both the pre- and post-processing of spatial and temporal data sets.

The interface is also used to apply rule-based methods to analyse landscape features. For instance, remnant native vegetation maps showing current coverage are used to assess the spatial significance of alternative revegetation options. Generally, this type of analysis is rule based (ie. patch size and shape, connectivity of remnant patches, distance from sources of refuge such as river corridors or sources of replenishment such as large patches of native vegetation,). In most cases the rules are developed based on current understanding of the spatial needs of relevant species and coded into the interface for application in different catchments. The interface was developed using MATLAB (commercially available software) and can be distributed as an executable to non-technical users and stakeholders.

The simulation environment is an assemblage of one-dimensional farming systems models capable of simulating pasture, crop and trees (Beverly *et al* 2006). The farming system models are explicitly linked to a fully distributed 3-dimensional groundwater model. The simulation environment has been designed to produce scripts that automate the process of employing third party software, MODFLOW. The CMF simulates daily soil/water/plant interactions, overland water flow processes, soil loss, carbon sequestration and water contribution to stream flow from both lateral flow (overland flow and interflow) and groundwater discharge (base flow to stream). The agronomic models can be applied to any combination of soil type, climate, topography and land practice. Using the interface, outputs from these simulations can be compiled for visualisation, interpretation and interrogation.

The CMF develops both a surface element network and a groundwater mesh based on unique combinations of spatial data layers. Typically the spatial data necessary to derive the surface element network includes soil, topography, landuse and climate. The groundwater model requires spatial data pertaining to aquifer stratigraphy such as the elevations of the top and basement of each aquifer, spatially varying aquifer properties and river/drainage cadastral information. Additional data includes time-series records of stream flow, groundwater hydrograph, groundwater pumping, and irrigation.

Outputs from the model can be characterised based on scale as either specific to the management scale (paddock/farm) or the sub-catchment to catchment scale. Simulations predict soil/water/plant interactions on a daily basis providing a comprehensive range of time-series outputs for each surface element. These include:

- complete water/soil balance (soil moisture, soil evaporation, transpiration, deep drainage, runoff, erosion),
- vegetation dynamics (crop/plantation yield, forest stem diameter, forest density, carbon accumulation).

At the sub-catchment to catchment scale outputs include:

- stream dynamics (water quantity and salt loads);
- groundwater dynamics (depth to watertable, aquifer interactions, groundwater discharge to land surface and stream).

The following section outlines how the CMF is used for the development and application of environmental outcomes adopted in the pilot study.

4.2 Estimating environmental outcomes

Modelled outputs from the CMF need to be presented so purchasers (in this case the State government) can express their preferences for different quantities of environmental outcomes. Such investment decisions are often further complicated by the need to compare a range of actions across broad landscapes and different ecosystem types that may produce varying amounts of different outcomes of dissimilar intrinsic value.

The EcoTender pilot uses an information framework that defines each environmental "outcome" in terms of 'service' or the change in the level of function resulting from the landholder actions and the 'significance' of the change.

To estimate the change in level of function, it is necessary to have a standard reference point against which change is measured. Adapting the policy approach applied in Victoria for assessing conservation status of biodiversity assets (NRE 2002), it was decided to use pre-1750 as the "natural benchmark" against which current ecosystem function and change in function arising from landholder management actions in the catchment can be assessed. Under such an approach, the pre-1750 landscape is modelled using the assumed pre-European settlement vegetation types to provide an understanding of native vegetation cover both current and prior to clearing. The current and pre-1750 modelled landscapes can then be used to measure changes in landscape function resulting from landholder interventions based on a progression towards 1750. In this context, the pre-1750 "function" is not a target but simply a reference point for measuring change. The pre-1750 benchmark approach is also used to estimate the change in native vegetation quality or extent resulting from landholder actions.

Landholder actions in the pilot were limited to indigenous revegetation and improved remnant native vegetation management. In the future other on-farm management actions could be evaluated but further research is required to determine appropriate monitoring and enforcement strategies.

Revegetation requires the establishment of indigenous species in formerly cleared areas to achieve a required target based on the modelled pre-1750 vegetation types for the site. Remnant native vegetation management involves landholder commitments that improve the vegetation quality of the site as assessed in comparison to a 'benchmark' that represents the average characteristics of a mature and apparently long-undisturbed state for the *same* vegetation type (Parkes *et al*. 2003, DSE 2004).

The following table summarises the outcomes used in the pilot.

Table 3. Summary of outcomes, service and significance

Attribute	Change in level of service	Desirable change	Significance
Terrestrial Biodiversity	Δ habitat score (habitat maintained or improved per ha)	Increase	Biodiversity conservation significance , threatened species conservation status, habitat quality, landscape preference
Aquatic function	Δ water "quality" (tonnes of soil / ha to stream) Δ water quantity (mm of water / ha to stream)	Decrease	(not applied in pilot)
Saline land area	Δ saline land (ha with groundwater < 2m)	Decrease	can discriminate - but given equal weighting in pilot
Carbon sequestration	Δ carbon sequestered (tonnes / ha)	Increase	n/a

4.2.1 Aggregate Environmental Benefits Index (EBI)

To choose successful bids, the following method was used. For each environmental outcome, the difference between the estimated pre-1750 level and the estimated current stock was calculated. The raw outcome score for an outcome in a bid was then divided by the difference between pre-1750 and current stock levels to produce a percentage movement towards pre-1750 conditions for each outcome. The percentage movement or adjusted scores for each outcome produced by a bid were then added to produce a total score, which when divided by the cost of the bid produced the 'total value for money' produced by that bid. Choosing those bids that provide the best value for money, or the greatest total adjusted score per dollar, until the budget is exhausted ensures that it is not possible to get more of one good without giving up some of another.

By using this method the department is effectively indicating that it is indifferent between a score that reflects a 1% movement towards pre-1750 levels for biodiversity and a score that reflects a 1% movement towards pre-1750 levels of aquatic function. For each of the environmental outcomes the pre-1750 and current stock of each outcome was calculated under steady state conditions for the catchment (see Table 4 below).

Table 4. Pre-1750 and current environment outcome stocks

Environmental outcome	Pre-1750 stock (A)	Current stock (B)	Difference (A-B)
Habitat hectare[1]	418,140	19,081	- 399,059
Saline land area (<2m)	83,702	127,153	+ 43,451
Aquatic function	27,070	94,320	+ 67,250

1) Applied to both remnant management and revegetation

For each site assessed in the auction equation (1) was applied to determine the aggregate score.

$$EBI = \left(\frac{A_i}{D_A} + \frac{S_i}{D_S} + \frac{B_i}{D_B} \right) * 100 \qquad \text{(ii)}$$

where:

A_i, S_i and B_i are the aquatic, saline and biodiversity outcomes respectively for site i

D_A, D_S and D_B are the respective aquatic, saline and biodiversity differences from Table 4 above

In effect the above equation calculates the total percentage movement towards pre-1750 conditions for each of the environmental outcomes.

Carbon sequestration is dealt with as a market good and landholders are paid separately for each unit produced. As previously discussed, when bidding landholders understand that if their bid was accepted using the above scoring method, for each tonne of carbon sequestered they would receive a payment of $12, paid for by a third party. Landholders are not obliged to sell their carbon for $12/t they can elect to retain the rights for use later.

The selection of bids is based only on the EBI and the cost of the bid, farmers adjust their bid given the knowledge they will receive carbon payments if their bid is accepted. The simplicity and transparency of this option allows reflection on the result, facilitates feedback from stakeholders on the goods chosen and the trade-offs made and other lessons that will help inform and refine the method of dealing with demand to more accurately capture society's preferences.

4.3 Implementation

The following table outlines the steps taken to implement pilot. Each step required a different level and type of communication ranging from very simple to intensive and complex.

Table 5 . Pilot Implementation Steps

1. Expressions of interest – landholders located in project areas register an expression of interest through their EcoTender field officer.
2. Site Assessments – the EcoTender field officer arranges a site visit with each registered landholder. The field officer assesses the site and advises the landholder on the significance of the site from a range of environmental perspectives, and identifies potential native vegetation management and revegetation options for consideration by the landholder.
3. Development of draft management plans – landholders identify the actions they are prepared to undertake and the field officer prepares a management plan as the basis for a bid.
4. Submission of bids –landholders submit a sealed bid that nominates the amount of payment being sought by them to undertake the agreed management plan.
5. Bid Assessment – all bids are assessed objectively on the basis of:

- the estimated change in the on and off-site environmental outcomes (the amount of change in environmental outcome);
- the value of the assets affected by these changes (significance);
- dollar cost (price determined by the landholder).

Funds are then be allocated on the basis of 'best-value for money'.

6. Management agreements – successful bidders are able to sign final agreements based on the previously agreed draft management plan (from 3 above).
7. Reporting and Payments – periodic payments and reporting occur as specified in the agreement.

4.3.1 Site assessments and application of CMF

The site assessment step was critical in communicating the 'whole of catchment' view to each participating landholder and providing a relative view of where their property was placed with respect to the various environmental outcomes being sought. This was new information that had not been previously communicated to any landholders in the pilot areas and required the field officers to fully understand the outputs generated from the CMF and to be able communicate this in a simple way.

As such, field officers needed training to understand the principles of the CMF and how to use the purpose-built interface designed to access the CMF for scoring. It was important the field officers had a sound appreciation of the CMF in order to address questions posed by landholders about the scoring methodology. The officers needed to feel comfortable with the concept of modelling landscape processes so that during the site visit landholders were left feeling confident in the scoring process and felt the agency was using a reliable methodology.

Given the spatial nature of the pilot, a system was devised whereby field officers entered GPS data into a hand held device (IPAQ, similar to a personal organiser with a GPS locater attached), which was later down-loaded for use in the CMF.

For each site, field officers used the IPAQ to collect and store GPS coordinates, record current landuse or EVC, and record detailed information about the current condition of the EVC (tree density, logs present, weeds, pests, etc). This was followed by a discussion with the landholders about actions (for inclusion in the management plans) that could be undertaken to provide environmental outcomes. Field officers would indicate to each landholder the type of actions best suited for the site and the minimum standards required.

The field officer then used the interface to down-load the information from the IPAQ to the CMF. They used the interface to validate data already within the model (e.g. ground truth land use data) and then calculate the environmental outcomes for the site. Additional utilities made available to the field officer in the interface included: recording system for weed and pest control; selection of observed threatened flora and fauna; copy/paste sites and zones; modify site way points; recording fencing location and length; edit habitat scoring and print management plans and bids sheets for each site. All information entered by the officers was recorded in a single file that could be readily e-mailed (via dial in, the files average 4KB) to others for validation etc.

In addition to the above information sheets, the field officers also had access to colour "maps" that spatially represented the catchment view for each of the four environmental outcomes being sought on a scale from low to high (see Appendix II for example of aquatic function). These catchment views were produced to assist landholders in understanding the idea that environmental outcomes arising from landuse change are spatially variable. They were also designed to provide landholders with a simple relative view of where their property was placed in a catchment environmental outcome context..

5 Results

The pilot called for expressions of interest from May 2005 and completed site assessments in late October 2005. 84 sites were assessed on a total of 40 farms. 50 bids were submitted from 21 farms. The total value of these bids was $835,000.

The following notes characterise the bids:

- 46% of the bids were revegetation
- the total revegetation bids resulted in an estimated 21,000 tonnes of sequestered carbon
- 72% of the bids produced two or more environmental outcomes
- All bids provided a biodiversity benefit, 72% provided an aquatic function benefit while only 8% provided any salinity benefits.

A tender evaluation panel was appointed to open the bids and enter them into an electronic database. Once all the bids were opened, the cost per environmental benefit was calculated for each bid and the bids were ranked on the basis of 'best value for money', lowest cost per unit benefit to highest. Bids were then selected from lowest cost up until the $500,000 budget was exhausted. Figure 4 below shows the supply curve for the all submitted bids.

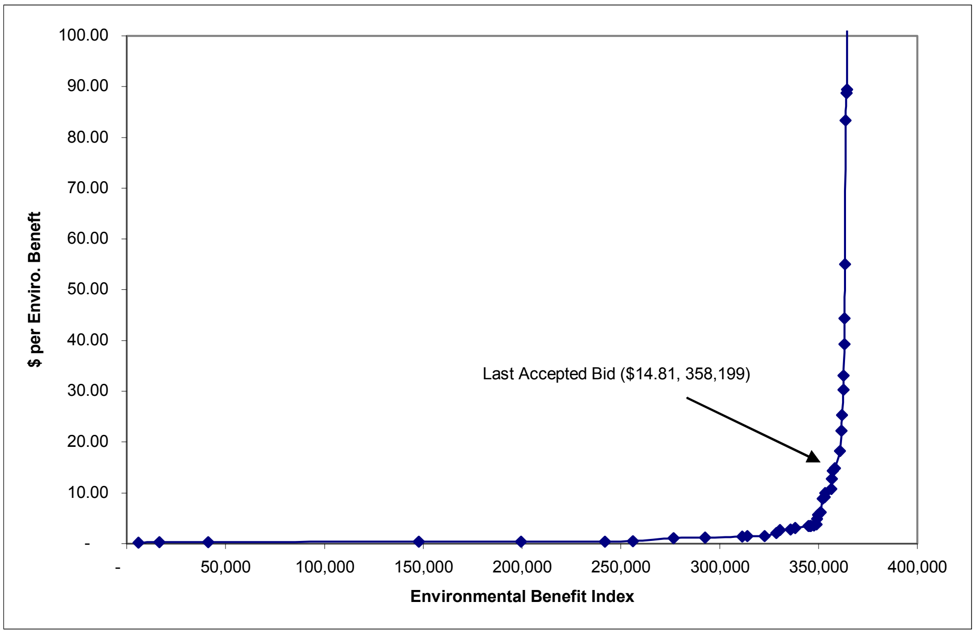

Figure 4. EcoTender Supply Curve

The supply curve shows the rising price of environmental benefits from landholders that bid. The supply curve in Figure 4 does not show the full price range on the y-axis, the price went up to $1,500 per unit environmental benefit. The last bid accepted within the budget ($500,000) cost $14.81 per unit environmental benefit.

The following points characterise the accepted bids:

- 31 bids accepted (62% of total)
- successful bids covered 259 ha (revegetation 76 ha, native vegetation management 183 ha). This was 70% of the total area offered (353 ha).
- 10,078 tonnes of carbon of which 8,087 tonnes were sold by the landholders to a third party, the remaining carbon was retained by landholders.
- of the bids selected 97% of them had two or more environmental outcomes

Only a few bids provided a salinity benefit, which can be explained somewhat by the size and location of the sites. The largest site was 45 ha which is sufficient to provide salinity benefits, however it was located in an area of the catchment that is not amendable to providing salinity benefits. Other smaller sites were located in areas of the catchment amenable to providing salinity benefits, but they were not large enough.

6 Concluding Comments

The EcoTender approach piloted an auction to procure environmental outcomes as part of a larger market based instruments program. EcoTender represents a significant advance towards implementing a comprehensive market-based approach to managing environmental problems. The design of a successful auction requires implementation of an auction mechanism that can process complex natural resource information combined with information elicited from landholders to ensure cost effective use of government funds.

If correctly applied auctions can help to overcome common problems involving *asymmetric information* – where landholders have information about the cost of undertaking an action but this information is hidden from the agency that is providing the funds. The agency needs both cost information from landholders and information linking landholder actions to environmental outcomes (*missing information*), to allocate funds cost effectively.

This is the first time a market-based policy has been fully integrated from *desk to field* with a biophysical simulation model, the CMF, for the purchase of multiple outcomes. Economic theory demands a non-point production function to solve the *missing information* problem. This CMF solves the *missing information* problem of linking paddock scale landuse and management to catchment scale environmental outcomes.

The CMF has incorporated biophysical processes to account for soil erosion, water, carbon and saline land to estimate environmental outcomes. Further, biodiversity algorithms have been incorporated which evaluate the current location of native vegetation and biodiversity landscape preference which assesses the future spatial needs of key mobile fauna species. The CMF is the only framework (the authors are aware of) that has brought together both biophysical and eco-system information.

The framework has demonstrated the importance of joint production in environmental outcomes and the heterogenous nature of the landscape in terms of environmental outcomes at the farm level.

Many authors have argued for greater disaggregation of the environmental production function (Babcock *et al* 1997, Shortle and Dunn 1986, Just and Antle 1990). This enables better targeting and hence improved policy efficiency. However, the costs of highly disaggregated spatial simulation models have been seen as prohibitive. The authors of this paper acknowledge the potentially large upfront investment costs required to build such models. However, this cost needs to be amortised of the life of the technology and the variable costs considered when assessing their ongoing use. Policy makers need to take into consideration the probability of needing this type of information for this program or others in the future. Clearly, the CMF has enabled this pilot and other policy approaches to better target landuse change and maximise the environmental outcomes for a given budget.

The CMF has significantly reduced the transaction costs associated with accurately determining environmental outcomes for any site within the landscape. The CMF can be readily calibrated to any catchment providing there is sufficient data for calibration. Further, the framework can be readily updated as new data becomes available.

If for some reason there is uncertainty as to whether the transaction costs are lower when the CMF is used one only needs to then consider the full cost of implementing the program and the benefits the program provides. As far as the authors are aware the benefit cost ratio of EcoTender is greater than that of any other environmental program implemented at the farm scale (the authors are not aware of any other program that can provide such a benefit cost ratio, making the conclusion somewhat easy).

During the development of the CMF the possibility that policy may change resolution and there are budget constraints associated with applying policy solution to environmental outcomes was taken into account. We believe the appropriate economic and scientific tradeoffs have been made – the cost is not too high for the additional benefit derived by using the approach and the science can be updated very readily as it becomes available or is updated. The CMF can be used to prioritise areas of investment to improve the accuracy of the model in order to have more confidence in its predicted outcomes – this aids investment in science. The approach is fully transferable to other regions within Australia and overseas. The CMF requires standard general information such as soil type, slope, elevation and landuse all of which are important for other policy requirements.

6.1 Further Research

The following areas warrant further research if the CMF or like approach is to be applied in the future:

- Demand side preferences and the assessment diminishing marginal product when developing metrics and assigning preferences.
- Bids are currently assessed independently of one another. However, a combination of bids may have a greater impact than the sum of them alone. Combinatorial approaches to bid selection warrant further investigation.
- The application of the CMF to other spatially explicit resource allocation problems including biosecurity and optimal ecological pathways.
- The CMF is a highly disaggregated spatial simulation model. There is an optimum in terms of the trade off that occurs disaggregation, better environmental outcomes and cost. More experimentation and research is required to find that point where the marginal cost of further disaggregation is balanced with the marginal benefit.

7 References

Beverly, C., Bari, M., Christy, B., Hocking, M., Smettem, K. (2005) "Predicted salinity impacts from land use change: comparison between rapid assessment approaches and detailed modelling framework." Australian Journal of Experimental Agriculture, 45, pp 1453-1469.

Beverly, C. (2006) Technical Manual: Catchment Analysis Tools (CAT1D), Department of Primary Industries.

Braden, J., Johnson, A., Miltz, D. (1989) Optimal Spatial Management of Agricultural Pollution, American Journal of Agricultural Economics, 76, pp. 404-13

Babcock, B., Lakshminarayan, P., Wu, J., Zilberman, D., (1997) Targeting Tools for the Purchase of Environmental Amenities, Land Economics, 73, pp. 325-39.

Babcock, B., Lakshminarayan, P., Wu, J., Zilberman, D., (1996) The Economics of a Public Fund for Environmental Amenities: A Study of the CRP Contracts, American Journal of Agricultural Economics, pp. 961-71.

Broughton, A. K. (1994) Mooki River Catchment – hydrogeological investigation and dryland salinity studies, Liverpool Plains, NSW. TS94.026, Department of Water Resources, Parramatta, NSW.

Carpentier, C., Bosch, D., Batie, S. (1998), Using Spatial Information to Reduce Costs of Controlling Agricultural Nonpoint Source Pollution, Agricultural and Resource Economics Review, 27, pp. 72-84.

DSE (2004). Vegetation Quality Assessment Manual – Guidelines for applying the habitat hectares scoring method. Version 1.3. Victorian Government. Department of Sustainability and Environment, East Melbourne.

Eigenraam, M., Strappazzon, L., Lansdell, N., Ha, A., Beverly, C., Todd, J. (2006) EcoTender: Auction for multiple environmental outcomes. National Action Plan for Salinity and Water Quality, National Market Based Instruments Pilot Program. Project Final Report.

Grafton, Q. (2005). Evaluation of Round One of the Market Based Instrument Pilot Program, National Market Based Instruments Working Group.

Griffin, R., Bromley, D., (1982) Agricultural Runoff as a Non-point Externality: A Theoretical Development, American Journal of Agricultural Economics, 68, pp. 668-77.

IETWG (2005) A National Emission Trading Scheme, A Report to First Ministers from the Inter-jurisdictional Emissions Trading Working Group.

Just, R., Antle, J., (1990) Interactions Between Agricultural and Environmental Policies: A Conceptual Framework, American Economic Association Papers and Proceedings, 80-2, pp. 197-202.

NMBIWG 2005, National Market-based Instruments Pilot Program: Round 1, An Interim Report by the National Market Based Instrument Working Group, December, http://www.napswq.gov.au/mbi/pubs/interim-report.pdf

Parkes, D., Newell, G. and Cheal, D. (2003). Assessing the quality of native vegetation: the 'habitat hectares' approach. Ecological Management and Restoration 4, S29-S38.

Ross, P. (1990) SWIM - a simulation model for soil water infiltration and movement. Reference manual, CSIRO Australia, Division of Soil Townsville.

Shortle, J., Dunn, J., (1986) The Relative Efficiency of Agricultural Source Water Pollution Control Polcies, American Journal of Agricultural Economics, 68, pp. 668-77.

Stoneham, G., V. Chaudhri, A. Ha and L. Strappazzon (2003). "Auctions for conservation contracts: an empirical examination of Victoria's BushTender trial." Australian Journal of Agricultural and Resource Economics 47(4): 477-500.

Stoneham, G., Lansdell, N., Strappazzon, L. (2003) A Transaction Cost Economics Approach to Considering Environmental Policy, Economics Branch Working Paper Series, Department of Primary Industries, Victoria, Australia.

Strappazzon, L. Ha, A., Eigenraam, M., Duke, C. and G. Stoneham (2003) The efficiency of alternative property right allocations when farmers produce multiple environmental goods under the condition of economies of scope, Australian Journal of Agricultural and Resource Economics, 47, pp. 1-27.

Vertessy RA, Bessard Y (1999) Anticipation of the negative hydrological effects of plantation expansion: Results from GIS-based analysis on the Murrumbidgee Basin. In: Croke, J. and Lane, P. (eds). Forest Management for the protection of water quality and quantity. Proceedings of the 2nd Erosion in Forests Meeting, Warburton, 4-6 May 1999, Report 99/6, Cooperative Research Centre for Catchment Hydrology, pp. 69-74.

Wu, J. and W. G. Boggess (1999). "The Optimal Allocation of Conservation Funds." Journal of Environmental Economics and Management 38: 302-321.

Wu, J. W. and K. Skelton-Groth (2002). "Targeting conservation efforts in the presence of threshold effects and ecosystem linkages." Ecological Economics 42: 313-331.

Zhang L, Dawes WR, Walker GR, (2001) The response of mean annual evapotranspiration to vegetation changes at catchment scale. Water Resources Research., 37, pp701-708.

Zhang L, Dowling T, Hocking M, Morris J, Adams, G., Hickel, K., Best, A. and Vertessy, R. (2002). Predicting the effects of Blue Gum plantations on water yield in the Goulburn-Broken catchments Cooperative Research Centre for Catchment Hydrology Report No. 02/12, Monash University, Victoria, Australia.