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Contracting for biodiversity in Australia

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ABSTRACT

This study is concerned with the design of a contract between a conservation agency and a private landholder who undertakes to provide environmental benefits. Paying private landholders for environmental benefits, rather than relying solely on inputs, has been proposed as a way to improve the performance of conservation contracts. Paying for an intangible good, such as environmental services, raises the question of how assessment accuracy impacts on landholder behaviour, including their compliance with the contract. The focus of this paper is the impact of assessment accuracy and cost on landholder compliance and the overall contract design. A model is developed to estimate the impact of on-ground and remote assessment technologies on the optimal levels of landholder labour and conservation payments. The model indicates the feasibility of conservation contracts is shown to be dependent on the ability of the conservation agency to observe the landholder's behaviour. The model shows inaccurate and costly assessment reduces the environmental and cost effectiveness of the conservation contract. Application of the model to the Australian broad acre agriculture suggests that remote assessment by satellite imagery is preferred to on-ground assessment.

Keywords and JEL codes (if available)

INTRODUCTION

There is increasing interest in paying landholders on the basis of environmental benefits or outcomes delivered, rather than paying in advance for labour and materials that may lead to environmental benefits. The intention is to more closely align the incentives of landholders to those of the conservation agency. In Australia this approach has already been applied to a limited extent in schemes such as EcoTender in Victoria and the Environmental Stewardship Scheme in New South Wales.

Payments for environmental benefits raise three key questions: (a) How should applications from landholders be assessed? (b) What is the ecologically and economically optimal duration for contracts? and (c) What level of investment in monitoring, evaluation and enforcement of contracts is appropriate? Extensive research has been conducted into the first of these questions, while limited work has been done on the second and third.

In research literature dealing with question (a), the assessment of landholder applications for competitive conservation scheme funding has been analysed primarily with auction theory. Both in Australia and internationally the auction mechanisms for conservation schemes has been extensively analysed and reviewed. Conservation auctions are seen by many economists to have substantial advantages in terms of the cost-effectiveness of outcomes relative to traditional grant schemes (e.g. Ferraro 2008; Latacz-Lohmann and Schilizzi 2005; Stoneham *et al.* 2003).

In cases where auctions have been used, the benefits of alternative projects are usually assessed using an environmental benefits index. For example, this is true of the EcoTender scheme in the Australian state of Victoria (Eigenraam *et al.* 2006), and the Nest Egg project in New South Wales (Gorddard *et al.* 2008). Hajkowicz (2008) provides a review of various agri-environmental benefit indices used in schemes internationally.

Research specifically targeting the optimal duration of contracts (question (b)) is beginning to appear in the literature (e.g.White 2007; White *et al.* 2008). Simultaneously, in the real world of policy, an emerging trend is towards longer contract time frames or permanent protection (a covenant) on the land title (Figgis 2004). This trend reflects a realisation that

environmental outcomes often require sustained management actions over long time frames.

Finally, the role of monitoring, evaluating and assessing the environmental outcomes of conservation projects (question (c)) has also been studied (e.g. see the review by Meijerink (2008)). For example, Fraser (2004) showed that it may be efficient to target monitoring effort to a subgroup of landholders, selected on the basis of information about their previous environmental performance. Other research indicates that the cost of monitoring and evaluation are likely to be relatively low in cases where landholders are risk averse and have high income variance (Fraser 2002; Ozanne and White 2008). Meijerink (2008) states that the design of conservation schemes must recognise (i) the type of environmental service and its underlying production process; (ii) the extent to which the environmental service can be freely observed or measured; (iii) the extent to which activities of the resource managers who provide the environmental service can be freely observed; and (iv) the deterministic or stochastic nature of production processes. The specific design of the conservation scheme given these issues remains to be researched.

In the above-cited studies, the dominant conceptual framework used is the principal-agent model, building on the earlier work of Choe and Fraser (1999) and Ozanne et al (2001). Principal-agent modelling has also been used to analyse the required accuracy of assessment in mitigation banks (offsets required for environmentally degrading development) (Hallwood 2007). All of the above studies of monitoring and assessment have only analysed single-period conservation contracts for labour and materials.

This paper builds on the existing research, to look at the additional question of how different levels of accuracy in assessing landholder compliance are likely to affect landholder behaviour, with implications for optimal contract design and assessment strategies. A principal-agent model of a conservation scheme with an initial payment for entering the contract and a final payment for the quality of environmental services provided is developed and applied to a case study in the extensive grain-producing region of Western Australia. The model incorporates the accuracy and cost of assessing compliance in contracts that extend over multiple time periods.

MODEL

BASE MODEL

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A principal-agent model is designed to replicate the contract process outlined in Figure 1. The conservation agency (principal) and the landholder (agent) enter into a conservation contract for the production of environmental benefits. The regulator's problem is to choose a payment amount and timing to maximise the social welfare function:

$$Z = w(l_t) + k(l_t, b_1, b_2) - c(l_t, b_1, b_2) \qquad (1).$$

The social welfare function is composed of the benefit society receives from the improvement in the vegetation quality the contract achieves (w), the landholder's profit (k) and the social cost of the contract (c). The social benefit of the contract (w) is calculated as:

$$w(l_t) = \sum_t \delta_t v(s_t - s_0) = \qquad (2).$$

The social benefit is the total value of pristine vegetation (v) scaled down by the quality of vegetation that is achieved by the contract in each period (s_t) compared to the original vegetation quality (s_0), and the discount factor (δ_t). The quality of vegetation that is achieved by the contract in each period (s_t) is a function of the labour effort of the landholder (l_t), described shortly.

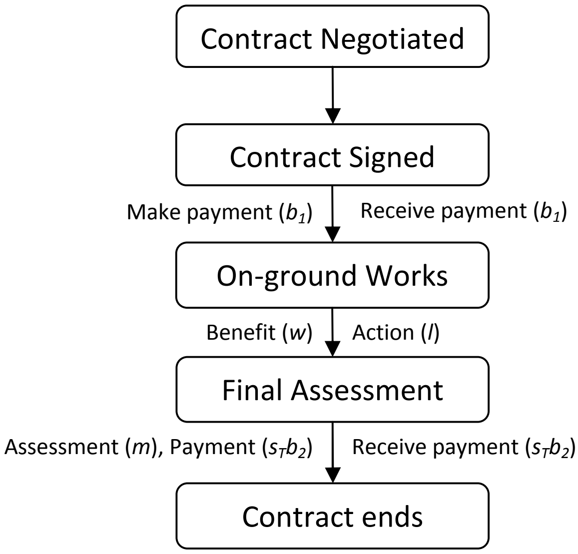

Figure 1 Contracting process for conservation contracts between conservation agency and landholder.

The landholder receives payment b_1 at the beginning of the contract period and/or payment $s_T b_2$ at the completion of the contract. The payment to the landholder at the completion of the contract is dependent on the environmental benefits the landholder achieves in the final period (T), measured as the quality of the vegetation (s_T). The quality of the vegetation (s_t) is measured on a scale of 0 to 1, with 1 being pristine vegetation and 0 being heavily degraded. It is assumed the vegetation entered into a conservation contract is remnant native vegetation and would not be used in agricultural production.

The landholder is able to affect the quality of the vegetation through their labour effort each period (l_t). The total return to the landholder (k) is:

$$k(l_t, b_1, b_2) = b_1 + \delta_t s_T b_2 - \sum_t (\delta_t g l_t) \qquad (3).$$

The landholder's total return is calculated as the payments they receive taking into account the discount factor (δ_t), less the opportunity cost of their labour (g) for their given labour effort (l_t).

The total cost to the regulator of these payments to the landholder's is the payment amounts b_1 and $s_T b_2$, allowing for the cost of public funds (e):

$$c(b_1, b_2) = (1 + e)(b_1 + \delta_t s_T b_2) \quad (4).$$

The state of the vegetation in each time period is calculated as:

$$s_t = s_{t-1} + al_t + r \quad (5)$$

The vegetation quality is a function of the quality at the beginning of the period (s_{t-1}) plus the outcome of labour effort of the landholder during the period (l_t) and any inherent natural rate of improvement or decline (r). The landholder's effort is scaled as to the ability/skills of the landholder to alter the vegetation state (a).

For the landholder to enter into a conservation contract it must offer a greater return than the alternative options, i.e. meet an individual rationality constraint. As the opportunity cost of the land is assumed to be zero the rational landholder simply requires the return from the contract is greater than the cost of their labour:

$$k(l_t, b_1, b_2) \geq 0 \quad (6).$$

Assuming the landholder is required to exert the same quantity of labour in each period and the discount factor is negligible the binding individual rationality constraint simplifies to:

$$b_1 + (s_0 + Tal_t + Tr)b_2 - Tgl_t = 0 \quad (7),$$

where T is the total number of periods.

The optimal outcomes based contract, with b_1 equal zero and only payment b_2, simplifies Equation 7 to give the optimal payment amount and labour effort of:

$$b_2 = \frac{Tgl_t}{s_0 + Tal_t + Tr} \quad (8)$$

$$l_t = \frac{(s_0 + Tr)b_2}{Tg - Tab_2} \quad (9).$$

The optimal outcomes based contract of this model provides a payment that relates the landholder's total labour cost and the environmental outcome achieved (8). This is effectively a cost:benefit ratio for the contract. The labour effort of the landholder is equal to the guaranteed payment for entering the contract per dollar of their net cost of labour

effort (9). The landholder is applying labour to balance the guaranteed payment against the return on their labour effort for entering the contract.

If the conservation agency is unable to observe the period in which the landholder applies their labour effort the landholder may be able to alter the timing of their labour to increase their profit. The conservation agency will be able to observe the final vegetation quality though, so the landholder will still be required to achieve the quality set by the contract terms. The landholder will structure their labour effort to maximise $k(l_t, b_1, b_2)$, potentially changing the overall social benefit of the contract $Z(l_t, b_1, b_2)$.

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Alternatively, the final payment to the landholder by the conservation agency could be based on the change in the quality of the vegetation achieved during the contract, rather than the total quality. In this case the final payment would be $(s_T - s_0)b_2$, reducing both the landholder's benefit of Equation 3 to:

$$k(l_t, b_1, b_2) = b_1 + \delta_t(s_T - s_0)b_2 - \sum_t (g\delta_t l_t) \qquad (10),$$

and the conservation agency's cost of Equation 4 to:

$$c(b_1, b_2) = (1 + e)(b_1 + \delta_t(s_T - s_0)b_2) \qquad (11).$$

The optimal payment for environmental outcome from the model when based on the change in vegetation quality, if landholder's labour effort is equal across all periods, is;

$$b_2 = \frac{gl_t}{al_t + r} \qquad (12).$$

The optimal payment is the ratio of the labour cost and the change in the overall vegetation quality in each period. The optimal payment again is the cost:benefit ratio for environmental improvements achieved by the labour effort. The optimal labour effort this outcomes payment corresponds to is;

$$l_t = \frac{rb_2}{g - ab_2} \qquad (13).$$

The landholder's labour effort is equal to the cost or benefit of entering the contract due the payment for natural change in the vegetation quality and the net cost or benefit of undertaking the contracted labour effort.

IMPERFECT ASSESSMENT

Contracting for vegetation quality

The model presented above implicitly assumes the regulator is able to perfectly assess the quality of the vegetation at the contract's completion. If the regulator is unable to accurately assess the state of vegetation this will alter the landholders expected return on the conservation contract and the overall social welfare from the contract. Inaccurate assessment leads to two types of error; (1) a landholder is assessed as compliant with the contract when in fact he/she is not, and (2) a landholder is assessed as non-compliant when he/she actually is compliant. The conditions for landholder compliance with the contract must be carefully defined to ensure this error is correctly incorporated into the model.

Typically landholders will be required by the conservation contract to undertake labour effort in restoring the state of the vegetation. Compliance is then defined as exerting labour effort, with the landholder receiving payments b_1 and $s_T b_2$. Non-compliance is not exerting labour effort, and no payments are received. There are four combinations of accurate or inaccurate assessment by the conservation agency with compliance or non-compliance by the landholder.

The conservation agency now faces a revised social welfare function:

$$Z = w(l_t) + k(l_t, b_1, b_2) - c(l_t, b_1, b_2, o) \quad (14).$$

The environmental benefit function is the same as the original presented earlier in Equation 2:

$$w = \sum_t \delta_t v s_t = \sum_t \delta_t v (s_{t-1} + a l_t + r_t) \quad (15).$$

The cost function, however, is altered to include a cost for investing in an assessment technology per hectare (o):

$$c(b_1, b_2) = (1 + e)(b_1 + \delta_t s_T b_2 + \delta_t o) \quad (16)$$

The four combinations of accurate assessment by the conservation agency and compliance by the landholder have different expected profits for the landholder, as summarised in Table 1. The probability of the conservation agency accurately assessing the landholder's compliance is m ; this is unique for each assessment technology. When the landholder is correctly assessed as compliant they receive the initial and final payments with probability m , and incur the labour effort cost (k_i). If a compliant landholder is incorrectly assessed as non-compliant they do not receive either payment but incur the cost of the labour effort (k_j). If the landholder does not undertake any labour effort and this is correctly assessed they do not receive any payments and do not incur any costs (k_k). The landholder who does not exert labour effort but is assessed has having done so receives both payments; however, their final payment would be lower as the state of the vegetation is less than when labour effort is applied (k_l).

TABLE 1 SUMMARY OF EXPECTED LANDHOLDER PROFIT FROM A CONTRACT WITH INACCURATE ASSESSMENT.

	Assessment accurate	Assessment inaccurate
Labour effort undertaken $l_t > 0$	$k_i(l_t, b_1, b_2)$ $(b_1 + \delta_t s_T b_2) - \sum_t (g\delta_t l_t)$	$k_j(l_t)$ $-\sum_t (g\delta_t l_t)$
Labour effort not undertaken $l_t = 0$	k_k 0	$k_l(b_1, b_2,)$ $(b_1 + \delta_t s_T^r b_2)$

The regulator must provide a contract where the landholder's profit from entering and complying with the contract is greater than entering and not complying. If it is profitable for the landholder to enter the contract and not comply the quality of vegetation will not increase beyond any natural improvement. This incentive compatibility constraint is:

$$mk_i + (1 - m)k_j \geq mk_k + (1 - m)k_l \qquad (17).$$

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Limiting the final payment to being for only the improvement in the vegetation quality instead of the total quality has the same overall benefit from the vegetation but alters the cost to the conservation agency and profit for the landholder when they are assessed as compliant. The reduced cost function of the conservation agency is:

$$c(b_1, b_2) = (1 + e)(b_1 + \delta_t(s_T - s_0)b_2 + \delta_t o) \quad (18).$$

The landholders profit when compliant with the contract, and assessed as compliant is:

$$k_i(l_t, b_1, b_2) = b_1 + \delta_t(s_T - s_0)b_2 - \sum_t (g\delta_t l_t) \quad (19).$$

The landholders profit when not compliant but assessed as compliant is:

$$k_i(b_1, b_2,) = b_1 + \delta_t(s_T - s_0)b_2 \quad (20).$$

APPLICATION: AUSTRALIAN SIMULATION

BACKGROUND

The Western Australian wheatbelt, and particularly the North Eastern Wheatbelt Regional Organisation of Councils (NEWROC), has received attention recently as it is important both for agricultural production and the natural environment. The area is a highly productive part of Western Australian agriculture, as well as being significant internationally for its biodiversity, especially in areas where native vegetation has not been cleared for agriculture. In the area 69% was classified as Intensive Land-use Zone, for agricultural use, with the remainder in the Extensive Land-use Zone for grazing and mining (Shepherd *et al.* 2001). In the Intensive Land-use Zone of NEWROC only 12% is currently remnant natural vegetation (Shepherd *et al.* 2001). Both agricultural and environmental values are under threat from land degradation. A number of conservation projects have been undertaken in the NEWROC, providing good sources of ecological and socio-economic data for empirical analysis of the model presented above.

The Auctions for Landscape Recovery project piloted a conservation scheme using an auction mechanism in the NEWROC area between 2003 and 2005. Farmers were contracted for 3 years to undertake fencing, revegetation and weed control activities (Gole *et al.* 2005). More recently, research has been conducted on the ecological change occurring in the NEWROC both with and without active management, as well as landholder perceptions of conservation efforts (White *et al.* 2008). This provides estimates of the various costs and outcomes of revegetation measures for remnant vegetation in the area.

The contract modelled is a three-year voluntary agreement between the conservation agency and the landholder. The landholder is to undertake conservation work during these years to receive an initial payment and/or a final payment based on the environmental services provided. The contracting process involves the conservation agency and landholder forming a contract, the landholder undertaking actions, being assessed and receiving payment, (refer to Figure 1 above). The regulator determines the initial payment (b_1) and final payment b_2. The landholder determines their level of labour effort (l_t). The final payment received by the landholder is the maximum final payment (b_2) scaled by the final quality of the vegetation achieved (s_T).

Estimates for each of the model parameters are given in Table 2 below based on the Auctions for Landscape Recovery scheme (Gole *et al.* 2005) and Auctions for Landscape Recovery Under Uncertainty project (White *et al.* 2008) in NEWROC. Few studies have been conducted into the community willingness to pay for environmental services in Australia. In this study a value of $1000 per hectare each year is used as an estimate of the benefit to society of the salmon gum woodland in NEWROC (v). This is based on a study in northern Queensland that valued teatree woodlands at $18/ha/year and wetlands at $2812/ha/year (Mallawaarachchi *et al.* 2001). As a comparison, the community willingness to pay for remnant native woodland vegetation conservation in the Murray catchment of New South Wales was estimated to be approximately $75 per household as a one off payment or $75 million in total, for 100,000 ha conserved over 5 years, and $73 per household or $61 million for equivalent conservation in North-east Victoria (Lockwood *et al.* 2000). The shadow price of public funds (e) is assumed to be 10%. The long term interest rate (i) used to calculate the discount factor (δ) was 5%.

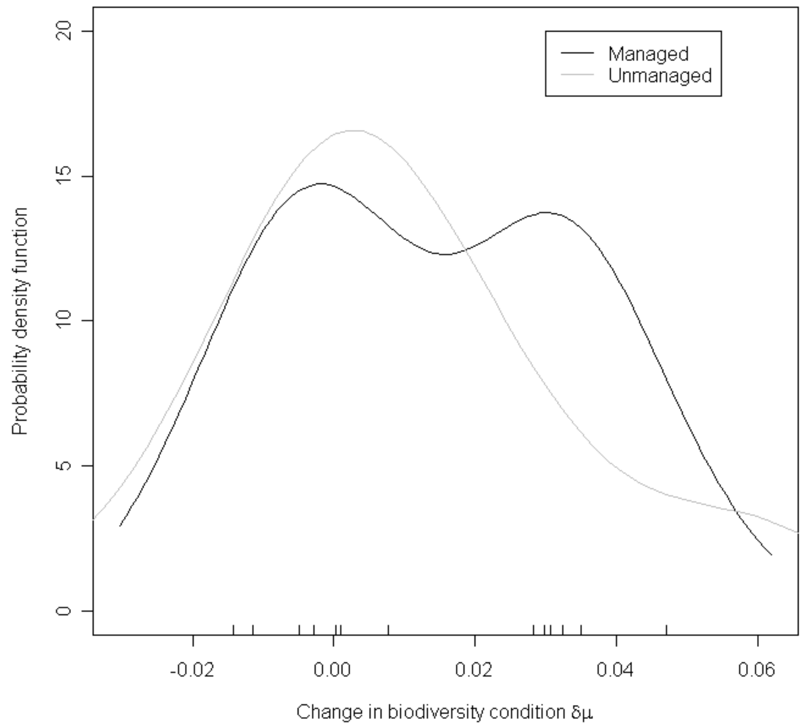
TABLE 2 PARAMETER ESTIMATES, VARIABLES AND FUNCTIONS PER HECTARE, BASED ON NEWROC (GOLE *ET AL.* 2005; LOCKWOOD *ET AL.* 2000; MALLAWAARACHCHI *ET AL.* 2001; WHITE *ET AL.* 2008)

Parameter	Symbol	Estimate
Value environmental benefit ($/yr)	v	1000
Opportunity cost of labour ($/hr)	g	10
Landholder efficiency vegetation change (%/hr/yr)	a	0.7
Initial state of vegetation (%)	s_0	60
Rate of decline of unmanaged native vegetation (%/yr)	r	0
Maximum change in vegetation quality (%/yr)	$s_t - s_{t-1}$	2

Interest rate (%)	i	5
Shadow price of public funds (%)	e	10
Monitoring accuracy of on-ground assessment (%)	m	95
Cost of on-ground assessment ($)	o	10
Monitoring accuracy of remote assessment (%)	m	70
Cost of remote assessment ($)	o	1
Variables		
Labour effort (hr/yr)	l_t	
Initial payment ($)	b_1	
Final payment ($)	b_2	
Functions		
Environmental benefit	w	
Landholder profit	k	
Cost of payments	c	
Quality of vegetation	s_t	

The landholder efficiency to change the vegetation quality (a) and rate of change of unmanaged vegetation (r) are estimated from remote and on-ground assessments of vegetation quality connected with the Auctions for Landscape Recovery project in NEWROC. The Auctions for Landscape Recovery required landholders to either maintain current state of the vegetation by fencing or undertake actions such as revegetation and weed control to improve their vegetation. Figure 2 shows the probable change in the quality of managed and unmanaged vegetation. The two 'bumps' of managed vegetation indicate the distinction between management to maintain and management to improve the vegetation. Management to improve remnant native vegetation over the three years of the contract required approximately 1 hour of labour per hectare each year and provided on average a 0.03 point increase on the 0 to 1 vegetation state scale over the 4 years 2003 to 2007. The impact of management is calculated as approximately 0.007 per hour of labour effort (a). Unmanaged vegetation (r) does not improve or decline, a natural rate of change of 0. The ability of the landholder to alter the state of the vegetation each period is capped at 0.02 as greater change is judged to be ecologically infeasible. The initial quality of the vegetation (s_0) is estimated to be 0.6. The opportunity cost of landholder labour for conservation work (g) is estimated by White et al (2008) to be $10 per hour.

Figure 2 estimated Biodiversity condition score of managed and unmanaged vegetation in the NEWROC Auctions for Landscape Recovery project. [I need to fix the legend still XX]



The assessment techniques available to the conservation agency are assumed to be on-ground assessment by a local government officer, and remote assessment via a global information system or satellite. The on-ground assessment provides an accuracy (m) of 95% at a cost (o) of $10 per hectare each year of assessment. The remote assessment has a lower accuracy of assessment (m), 0.7, but is also lower cost (o), $1 per hectare. Assessment takes place in the final year of the contract, year three.

RESULTS

With perfect and costless assessment the optimal total payment to the landholder is $57 per hectare (ha) for 2.9 hours of labour in the first two periods, providing a net present benefit of $33 per ha over a three year conservation contract. The landholder does not have a preference between a payment at the beginning of the contract (b_1) or at the completion ($\delta_t s_T b_2$), or between payment on the total quality ($\delta_t s_T b_2$) or change in quality ($\delta_t (s_T - s_0) b_2$). The payment must simply be greater than $57 to cover the landholder's labour costs as the individual rationality constraint is binding. This occurs because the deterministic calculation of the environmental outcomes from landholder labour efforts in

the model does not capture the uncertainty perceived by the conservation agency and individual landholders that leads to preferences on payment timing and design. Further work will be conducted into this area.

Table 3 shows the impact on the optimal labour effort, optimal payment and net benefit of changing the labour assumptions and incorporating inaccurate, costly assessment. The socially optimal landholder labour effort is 2.9 hours of labour per ha in the first and second years of the contract and none in the final year. In the first and second periods the landholder is exerting labour effort to achieve the maximum change in the quality of vegetation possible each period (0.02%). The labour effort increases the state of the vegetation from 0.6 to 0.64 over the life of the contract. Requiring the labour effort to be equal across the years of the contract increases the payment amount to $81 per ha as the labour effort becomes 2.9 hours in all three years of the contract. The net benefit decreases to $22 per ha though the quality of the vegetation increases to 0.66.

TABLE 3 LABOUR EFFORT, INITIAL AND FINAL PAYMENTS AND NET PRESENT VALUE OF CONSERVATION CONTRACT, WITH LABOUR AND ASSESSMENT ANALYSIS (PER HECTARE).

	Labour effort (hr) l_1, l_2, l_3	Payment ($) $b_1, \delta_3 s_3 b_2$ or $\delta_3 (s_3 - s_0) b_2$	Veg quality (%) s_3	Net Value ($) Z
Prefect, costless assessment	2.9,2.9,0	57	0.64	33
Labour equal in all periods	2.9,2.9,2.9	86	0.66	22
Landholder labour timing unobservable	0,2.9,2.9	57	0.64	-4
On-ground assessment	2.9,0,0	32	0.62	16
Remote assessment	2.9,0,0	71	0.62	23

Were the conservation agency unable to observe when the landholder applied their labour effort the landholder would profit from altering the timing of their labour effort from the optimal. If the landholder was contracted to provide the optimal final vegetation quality of 0.64, requiring two periods of 2.9 hours of labour, the landholder would apply their labour in the second and third period. Applying labour in the second and third year rather than the first and second increases the landholder's profit for the contract from $0/ha to $4/ha. The net benefit to society of the contract decreases to -$4/ha (Table 3). In this model it is not beneficial to society for the conservation agency to offer a conservation contract if they are unable to observe the timing of the landholder's labour effort and ensure the quality of the vegetation changes early in the contract term.

The numerical analysis indicates that the inaccuracy of on-ground and remote assessment tools in determining a landholder's compliance with a contract reduces the optimal labour effort of the landholder and increases the payment required for their labour effort. When the conservation agency uses on-ground assessment it is assumed they accurately determine landholder compliance 95% of the time at a cost of $10 per hectare. Were the conservation agency to offer the optimal contract with perfect and costless monitoring, but allowing for the impact of inaccurate and costly on-ground assessment the expected profit to the landholder from compliance with the contract is -$1.5/ha and non-compliance $2.9/ha. To ensure the landholder complies with the contract, the contracted labour effort is reduced to one period of 2.9 hours per ha for a total payment of $32/ha. The labour effort is limited by the relationship between the return on labour to the landholder to be compliant with the contract and the return on the environmental benefit to the conservation agency from the labour. In contrast, the total payment to the lamdholder increases from $28/ha to $32/ha with inaccurate assessment for the equivalent labour effort, as the expected payment to the landholder is scaled down by the accuracy of assessment. For it to be attractive to the landholder to enter the contract the expected payment must increase to be greater than the cost of labour, which has not changed. The expected profit of the landholder from both compliance and non-compliance with the optimal contract incorporating on-ground assessment is $1.6/ha. Altering the contract for on-ground assessment produces a final vegetation quality to 0.62 and reduces the net benefit of the contract to $16/ha from $33/ha with perfect costless assessment (Table 3).

Remote assessment of the compliance of landholders with the contract is assumed to have an accuracy of 70% and a cost of $1 per ha. Offering the optimal contract with perfect costless assessment but including remote assessment gives an expected profit for the landholder from compliance of -$15/ha and non-compliance $17/ha. The decreased accuracy of the assessment technology reduces the optimal landholder labour effort to one year of 2.9 hours/ha with a payment of $71/ha. A higher labour effort to the landholder would have a higher labour cost and require a higher total payment, and make it more profitable for the landholder to not comply with the contract than comply. The landholder's expected profit from both compliance and non-compliance is $21/ha. The optimal contract when adjusted for remote assessment has a net benefit of $23/ha (Table 3).

Sensitivity Analysis

Sensitivity analysis was conducted to determine the breakeven-values of the model parameters. Breakeven points define the minimum value of the parameter in order for society to benefit from the conservation agency offering the contract. Of particular interest was the value of vegetation, cost of labour, ability of the landholder to alter the vegetation quality and the natural rate of change in the vegetation quality. Sensitivity analysis on the optimal contract with perfect and costless assessment requires 2.9 hours of labour effort per ha in the first two periods of the contract, for a total payment of $57/ha. The results of the sensitivity analysis are presented in Table 4.

Table 4 The break-even value of labour effort, initial and final payments and Net present value of conservation contract (per hectare).

Parameter	Symbol	Breakeven value
Value of vegetation ($/yr)	v	651
Opportunity cost of labour ($/hr)	g	16
Landholder efficiency (%/hr)	a	0.46
Natural rate of vegetation change (%/yr)	r	0.58

The value of pristine vegetation to society (v) must be greater than $651 per ha each year for society to benefit from the conservation agency offering the conservation contract

assuming perfect and costless assessment (Table 4). The contract increases the quality of the vegetation from 0.6 to 0.64, providing a social benefit from the environmental improvement of $94 over the contract life. If society values pristine vegetation at $651/ha each year the environmental benefit from the contract is only $61/ha, equating to the landholder's profit of $2/ha less the $63/ha cost of the payment.

The opportunity cost of the landholder's labour (g) is assumed to be $10 in the model. For society to benefit from the conservation agency offering the contract with perfect and costless assessment the landholder's labour must cost less than $16/hr (Table 4). A cost for the landholder's labour above $16/hr makes the payment to the landholder greater than the environmental value of the change in vegetation they achieve.

The landholder's efficiency (a) at changing the vegetation quality refers to the vegetation change they are able to achieve per hour of labour effort applied. The optimal contract assumes the landholder's efficiency is 0.007. The landholder's efficiency must be greater than 0.0046 for society to benefit from the conservation agency offering the optimal contract (Table 4). With efficiency level lower than 0.0046 the environmental benefit from the vegetation change is less than the cost of the total payment required to secure the landholder's labour effort.

The natural rate of change in the vegetation is estimated to be zero, so the vegetation quality remains constant if unmanaged. The breakeven value of the natural rate of change is -0.0058 (Table 4). A rate of decline greater than 0.0058 counteracts the vegetation improvement the landholder is able to achieve in the optimal contract with 2.9 hours of labour in two periods. The environmental benefit is reduced to $61/ha as in the case of the breakeven point for the value of pristine vegetation.

The sensitivity analysis shows the feasibility of offering the contract with perfect costless assessment is limited. The feasibility of the contract is particularly susceptible to changes in the value and ability of improving vegetation quality and the payment required by the landholder. Overestimating the value of environmental benefits or underestimating the cost and ability to achieve them could easily see the conservation agency offering a contract with no benefit for society.

CONCLUSIONS

The paper provides an investigation of the design of conservation contracts for environmental benefits considering assessment accuracy and cost. The model presented extends the existing literature and the empirical analysis illustrates some key contract design issues for environmental services schemes. The empirical analysis indicates that the feasibility of conservation contracts within Western Australia is particularly vulnerable to the detection of when landholder's labour effort is applied. The inaccuracy and cost of assessment can also noticeably reduce the net social benefit of the contract.

The conservation agency would prefer the landholder undertake labour effort to improve vegetation quality in the initial periods of the contract. If the agency is not able to observe this and can only contract for the optimal final vegetation quality, it is more profitable for the landholder to apply their labour effort in the final period(s) of the contract. In this numerical analysis, if the landholder applies their labour effort in the final period(s) of the contract, the net benefit of the conservation contract is below zero. This indicates that if the conservation agency is not able to determine the timing of landholder labour effort, offering a conservation contract would not benefit society overall.

Assessment technologies are unable to perfectly determine whether a landholder has undertaken labour effort to comply with the contract. The fact the landholder can profit from not complying and being incorrectly assessed as compliant with the contract limits the contract design the conservation agency can offer. The model shows labour effort becomes restricted by the relationship between the return on labour effort to the landholder to be compliant with the contract and the return on the environmental benefit to the conservation agency from the labour effort. This reduces the improvement in vegetation quality that can be achieved by the conservation contract.

The numerical analysis indicates the net benefit of remote assessment is greater than for on-ground assessment in Western Australia. Remote assessment is less accurate but also less expensive. The lower cost of the remote assessment offsets the increase in total payment required by the landholder to enter the contract. The landholder requires a higher total payment as their expected profit is scaled down by the inaccuracy of the assessment.

As new technologies become available and alternatives such as self or peer assessment are investigated this preference may change and will need to be revisited.

REFERENCES

Choe C, Fraser I (1999) Compliance monitoring and agri-environmental policy. *Journal of Agricultural Economics* **50**, 468-487.

Eigenraam M, Strappazzon L, Lansdell N, Ha A, Beverly C, Todd J (2006) EcoTender: Auction for multiple environmental outcomes. DPI and DSE Victorian Government, Canberra.

Ferraro PJ (2008) Asymmetric information and contract design for payments for environmental services. *Ecological Economics* **65**, 810-821.

Figgis P (2004) 'Conservation on private lands: the Australian experience.' (IUCN: Grand and Cambridge).

Fraser R (2002) Moral hazard and risk management in agri-environmental policy. *Journal of Agricultural Economics* **53**, 475-487.

Gole C, Burton M, Williams KJ, Clayton H, Faith DP, White B, Huggett A, Margules C (2005) 'Auctions for Landscape Recovery Final Report.' (World Wide Fund for Nature - Australia: Sydney).

Gorddard RJ, Whitten S, Reeson A (2008) When should biodiversity tenders contract on outcomes? In '52nd Annual AARES conference'. Canberra (Australian Agricultural and Resource Economics Society).

Hajkowicz S, Collins K, Cattaneo A (2008) Review of Agri-Environment Indexes and Stewardship Payments *Environmental Management* **43**, 221-236.

Hallwood P (2007) Contractual difficulties in environmental management: The case of wetland mitigation banking. *Ecological Economics* **69**, 446-451.

Latacz-Lohmann U, Schilizzi SGM (2005) 'Auctions for conservation contracts: A review of the theoretical and empirical literature.' (Scottish Executive Environment and Rural Affairs Department: Edinburough).

Lockwood M, Walpole S, Miles C (2000) Economics of remnant native vegetation conservation on private property, National Research and Development Program on Rehabilitation, Management and Conservation of Remnant Vegetation Research Report. Land and Water Resources Research and Development Corporation, Canberra.

Mallawaarachchi T, Blamey RK, Morrison MD, Johnson AKL, Bennett JW (2001) Community values for environmental protection in a cane farming catchment in Northern Australia: A choice modelling study. *Journal of Environmental Management* **62**, 301-316.

Meijerink G (2008) The role of measurement problems and monitoring in PES schemes. In 'Economics of Poverty, Environment and Natural-Resource Use'. (Eds RB Dellink, A Ruijs). (Springer: Netherlands).

Ozanne A, Hogan T, Colman D (2001) Moral hazard, risk aversion and compliance monitoring in agri-environmental policy. *Eur Rev Agric Econ* **28**, 329-348.

Ozanne A, White B (2008) Hidden action, risk aversion and variable fines in agri-environmental schemes*. *Australian Journal of Agricultural and Resource Economics* **52**, 203-212.

Shepherd DP, Beeston GR, Hopkins AJM (2001) 'Native vegetation in Western Australia. Technical Recport 249.' (Department of Agriculture, Western Australia: South Perth).

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

White B (2007) A Bioeconomic Analysis of the Duration of Conservation Contracts. In 'Market Based Instruments for Natural Resource Management'. Canberra. (Land and Water Australia).

White B, Prober S, Sadler R, Smith P, Williams K, Burton M, Latacz-Lohmann U, Curry J, Schilizzi SGM (2008) 'Auction for Landscape Recovery Under Uncertainty.' (Department of Agriculture, Fisheries and Forestry: Perth).