Auction for Landscape Recovery Under Uncertainty (ALRUU) – Draft Final Report

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Contents

Brief Summary

Fragments of native vegetation in the Western Australian wheatbelt are of national and international importance as a source of biodiversity. Conserving bush fragments is a policy challenge: first as a large proportion of the fragments are on private land; second achieving conservation gains is a gradual process requiring constant investment and re-investment over many years; and third the response of bush fragments to conservation actions is highly variable.

The overall aim of this project is to contribute to the development of 'joined-up' and 'evidence-based' conservation policy where the nature of ecosystems (rates of change, threats and inter linkages) determines both the design of contracts and their monitoring.

To address the key elements of the design of conservation schemes namely, tender selection, contract design and monitoring, this project developed novel applications of analytical methods to make use of existing publically available spatial data.

Assessing tender selections under uncertainty re-evaluates the tenders from the MBI1 project Auctions for Landscape Recovery as a case study. Methods were developed to measure bush condition, allocate bush fragments to a response class and determine the probability of bush condition improving or deteriorating through time. The observed trend in biodiversity condition over the last 20 years is that 18% of fragments in good condition have degraded. The proportion of the landscape in poor condition in 1988 was 17%, by the end of the century it is predicted to be 33%. The tenders selected were different to those selected by the ALR. In general the algorithm chose those remnants with the highest area per dollar bid and selected rare vegetation types in moderate condition that show the greatest response to management over common vegetation types in either good or poor condition.

The project used choice modelling to evaluate outcome-based contracts where landholders are paid on ecological outcomes. Results from a survey of 60 farmers showed that outcome contracts were acceptable to most farmers, that farmers have a moderate to high level of risk aversion and that, if participation rates are low, it may be necessary to combine an initial payment with an outcome-based payment. A series of student experiments were undertaken to assess the effect of an auction mechanism on the efficiency of an outcome-based contract. Results indicate that outcome-based contracts increase cost-effectiveness over input-based contracts. If outcome-based contracts are auctioned, this further increases efficiency. However, increasing the weight of payments on outcomes reduces participation. The analysis of outcome-based contracts highlights that conservation contracts are closely related to performance-based labour contracts.

Ecological monitoring is of most value if observations result in regulator actions, for instance in terms of stopping the scheme, continuing or paying a bonus. Using a mathematical model, monitoring was found to give the greatest return when the vegetation starts in moderate condition and either improves or deteriorates rapidly in response to conservation. There was no value in monitoring vegetation in a highly degraded state and good quality bush fragments tend to change gradually and require infrequent monitoring.

Executive Summary

The Auction for Landscape Recovery (ALR) was one of eleven market-based instrument (MBI) pilot projects conducted across Australia from 2003 to 2005. The ALR was run over two rounds and applied a sealed-bid price discriminating auction. Tenders from the auction were selected using Systematic Conservation Planning methods incorporating biodiversity complementarity, and this metric was compared with an Environmental Benefit Index (EBI). A finding from the ALR was that biodiversity outcomes from conservation actions were highly uncertain. To address this problem a Management Benefit Review Group was established to assess the likelihood that conservation actions would lead to successful conservation outcomes. However, it was not possible to fully assess the uncertainty in biodiversity outcomes and include this uncertainty in the tender selection process. The overall aim of this project is to assess how auction contract design, tender selection and monitoring can be modified to account for uncertain biodiversity outcomes.

Tender Selection

This project *Auction for Landscape Recovery* (ALRUU; MBI R2-23) took an empirical, evidence-based approach to assessing conservation actions under uncertainty. This involved using an archive of Landsat imagery which is a record of changing vegetation condition in the landscape from 1988 to 2007. A method based on Landsat data has the advantage that the models developed can be generalized to a broad range of Australian landscapes as Landsat data are widely available and relatively inexpensive. We developed a metric of biodiversity 'condition' that linked on-ground assessments of biodiversity to changes in the Landsat archive. This metric was then incorporated into our tender selection process. Different sources of uncertainty in the metric include (i) the on-ground biodiversity assessments; (ii) prediction of biodiversity condition from the imagery; (iii) uncertainty in the responses of individual fragments to variable management. The analysis (Functional Data Analysis) of the Landsat archive allows us to predict the expected outcome with and without conservation actions and assign a probability distribution to the outcomes.

The observed trend in biodiversity condition over the last 20 years is that 18% of the high condition fragments have degraded. The proportion of the landscape in poor condition in 1988 was 17%. If we project this trend into the future it is predicted that 33% of today's high quality fragments in the NEWROC region will have a significantly lower biodiversity value by the turn of this century.

The tender selection process was relatively robust to the different sources of uncertainty and also to the time frame over which predictions of biodiversity condition were based. The tenders selected were generally those with the highest area per dollar bid. This reflected the greater weight in the objective function on large fragments being able to potentially supply rare and endemic species. The tender selection algorithm prioritised rare vegetation types in moderate

condition that had been observed to show the greatest response to management in preference to common vegetation types in either good or poor condition.

Contract Design

In the absence of an on-ground scheme, this project resorted to three indirect methods for predicting how landholders would respond to outcome-based conservation contracts. These were (i) a choice experiment administered to 60 landholders in the NEWROC; (ii) lab-based experimental outcome-based auctions with students; and (iii) an estimation of optimal regulator monitoring and self-monitoring based on the evidence of the Landsat archive, derived from a set of biodiversity condition classes nested within the Vegetation Asset, State and Transition (VAST) framework.

The results of the choice experiment show that the regulator would prefer to contract with less risk averse producers as they will accept a lower outcome-based payment and will apply a higher level of conservation effort. The lab-based experiments reinforce this result and indicate that there is a trade-off between placing a higher weight on outcome payments and the level of participation in the auction.

Monitoring

Results on optimal monitoring generally show that on-ground monitoring should be undertaken relatively infrequently and be conditional upon the state of the vegetation. Thus monitoring should be focused on fragments in an intermediate condition and should not be applied to highly degraded fragments or fragments in a relatively good condition as both of these conditions change slowly.

1. Introduction

1.1 The Threat to Biodiversity

The study area is defined by the northeast wheatbelt regional organisation of councils (NEWROC) in Western Australia (117^0 E 31^{0}30' S, 119^0 E 29^{0}30' S; Figure 1.1). The area is more than 250 km north east of Perth, comprising ~17000 km^2 of cropping land within the intensive land use zone (ILZ) and ~7000 km^2 in the extensive land use zone (ELZ). Average rainfall decreases north eastward from 340 mm to 290 mm, with ~65% of rain falling within the five month growing season (May-September). The NEWROC region is part of the Avon River Basin, in which over 50% of the 4000 vascular plants indigenous to the Basin are known to be endemic (Gibson *et al.* 2004).

Biodiversity in Western Australia's north eastern wheatbelt faces significant regional threats from landscape fragmentation and increasing salinisation. Land clearing has been extensive, with only 12% of indigenous vegetation remaining within the intensive land use zone of the NEWROC region (Figure 1). The remaining vegetation occurs as highly isolated fragments, inhibiting the ability of species to recruit from neighbouring areas after disturbance events such as fire. Currently, 6% of the ILZ is classified as saline affected, while 28% is considered at risk of salinisation by 2050. Combined with other threats such as grazing and biotic invasions, the high endemism means that there is a high expected rate of species loss. The degree of degradation of vegetation fragments across this region has not been systematically surveyed, however, the degradation is known to be extensive. With the majority of the remaining vegetation fragments found on private land, the traditional conservation practice of placing land in public reserves is not an adequate measure. Round 2 of The National Market Based Instruments Pilot Programme seeks to develop new methods of targeting conservation on private lands, and includes this project on *Auction for Landscape Recovery Under Uncertainty* (ALRUU; MBI R2-23). The project builds on the results achieved in the Round One MBI pilot programme *Auction for Landscape Recovery* (ID21).

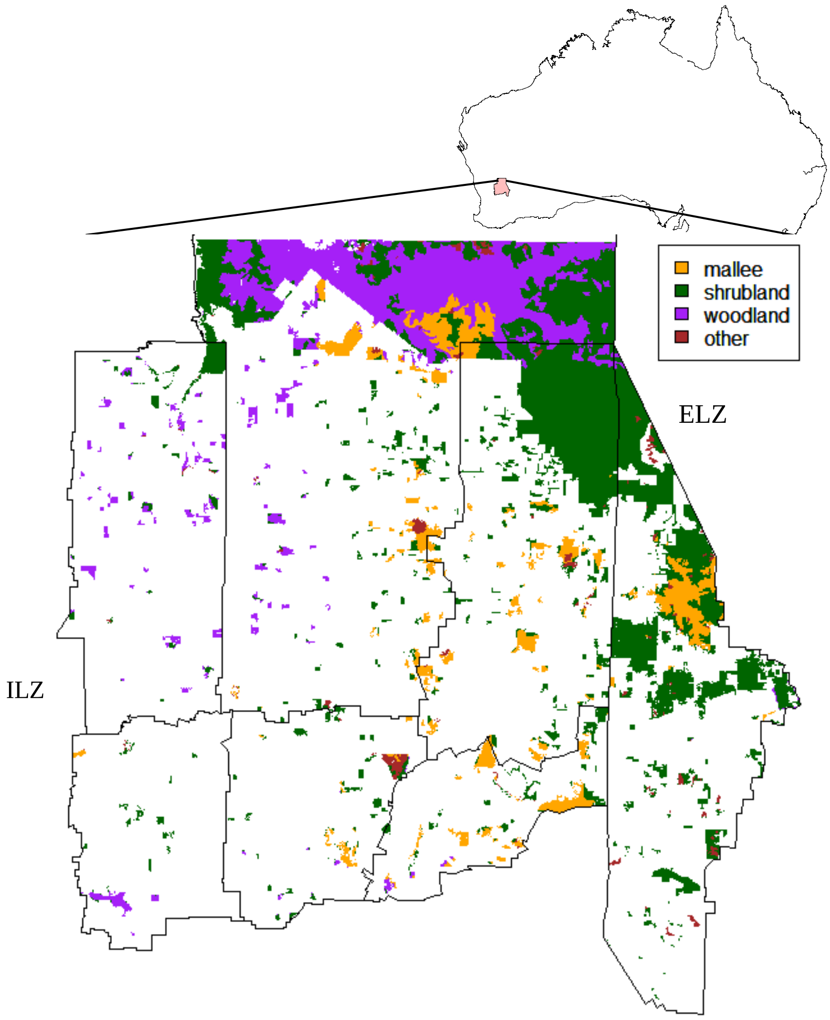

Figure 1 Distribution of Remnant Vegetation in the NEWROC Region

1.2 Auction for Landscape Recovery, MBI Round 1

The Auction for Landscape Recovery (ALR) was one of 11 market-based instrument pilot projects conducted across Australia from 2003-2005 (Gole *et al.* 2005). The ALR was conducted over two rounds as a sealed-bid, price discriminating auction. Private landholders within the project region were encouraged to submit a tender describing their proposed management activities, identifying anticipated environmental outcomes and the monetary compensation required to undertake and complete on-ground works. A total of 55 tenders were received from 38 landholders in Round One and 33 tenders from 21 landholders in Round Two, resulting in 21 management contracts for periods of up to three years. Tenders were evaluated using a regional metric of biodiversity complementarity within a Systematic Conservation Planning (SCP) framework, incorporating biodiversity condition information from field assessments and desktop analyses. Key research objectives for the pilot included a comparison between the SCP approach and an Environmental Benefits Index (EBI).

1.3 ALRUU Approach

The guiding principle of this research is that the state of an ecosystem through time is uncertain. Conservation through management is not a deterministic process but instead perturbs the ecosystem in a 'noisy' fashion, so that realising a gradual transition to a desirable state is a chance outcome. Furthermore, our lack of information about ecosystems is profound. We are uncertain about the current state of an ecosystem as well as its future state. This lack of information should be accounted for in conservation policy at three levels. First, tender selection should account for the rate of change in dynamical ecosystem processes given a particular starting condition and management regime. Second, monitoring to determine payment and recontracting should depend upon the costs of monitoring and also the probability of transitions between vegetation states . Third, if target conservation outcomes are uncertain then the conservation contracts administered to farmers whether through an auction or at fixed prices should reflect that uncertainty. The probability of failure must be recognised as at least partly endogenous, and be incorporated in the design of the auction mechanism.

2. Achievement of Project Objectives

2.1 Project Objectives

i) Tender Selection - develop a metric for conservation tenders that reflects uncertainty about species persistence.

ii) Contract design - design cost-effective contracts where outcomes are uncertain.

iii) Monitoring **-** *optimal regulator and landholder monitoring where outcomes are uncertain.*

2.2 Activities and Methods

(i). Tender Selection

A conservation scheme is only as good as the metric used to measure environmental and ecological outcomes. The Auction for Landscape Recovery project explored two alternate metrics: an Environmental Benefit Index (EBI) and a complementarity measure from Systematic Conservation Planning (SCP). ALR came to two conclusions, first that the two metrics gave similar results and second it is difficult to weight biodiversity and other NRM objectives together in the same metric. That project also employed an expert panel to undertake a check that project inputs would be expected to bring about project outcomes to filter out undesired or unrealistic tenders.

The approach used in this project was to assess the historical evidence that actions lead to conservation outcomes using publically available Landsat data and use that information to determine how variable the biodiversity response is to actions. It was necessary to use a statistical modelling technique in functional data analysis, which placed bush fragments into unobserved 'latent' classes which have similar patterns of change through time. This model overcomes a fundamental problem in conservation management that the relationship between actions and outcomes is often not measured over an ecologically significant time scale.

These results enabled us to select the optimal set of tenders based on maximising the expected gain in biodiversity from managing a subset of remnants.

(ii) Contract Design

The main implication of uncertainty in outcomes is that the form of a contract with the landholder either as part of a market based instrument or a fixed-price scheme must account for uncertainty and the design of a contract determines how risk is shared between the regulator and the landholder. In this respect outcomes-based contracts have desirable properties in that they place a strong incentive on landholders to put on-going effort into conservation. The downside of outcome-based contracts is that they can reduce participation amongst risk-averse producers.

This conclusion was drawn from two novel pieces of analysis. First a choice modelling survey was administered to 60 landholders that estimated their risk aversion, implicit labour costs and discount rate and was able to assess the optimal contract design. The conclusion from this analysis was that it may be optimal to offer contracts which include an upfront payment combined with a payment for outcomes. The importance of this result depends upon how critical a high participation rate is: if only a small participation rate is required then the regulator may consider ‘cream skimming’, that is, contracting with farmers with low levels of risk aversion.

This result was reinforced by experiments with groups of students where they were asked to choose levels of effort and bids in outcome based contracts. These experiments showed that there exists a trade-off between efficiency in terms of effort per dollar spent and participation: outcome-based contracts are efficient, but reduce participation.

(iii) Monitoring

Monitoring was evaluated using a mathematical model which allowed an assessment of the frequency of monitoring based on the choices available to the regulator and the starting point of the bush fragment.

3. Achievement Against M&E Framework

3.1 Tender Selection

3.1.1 Remote Sensed Prediction of Biodiversity Condition

To avoid the cost of extensive on-ground assessments of biodiversity we investigated the use of publically available remote sensed imagery in providing landscape scale biodiversity assessments across the NEWROC study area. Remote sensed imagery enables us to extrapolate a sample of on-ground measures of biodiversity condition across a landscape, and back in time using historical archives of imagery. Understanding the temporal change in biodiversity condition, and the ecological processes that drive that change, is key to predicting future biodiversity outcomes, with or without conservation management. These predictions of future biodiversity condition forms the basis for valuing the contribution of different conservation tenders toward meeting the goals of the auction. The use of publically available remote sensed imagery ensures the methods developed through this project have application to other regions of Australia where there is a need for comprehensive assessments of biodiversity condition, conducted consistently over large areas over time.

Biodiversity condition estimated from site photos (77 fragments in total) were used to ground truth the predictive model based on measures of image texture applied to Landsat Band 5 for each fragment. The predictive model explained 74.5% (adj R^2) of the variation in on-ground estimates of biodiversity condition. However, the model was large relative to the sample size as it included smoothed tensor products of the image pattern metrics (Wood 2006). Predictions were made at each capture time of the Landsat imagery (12 capture times between 1988 and 2007), forming a time dependent response function for each individual fragment.

A functional principal components analysis (FPCA) allowed each vegetation fragment to be assigned to one of six biodiversity response classes (Figure 2). The response over time of each fragment may be represented by a smoothed function rather than a single value. Two classes out of six displayed a net positive gain in biodiversity condition over the 20 year period of the image archive (classes 1 and 4; Figure 2)

Declines in biodiversity condition depend on a range of environmental factors in addition to management. Both low biodiversity condition values and observed historical declines in the biodiversity condition of vegetation fragments were correlated with: (i) increased salinity risk (salinity leads to degradation); (ii) increased distance from other fragments (increased distance inhibits recruitment from neighbouring fragments and hence results in biodiversity decline); (iii) being on private rather than public land (public land has legal strictures to avoid biodiversity loss); and, (iv) a large boundary length for the size of the fragment. Though statistically significant, these relationships explain little of the variability in predicted biodiversity condition values justifying a restriction of the dependence of the predicted biodiversity condition outcome to management and current condition only.

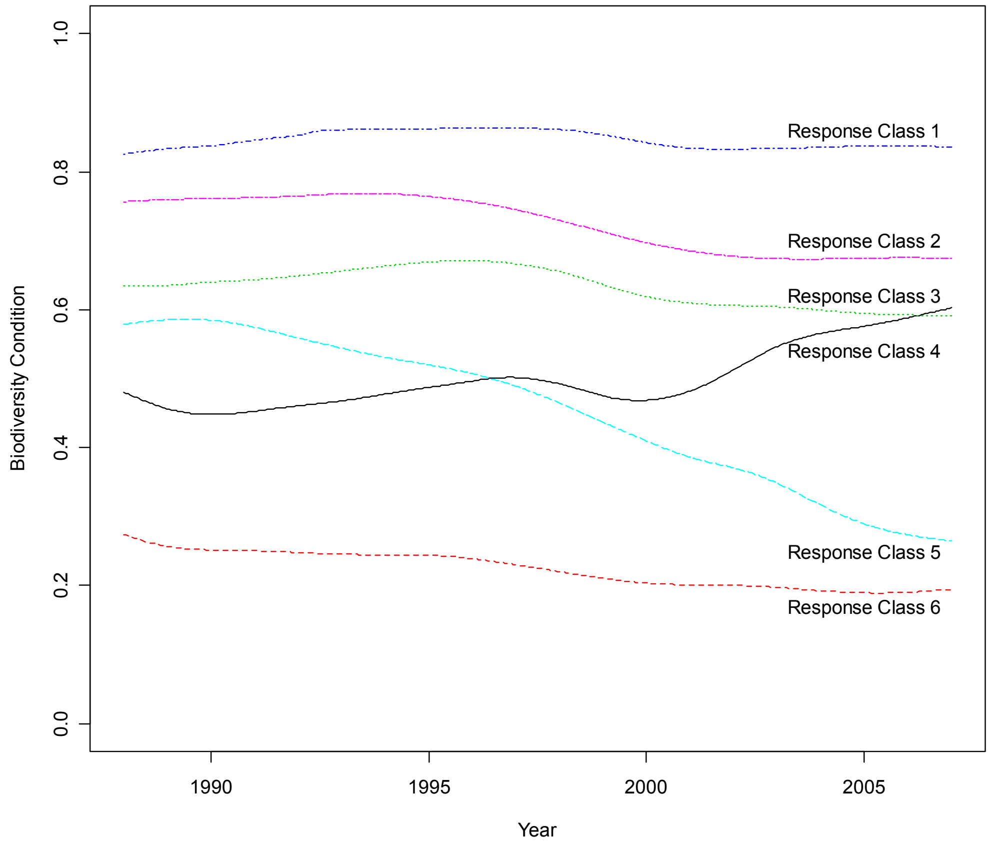

Figure 2: Biodiversity Condition Response Classes

Mean trends in biodiversity condition over time of six response classes, into which different fragments (n=465) were mapped through a functional principal components analysis.

3.1.2 Comparison to the ALR Selection of Tenders

The performance of the biodiversity condition approach was assessed in two ways: by comparison with the tender selections in the ALR (MBI Round 1), employing either an environmental benefits index (EBI) or a complementarity based measure of representation; and, by evaluating how robust the tender selection was to different sources of uncertainty, and a variable time frame. Biodiversity condition could be assessed for 22 tenders submitted during the *Auction for Landscape Recovery* (MBI Round1, Gole *et al.* 2005), where both site photos taken in 2003 and for which EBI data were available. The EBI and the complementarity based selections were similar for the ALR auction (Gole *et al.* 2005). In the absence of conservation the expected loss in the objective function (Equation 2.1) over all 22 tenders was 2.63 species-equivalents. If all conservation tenders were awarded contracts for payment, for a total cost of $253,000, then the expected gain would be 1.54 species-equivalents. A $100,000 budget effected 91% of the total possible gain among available tenders, while a budget of $50,000 effected 75% (Figure 3a). The marginal cost of selected tenders equated to the mean marginal cost when including all tenders at a budget of $60000. Which conservation tenders were selected was highly correlated with:

(i) Fragment area to bid price ratios (ha/$): Selected tenders had on average a higher fragment to bid price ratio. A high ha/$ ratio implies the dollars spent on a tender will beneficially impact more land. As area is a key component of the objective function through the species-area relationship, then relatively cheap access to large fragments in at least reasonable condition will benefit the most species.

(ii) Differences between predicted gain and loss in condition with and without management: Large differences in predicted biodiversity condition change between management and non-management meant that the biodiversity cost of not undertaking conservation in that fragment was high. The differences in predicted outcomes were highest for fragments of intermediate condition, where Class 4 and Class 5 responses were observed (Figure 2). The extremes of poor or good biological condition states were on the whole stable over time.

(iii) Type of vegetation: Broadly different vegetation types are described by different species-area relationships. The vegetation types grouped by increasing species richness for equivalently sized areas were woodland, mallee and shrubland. That is, the selection of tenders favoured fragments containing significant proportions of shrubland or mallee over woodland.

In comparison to the EBI metric, the biodiversity condition metric selected more costly tenders on average. Significantly, the selected tenders were those with the highest ha/$ ratio. In comparison, the EBI selected tenders had the highest EBI/$ values, and included more tenders as these were the smaller, ‘cheaper’ fragments. We conclude that the EBI methodology implemented during ALR suffered from not adequately scaling the EBI measure to fragment size, effectively ignoring the dependence of biodiversity on area (fragment size was but one component of the EBI).

3.1.3 Robustness of the Results

Robustness to Time Frame

A key question is how much temporal data is needed before a selection of tenders is robust. A sensitivity analysis compared the current solution with solutions from predictions of biodiversity condition change based on shorter segments of the Landsat image archive. We found that there were three distinct phases when comparing predictions: 'not robust' (<5 years); 'robust' (5-13 years); and 'fully robust' (>13 years; Figure 3c).

Robustness to Uncertainty in Predictions

The probability of observing at least 5 matches between the current tender selection solution and a selection derived from our model of uncertainty was 0.97. However, the probability of observing more matches declines, with a 0.348 probability of at least eight matching tenders (Figure 3d). This provides a distributional measure of the robustness of the optimal solution that can be compared with a random draw of tenders, where there is a 0.388 probability of observing at least 5 matches, and only a 0.006 probability of observing at least 8 matches.

Risk of Losing the Status Quo

A fully certain selection of tenders will realise no comparative loss in biodiversity condition. When uncertainty is introduced incrementally then the distribution of expected loss will approach the distribution describing totally random selections of tenders (Figure 3e). The uncertain and random distributions are significantly different. Pursuit of an optimal selection, despite the uncertainty, will still realise an expected benefit of 1.21 species-equivalents more than a random selection. The consequence of needing to make predictions is a selection that is 0.98 species-equivalents on average less efficient than a fully certain selection. Further, the comparative biodiversity loss at the 0.05 significance level is 2 species-equivalents, and may be defined as the 'Biodiversity at Risk' or BaR.

In implementing a budget of $100000, we expect (if the ALR auction was repeated 100 times) that 35% of auctions will still show a net loss in biodiversity condition after 20 years, despite the large investment in conservation (Figure 2.2f). This high probability of a net biodiversity loss is due to the variability in the possible responses to conservation, errors in prediction, and the observed tendency of the system to degrade in the absence of focused conservation. The risk of not being able to maintain the status quo over time can be hedged against by investing further in conservation. However, purchasing a further $50000 worth of tenders will reduce the risk of no net loss in biodiversity condition by only

10%, over the whole selection of projects. Asymptotically, it doesn't matter how much is invested in conservation there is only at most a 76% chance of maintaining or bettering the status quo.

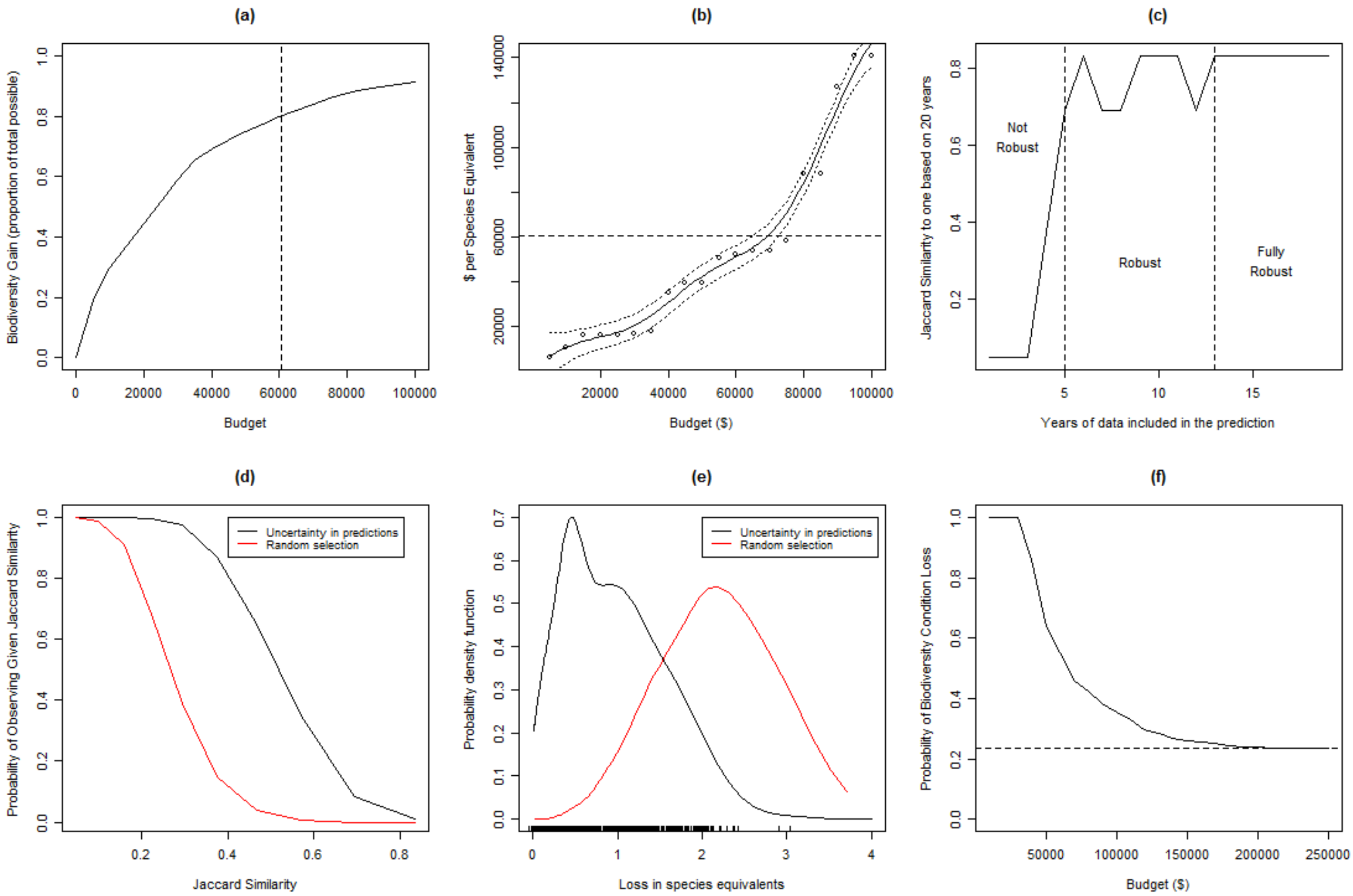

Figure 3: Performance of the Biodiversity Condition Metric

Panels (a),(b) map the cumulative biodiversity gain and marginal cost of the optimal tender selection with increasing budget, respectively. The dashed reference line equates to the mean cost of each biodiversity equivalent if all tenders in the ALR auction were purchased by the regulator. Panel (c) maps the robustness of the tender selection (measured as the Jaccard similarity index) to basing predictions of biodiversity condition change on shorter segments of the Landsat image archive. Panel (d) gives the probability of observing a given similarity between the tender selection and selections drawn from the uncertainty distribution. Panel (e) shows the expected distribution of losses stated in terms of species-equivalents for both a random tender selection, and a selection drawn from the uncertainty distribution. Panel (f) provides the frequency by which the status quo or better (in terms of biodiversity condition) cannot be achieved when uncertainty is accounted for in the tender selection process, and to what extent budgets of varying size hedge against the risk of a net biodiversity loss across all fragments tendered during a conservation auction.

3.2 Outcome-Based Conservation Contracts

If ecosystems exhibit variable behaviour and society invests in them through paying landholders to undertake conservation actions, this leads to a policy design problem. Contract design includes monetary incentives, monitoring methods, contract duration and, in the case of outcome-based payments, definitions of the outcomes. Input-based conservation contracts may be designed either using auctions (Latacz-Lohmann and van der Hamsvoort 1997) or principal-agent models (Moxey *et al.* 1999). Where ecosystem outcomes are variable, but depend critically on landholder technical skill, labour input and diligence (most of which are unobservable or are only observable at significant cost) then arguably input-based contracts will be largely ineffective as they do not provide incentive for on-going labour inputs. Therefore, in this project (in common with CSIRO MBI 2 project R2-15) the focus is on outcome-based biodiversity conservation contracts. Any effective input or outcome-based conservation contract is based on some form of contract. These contracts can be funded using either fixed prices, multiple contracts price or an auction mechanism.

3.2.1 Survey Data

Landholders were presented with a project that was familiar to most of them, namely a project run by the local catchment council (Avon Catchment Council) to protect and restore a 10 hectare block of degraded remnant vegetation over a five year period. The actions prescribed include stock exclusion, fencing and not collecting firewood. The landholders are offered two contract choices with different characteristics in terms of labour input, the probability of success, initial payment and final payment. There is a positive relationship between the level of labour input and the probability of successful bush restoration

The farmers surveyed show a moderate level of risk aversion with risk aversion declining with the level of wealth. The shadow price of a day of labour over five years is approximately $600 per day over five years, or $120 per day per year. The implicit discount rate was r=0.12 (12 per cent). The implications of these results for the regulator are illustrated in Figure 4 where high values of the α parameter indicate low levels of risk aversion. Risk aversion in the wheatbelt is around 0.25 to 0.60 (depending on the estimation equation). This indicates that a policy which combines an inttial payment with a final payment will be optimal.

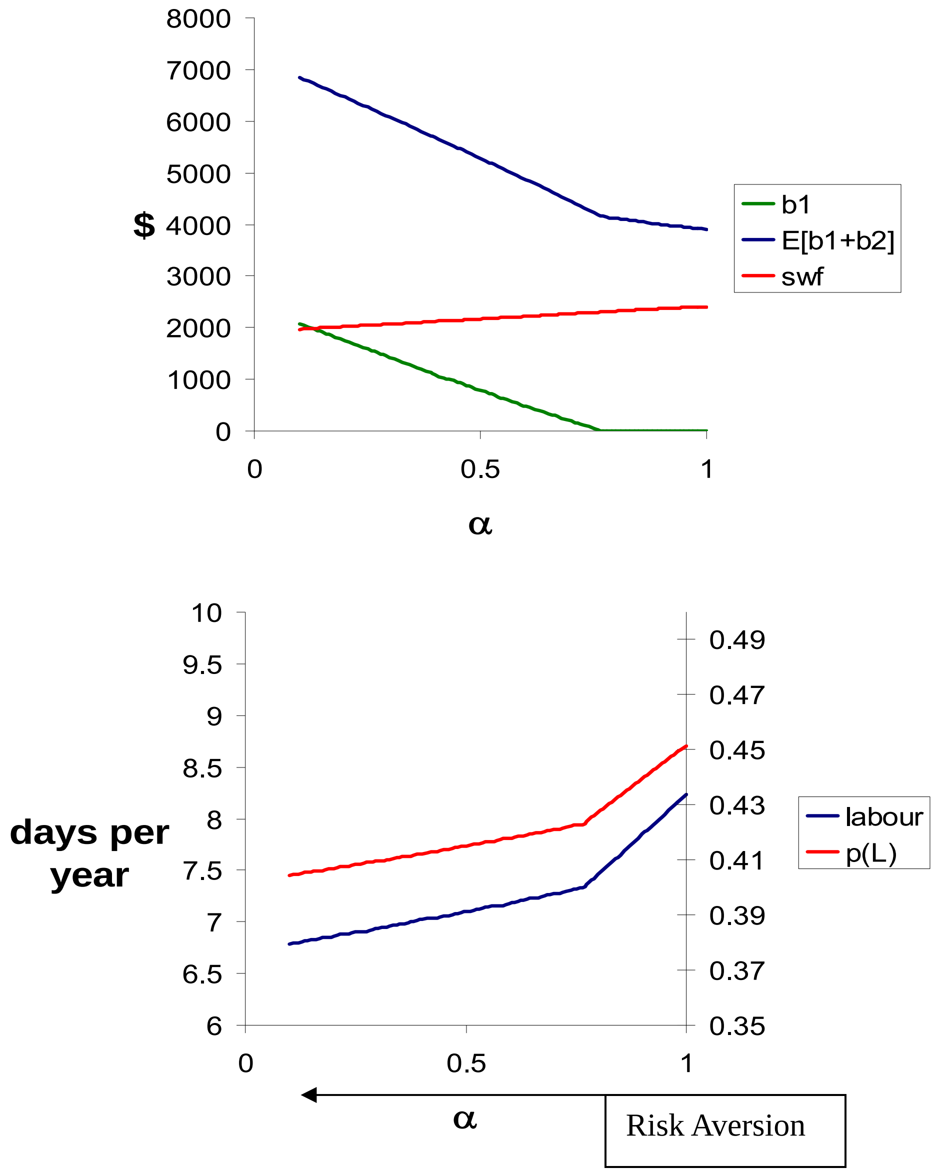

Figure 4 First-best Solution

In the top diagram the parameters b1 represent the initial payment and b2 the final payment, swf gives the regulators objective function. In the bottom diagram p(L) gives the probability of a successful conservation outcome and L=labour refers to conservation input in days per year.

3.3 Monitoring Vegetation Condition States

The characteristics of the monitoring problem for bushland fragments are as follows. First the variable monitored is a categorical variable classifying the state of the vegetation community into a finite number of classes. The monitoring problem here is dynamic and extends from two-periods up to any time horizon. The success of transition depends on natural processes and landholder non-compliance, but it is not possible to separate these two components out therefore they are lumped together in the probability of success.

Six transfer matrices/actions were derived being, no management with regulator monitoring (0), low management with regulator monitoring (1), high management with regulator monitoring (2), no management (3), low management (4) and high management (5), and were attributed costs of $8, $13, $18, $0, $5 and $10 respectively. Costs were derived from a combination of Regulator monitoring, Landholder maintenance and opportunity costs of excluding an area of land. The five biodiversity condition classes (20%, 40%, 60%, 80% and 100% values of the biodiversity condition metric) were specified rewards of $8, $23, $46, $69 and $91 respectively. Category rewards were calculated from figures presented in Mallawaarachchi *et al.* (2001) and Gole *et al.* (2005). A sensitivity analyses was conducted on vegetation state (biodiversity condition) rewards with benefits decreasing from 100% to 0% in 10% increments.

High management with regulator monitoring was optimal on an annual basis for all category classes under all contract horizons, and for all rewards equal to or greater than 60% of the initial rewards. Decreasing final payments to 60% of initial rewards resulted in fragments with 60% biodiversity condition not being managed or monitored until the fragment either shifted up or down a state, in which instance either high management with monitoring, low management with monitoring or no management was deemed to be optimal. Reducing payments below 60% of initial rewards and examining biodiversity condition categories either side of 60%, resulted in considerable variance between horizons and payments.

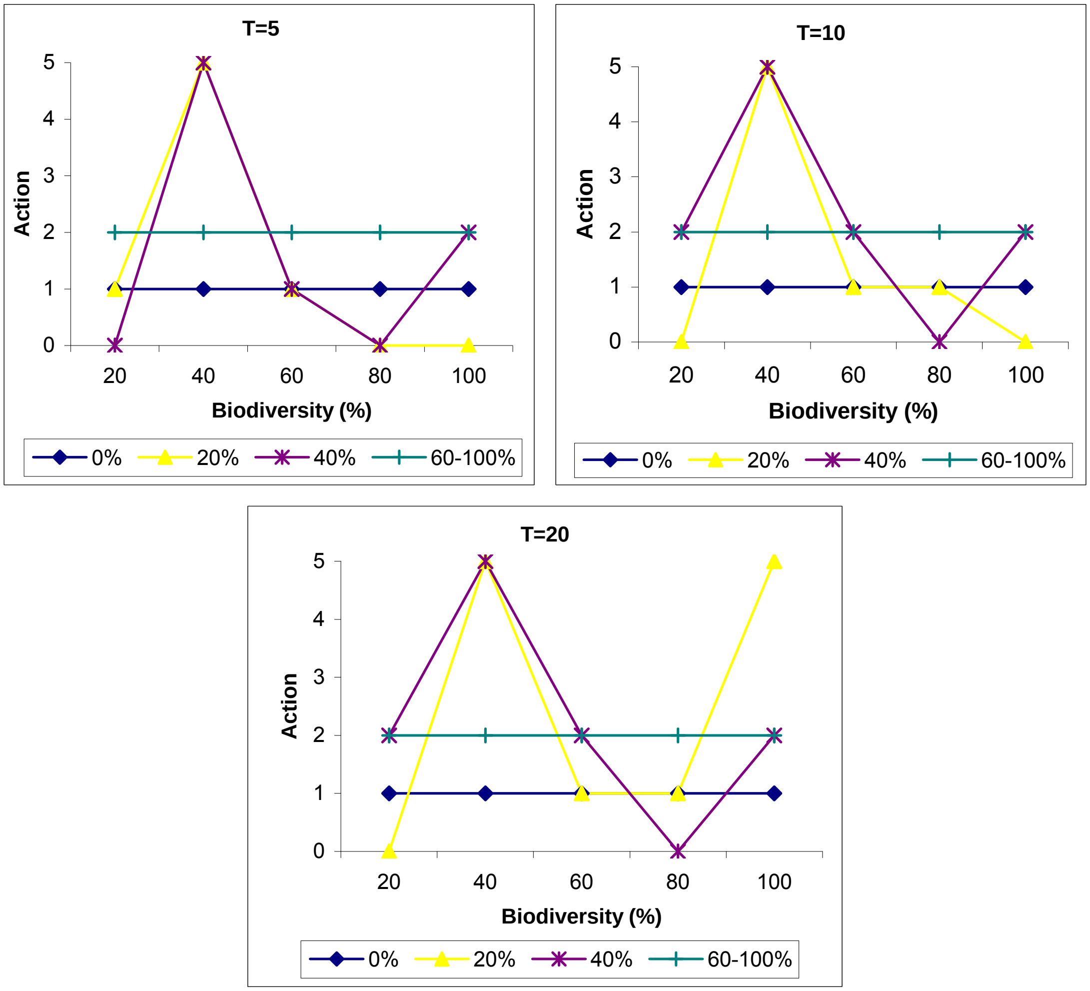

Figure 5: Optimal annual regulator actions with changes in final payment and remnant biodiversity percentages

Panels map the change in optimal actions selection for each reward scenario (ie. 0, 20, 40, 60-100% of base rewards) and at each remnant condition (20, 40, 60, 80, 100% biodiversity). This was repeated for time horizons of 5, 10 and 20 years respectively.

3.4 Outcome-based Contracts Experiments

The experiments were designed to test three issues. First do outcome-based contracts increase incentives for farmers to increase their level of conservation effort? Second, does auctioning outcome-based contracts increase the incentives of landholders to increase their level of effort? Third, do outcome-based contracts reduce the rate of participation in the conservation scheme?

3.4.1 Experimental Design

The experiment offered respondents in turn a series of contracts: Contract 1 payed 50% on inputs and 50% on outcomes; Contract 2 (33%, 67%); and Contract 3 (0%, 100%). The following results were obtained**.** First, effort is declining for all groups as the proportion of the total payment on outcomes increases. These results are explained by a reduction in participation. Given that the effort is minimal for pure input-based contracts, this implies an inverse u-shaped pattern for total effort, indicating that there is an optimal design of contracts. This result is shown analytically for the landholder survey. Auctions induce more effort from the participants, but this effect diminishes when the payment is entirely on outcomes.

3.5 Priority Knowledge Gap Filled

Prior to this project and the CSIRO project (MBI2-15) there has been virtually no work on outcome-based conservation contracts. The results that outcome-based contracts are efficient, acceptable to landholders and can be administered using the metrics developed in this project has the potential to significantly increase the efficiency of Australian environmental policy, especially when combined with monitoring (either remote sensing or self-monitoring).

There are two approaches to outcomes-based contracts based on how evaluation and assessment is conducted, described by either a filter model or a predictive model. A filter model tenders for contracts where the target outcomes and the actions to enable those outcomes are tightly controlled. For example, the NestEgg project (R2-15) allows only for specific outcomes: the viability of contracts and outcomes-based payments are assessed based on enhanced nesting habitat; the presence of ground-nesting birds; and invites only landholders who own habitat capable of providing nesting sites to submit tenders. This high level of specification 'filters' out most tenders that possess a low likehood of success. Due to the 'filter' there is a high likelihood that if the proposed conservation actions are undertaken then successful outcomes will result. Consequently, failure to acquire the outcome-based payment will more likely be the result of non-compliance. However, such a strong causal relationship between management and ecological response, more often than not, does not exist as the behaviour of ecological systems is highly variable, dynamic and of limited duration.

In contrast, broader conservation targets such as enhancing biodiversity across a landscape are unlikely to show consistent responses to management as these system responses are confounded by a range of ecological factors (e.g. salinity, vegetation type, fire, and landscape fragmentation). For high value outcomes such as landscape biodiversity the policy maker will need to consider investing in more sophisticated monitoring and modelling in order to evaluate tenders, the uncertainty surrounding responses to conservation, and the economic efficiency and risk of larger scale projects. To address broader conservation objectives using outcome-based contracts there is a need for two levels of analysis based around an ecological metric. First a 'prediction' of the outcomes resulting from conservation actions and how variable these outcomes will be to allow conservation to be targeted. Second, the definition of a metric as a measure of success. In this project the biodiversity condition metric estimates on-ground biodiversity from remote sensed imagery. This metric is adaptable to different roles: it predicts responses to actions; can be reclassified to discrete national vegetation condition classes (VAST) as a basis for ground truthing; it may be applied to extensive landscapes; it is the basis for an optimal monitoring schedule; it provides a risk assessment in the form of a probability of persistence; and finally can be used to define the expected ecological outcomes of conservation contracts. The complexity of a predictive model adds additional costs to conservation planning, but provides benefits by fulfilling an integrating role in the planning, implementation and monitoring of MBI schemes.

3.6 Communication

The involvement of Cheryl Gole (DEC, WWF and Coordinator of the Southwest Australia Ecoregion Initiative (SWAEI)) as this project's end-user advisor, and Pauline Guest (Deputy Chairperson of the Avon Catchment Council) in administering and coordinating the landholder surveys, has meant that the findings of this research have been communicated to these organisations throughout the project.

More formal communication activities include a paper presented at the Australian Agricultural and Resource Economics Society Annual Conference in Canberra In February 2008 on outcome-based conservation contracts and a presentation to the SWAEI executive committee on June 6 2008. Future communications will involve a series of journal papers and a continued engagement with the SWAEI as they analyse the prioritisation of conservation activities for the southwest region. ALRUU has produced a set of tools which are applicable to conservation planning through optimal contract design, tender selection and monitoring. There are relatively few organisations involved in these activities in the State, SWAEI represents all of them and therefore will be the focus of communication activities as papers and reports are produced from this project.

Outside WA, the research groups has strong links with DSE in Victoria and the findings of this research will be presented to Gary Stoneham's group at the DSE in the next two months.

4. Conclusions and Recommendations

Policy Recommendations

1. Landscape scale conservation policy should assess the likelihood that actions are successful, possibly by using historical data such as the Landsat image archive. In the absence of evidence, funds risk being wasted on projects which have a small probability of success.
2. Outcome-based contracts should be considered in the design of conservation auctions as they have desirable incentive properties and overcome the moral-hazard problem associated with input-based contracts. The participation problem may be addressed, if necessary, by offering an initial certain payment as well as an outcome-based payment.
3. There is experimental evidence that auctioning outcome-based contracts will increase efficiency.
4. Monitoring should not be routine, but should be contingent upon the expected state of the ecosystem to decide if a conservation project receives further funding or not. It might be possible to use remote sensing and self-monitoring for many projects as an approach to reducing costs.

Linkages to Other MBI projects

There are two MBI2 projects to which our findings have relevance.

1. The project *Design Auctions with Outcome Bonuses: An Application to Ground Nesting Birds in the Murray Catchment* (R2-15) trialled an outcome-based auction payment. The target of the pilot auction was bird habitat rather than bush fragment conservation. Their results indicate that outcome-based contracts would be 33 percent more cost-effective than input contracts. A similar result was found in the outcome-based contract experiments.
2. The links to *Bushbrokers* (R2-20) are in terms of developing metrics which are able to represented bush fragment biodiversity condition. The analysis of edge effects and bush fragment quality (Appendix A.5) is also relevant to R2-20.
3. The project *Issues Of Enforcement And Regulation In The Application Of Market Based Instruments* (R2-48) and ALRUU both address the issue of monitoring, R2-48 in the context of non-point source pollution and ALRUU in terms of when to stop a conservation project which is not achieving its outcomes.

Key outcomes

1. Effects of conservation are only short-term if the underlying causes of biodiversity loss are not being addressed. For instance, landscape salinisation, and small fragment size leading to the extinction of local populations (Appendix A.4). The implication is that there needs to be continued and targeted investment in conservation otherwise biodiversity will gradually decline through time. This point is illustrated by the observed 18 per cent loss in high quality fragments over the period 1988 to 2007, and that a minimum of $40000 in conservation contracts would need to be purchased just to maintain the status quo (i.e. no net loss) in biodiversity (Appendix A.5).
2. Tender selections are relatively robust to the time period of the image archive upon which predictions of biodiversity condition change are based. At least 5 years, and preferably 15 years, of historical imagery are required before confidence may be placed in the optimality of a selection of tenders
3. In terms of market-based instruments, there is significant potential in outcome-based contracts to increase cost-effectiveness, from the evidence of the experiments and the landholder survey.
4. Outcome-based contracts, although cost-effective, may in some situations reduce participation by landholders with high levels of risk aversion. If necessary, this can be overcome by using an initial payment as well as an outcome-based payment.
5. The timing and frequency of monitoring to determine the status of a conservation scheme should depend upon monitoring costs, the expected rate of change in biodiversity condition and the value of the bush fragment.
6. Conservation effort should ideally be targeted towards underrepresented (i.e. irreplaceable) vegetation types. This can be addressed by providing landholders with information and the use of a metric which accounts for the rarity of a vegetation type at a regional level.
7. Conservation policy should use a systems approach where links are made between project selection, mechanism design, monitoring and reselection. Of these aspects of conservation policy the issue of reselection is often neglected, but most schemes should be established with some mechanism in place to allow reselection at the end of the project.

5. References

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