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The impact of inaccurate and costly assessment in payments for environmental services

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THE IMPACT OF INACCURATE AND COSTLY ASSESSMENT IN PAYMENTS FOR ENVIRONMENTAL SERVICES

ABSTRACT

Paying private landholders for environmental services, rather than input-based payments, has been proposed as a way to improve the performance of contracts for conservation agencies. A challenge is that the assessment of environmental services is subjective, raising the question of how assessment accuracy impacts on landholder behaviour and contract design. A model is developed of a contract between a conservation agency and a private landholder for the provision of environmental services. The model is used to estimate the impact of inaccurate and costly assessment on the optimal landholder labour effort and the optimal incentive payment. The model shows that inaccurate and costly assessment reduces the cost-effectiveness of the contract. Application of the model to Western Australian broad acre agriculture suggests that remote assessment by field assessment by a scientist is preferred to remote assessment by satellite. The study also shows the feasibility of contracts for environmental services is potentially dependent on the ability of the conservation agency to observe the landholder's behaviour during the contract.

INTRODUCTION

In Australia, government and non-government environmental and conservation agencies have begun including private lands into conservation programs primarily due to the high cost of establishing national parks and reserves (Figgis 2004). Private ownership and leasehold land constitutes 77% of Australia's land area (DEHA and DAFF 2008). The land available to enter national parks and reserves, and budget restrictions, mean that reserves alone will be insufficient to achieve the environmental agency's goals and objectives for biodiversity and environmental service provision into the future. The goals and objectives of government and non-government environmental agencies are diverse, but consistently include broad environmental aims which require long-term investment. For example, the *Department of the Environment, Water, Heritage and the Arts* mission is *protecting and enhancing Australia's environment, heritage and culture (Dept Envir Water Heritage & Arts 2009 pg 9)*. The World Wide Fund for Nature state that their mission is *to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature by: conserving the world's biological diversity; ensuring that the use of renewable natural resources is sustainable; and promoting the reduction of pollution and wasteful consumption* (WWF 2007 pg 7). The broad, long-term nature of the goals and objectives of environmental agencies require them to make long-term investments in environmental service provision and work on private land.

Australian environmental agencies have introduced a number of conservation schemes and programs designed to provide biodiversity and environmental services on private land through market-based instruments (Figgis 2004). Development of new market-based instrument programs in Australia has progressed rapidly, with 19 pilot programs within the National Action Plan for Salinity and Water Quality alone (Grafton 2005; NAPSWQ 2008). In 2009, a dedicated Environmental Stewardship program was launched as part of the national Caring for Our Country Program. Currently in Western Australia, private landholders can receive a wide range of support for providing environmental services, including financial or labour assistance for conservation works, assistance entering into a covenant, as well as technical advice and training (Government of Western Australia 2004). Internationally, conservation programs are well established. Most well known are the USA Conservation Reserve Program and the Wetlands Reserve Program (Hanrahan and Zinn 2005), and the UK Countryside Stewardship Scheme and Environmental Stewardship (Natural England 2006). Typically, conservation schemes support landholders to undertake actions which increase the probability of establishing or conserving a target vegetation community. Programs are beginning to focus on contracts for the environmental outcomes of actions, rather than the actions themselves because it is hoped that this can lead to greater achievement of environmental outcomes in a more cost-effective way.

Figure 1 and Figure 2 show the contracting process of a payment for environmental services contract between the conservation agency and landholder. The contract requires the landholder uses their resources and labour effort (l_t) to provide environmental services, without payment until the completion of the contract. The conservation agency would receive the benefit of environmental services (w) produced by the landholder's labour effort. At the completion of the contract a final assessment of the environmental services provided or a proxy such as vegetation quality (s_T) would be made and a final payment ($s_T b$). The final assessment of vegetation quality (s_T) has an accuracy (m) and cost (o) dependent on the assessment technology chosen. The land is again controlled by the private landholder at completion of the contract, returning to the rate of environmental service provided without a contract.

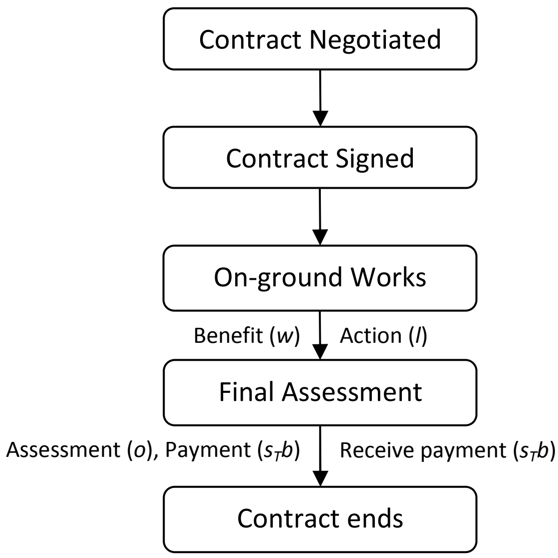

FIGURE 1 CONTRACTING PROCESS FOR A CONTRACT BETWEEN CONSERVATION AGENCY AND PRIVATE LANDHOLDER FOR ENVIRONMENTAL SERVICES.

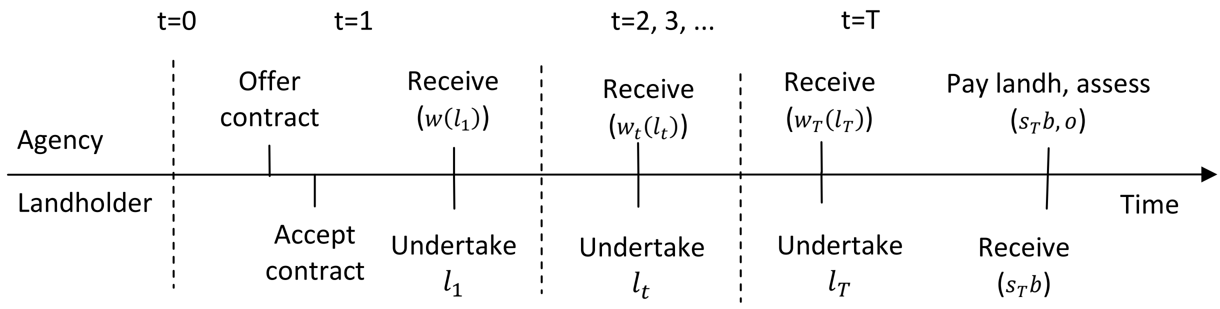

FIGURE 2 TIMELINE OF CONTRACTING PROCESS OF A CONTRACT FOR ENVIRONMENTAL SERVICES BETWEEN CONSERVATION AGENCY AND PRIVATE LANDHOLDER.

Australian schemes with payments for environmental services are on a small scale and require further development to meet the long-term and large-scale goals of environmental agencies. In particular, the final assessment of the contract between the agency and the landholder to ensure the environmental objectives of the scheme are achieved requires further attention. At present, assessment of compliance and the environmental outcomes of these schemes is primarily focused on prediction for efficient allocation mechanisms such as auctions. The success of environmental schemes to date has generally been measured by the quantity of inputs contracted to be supplied, rather than the quantity of inputs achieved or environmental services provided.

The assessment of compliance with the contract by the landholder and the environmental outcomes of contracts by agencies have received limited attention in the literature (e.g. see the review by Meijerink (2008)). Internationally, reviews of agri-environmental policy monitoring conclude that monitoring to assess ecosystem change incurs significant costs and is prone to inaccuracy in the form of mis-classifications of vegetation types (Hooper 1992; National Audit Office 1997; World Bank 1998). A wide variety of monitoring and assessment techniques are available to the agency, each with different combinations of accuracy, cost and ease of use. Currently, the most popular method is on-ground field surveys by trained experts, but remote satellite imagery can also provide some information about vegetation change.

Theoretical research has shown 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 (Fraser 2004). 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 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. The implications of unobservable landholder labour effort are then investigated.

MODEL

BASE MODEL

A principal-agent model is designed to represent the contract between aconservation agency and a landholder outlined in Figure 1 and Figure 2. The agency (principal) and the landholder (agent) enter into a contract for the provision of environmental services. Environmental services in this study are measured using an index of bushland biodiversity condition. The agency's problem is to choose a payment to the landholder that will maximise the social welfare function:

$$Z = w(l_t) + \pi(l_t, b) - c(l_t, b) \qquad (1)$$

The social welfare function includes the expected benefit society receives from the improvement in tbiodiversity condition of bushland due to the contract (w), the landholder's profit (π) and the cost of the contract (c). The conservation agency sets the payment for the contract (b) and the landholder determines their labour effort each period. The social benefit of the contract (w) is calculated as:

$$w(l_t) = \sum_t \delta_t v(s_t(l_t) - s_t^r) \qquad (2)$$

The social benefit is the value of pristine bushland (v) scaled down by the biodiversity condition of the bushland that is achieved by the contract in each period ($s_t(l_t)$) compared to the bushland condition without the contract (s_t^r), and the discount factor (δ_t). The condition of bushland that is achieved by the contract in each period ($s_t(l_t)$) is a function of the labour effort of the landholder (l_t), described shortly.

The landholder receives $s_T(l_t)b$ at the completion of the contract. The payment to the landholder at the completion of the contract is dependent on the biodiversity condition ($s_T(l_t)$) the landholder achieves in the final period (T). The biodiversity condition ($s_t(l_t)$) is scored on a scale of 0 to 1, with 1 being a pristine vegetation community and 0 being complete and irreversible degradation. It is assumed the bushland entered into a conservation contract is remnant native bushland 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 (π) is:

$$\pi(l_t, b) = \delta_t s_T(l_t)b - \sum_t(\delta_t g l_t) \quad (3)$$

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

The total cost to the agency of these payments to the landholder's is the payment amount ($s_T b$), allowing for the cost of public funds (e) and the discount factor (δ_t):

$$c(b) = (1 + e)\delta_T s_t(l_t)b \quad (4)$$

The landholder is able to affect the biodiversity condition of the bushland through their labour effort (l_t). The biodiversity condition of the bushland in each time period ($s_t(l_t)$) is calculated based on the Ricker curve of the growth of renewable resources (Clark 2005).

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

The Ricker curve is a general metered stock-recruitment model, used here to capture the decreasing marginal improvement in biodiversity condition from landholder labour effort. The biodiversity condition ($s_t(l_t)$) is based on the quality at the beginning of the period (s_{t-1}) and scaled by the aggregate improvements due to labour effort and natural improvement or decline. The biodiversity condition is improved by labour effort of the landholder during the period (l_t) depending on the landholder's efficiency at converting their labour effort into a change in the biodiversity condition (α). Any inherent natural rate of improvement or decline (r) is also taken into account. Figure 3 shows the relationship between the biodiversity condition score and labour effort.

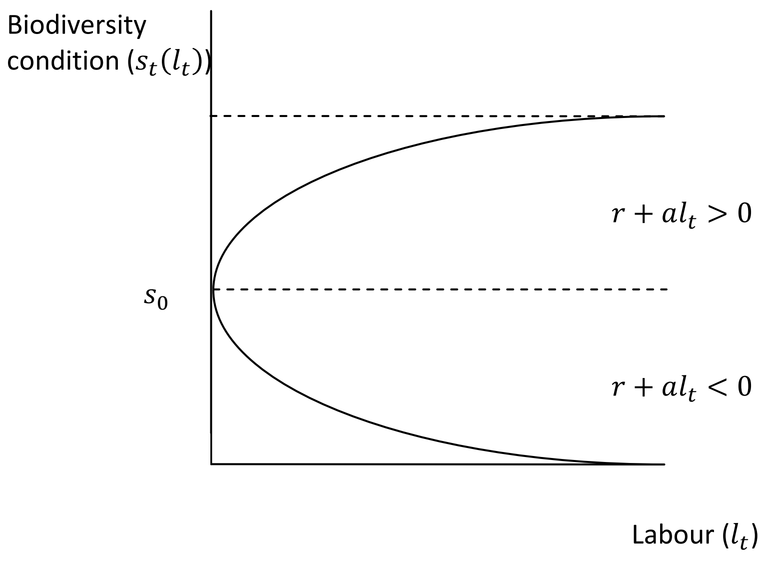

FIGURE 3 BIODIVERSITY CONDITION SCORE RESPONSE TO LABOUR EFFORT.

Without the conservation contract, the biodiversity condition (s_t^r) is:

$$s_t^r = s_{t-1}e^{r(s_{t-1})} \tag{6}$$

For the landholder to enter into a conservation contract, the contract must offer a greater return than the alternative options, i.e. it must meet their 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 be greater than the cost of their labour:

$$\pi(l_t, b) \geq 0$$

$$\delta_T s_T(l_t)b - \sum_t(\delta_t g l_t) \geq 0 \tag{7}$$

Therefore, a conservation contract has a minimum payment amount to ensure labour effort of:

$$b = \sum_t(\delta_t g l_t)\,/\delta_T s_T(l_t) \tag{8}$$

The contract provides a payment that relates the landholder's total labour cost and the environmental outcome achieved. This is effectively a cost:benefit ratio for the contract.

Imperfect assessment

The model presented above implicitly assumes that the agency is able to perfectly and without cost assess the biodiversity condition at the contract's completion. If the agency is unable to accurately assess the biodiversity condition, this will alter the landholders expected return on the conservation contract and consequently their decision constraints. The landholder's change in decision making leads to a change in the overall social welfare of the contract. Social welfare is also reduced by the cost of the assessment technology employed.

The conditions and outcomes of landholder compliance with the contract must be carefully defined to ensure this error is correctly incorporated into the model. 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. Typically landholders will be required by the conservation contract to undertake labour effort to improve the biodiversity condition of the bushland. Compliance is then defined as improving the biodiversity condition, with the landholder receiving payment $s_T b$. Non-compliance is not exerting labour effort, and no payment is 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 faces the same social welfare function as above (refer to Table 2 for a list of symbols):

$$Z = w(l_t) + \pi(l_t, b) - c(l_t, b, o) \tag{1),$$

and the environmental benefit function remains:

$$w(l_t) = \sum_t \delta_t v(s_t(l_t) - s_t^r) \tag{2}$$

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

$$c(b) = (1 + e)(\delta_T s_T(l_t)b + \delta_T o) \quad (9)$$

The four combinations of accurate/inaccurate assessment by the conservation agency and compliance/non-compliance by the landholder have a different expected profit 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 payment with probability m and incur the labour effort cost, giving an expected profit of π_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 (π_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 (π_k). The landholder who does not exert labour effort but is assessed has having done so receives the final payment; however, the payment would be lower as the state of the vegetation is less than when labour effort is applied (π_l).

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

	Assessment accurate	Assessment inaccurate
Labour effort undertaken $l_t > 0$	$\pi_i(l_t, b)$ $m(\delta_t s_T(l_t)b) - \sum_t (\delta_t g l_t)$	$\pi_j(l_t)$ $-\sum_t (\delta_t g l_t)$
Labour effort not undertaken $l_t = 0$	π_k *0*	$\pi_l(b)$ $(1 - mm)\delta_t s_T^r b$

The agency 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 biodiversity condition will not increase beyond any natural improvement. This incentive compatibility constraint is then:

$$m\pi_i + (1 - m)\pi_j \geq m\pi_k + (1 - m)\pi_l$$

$$m(\delta_T s_\mathrm{T}(l_t)b) - \textstyle\sum_t (\delta_t g l_t) \geq (1 - m)\delta_T s_T^r b \quad (10)$$

The minimum payment amount to secure landholder labour effort with inaccurate assessment is:

$$b = \textstyle\sum_t (\delta_t g l_t) / \left[m\left(\delta_T s_\mathrm{T}(l_t)\right) - (1 - m)\delta_T s_T^r\right] \quad (11)$$

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. In NEWROC, 69% of the land area is 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 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 NEWROC between 2003 and 2005 (Gole *et al.* 2005). Landholders were contracted for three years to undertake fencing, revegetation and weed control activities. More recently, research has been conducted on the ecological change occurring in NEWROC both with and without active management, as well as landholder costs for conservation work (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 five-year voluntary agreement between the conservation agency and the landholder. The contract length reflects recent trends towards longer contracts in Australia and internationally. 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 and Figure 2 above). The landholder is to undertake conservation work during these years to receive a final (b) payment based on the environmental services provided (s_T). The environmental services are measured as a biodiversity condition score from 0 to 1. The conservation agency determines the optimal payment to offer the landholder based on the benefits from biodiversity condition improvements that their labour effort (l_t) provides. The final payment received by the landholder is the maximum final payment (b) scaled by the final biodiversity condition score achieved (s_T) and the discount factor (δ_t). The conservation agency measures the costs and benefits from the contract over a 25 year period.

Estimates for each of the model parameters are given in Table 2 below. Few studies have been conducted into the community willingness to pay for environmental services in Australia. In this study a value of $40 per hectare each year is used as an estimate of the benefit to society of eucalyptus (salmon gum) bushland in NEWROC (v). This estimate is derived from work on similar eucalyptus bushland in NSW and Victoria, and the Western Australian Department of Environment and Conservation cost for managing State Forest and Timber Reserves. The community willingness to pay for management of remnant native bushland in the Murray catchment of New South Wales was $75 and in the North-east region of Victoria $72 (Lockwood *et al.* 2000). Management of remnant native bushland was for 40 years and included fencing large remnant vegetation blocks, prohibiting clearing, and restricting grazing and collecting timber. Management would provide a benefit of $75.6 million on aggregate to the New South Wales population for management in the Murray catchment's 203,429 ha of remnant vegetation, a benefit of approximately $30/ha/year. Management of the 113,313 ha of remnant vegetation in North-east of Victoria would benefit Victorians by $60.7 million, approximately $40/ha/year. The Department of Environment and Conservation in the 2008/09 had a budget of $30/ha to manage State Forest and Timber Reserves, with actual expenditure being $41/ha (Dept Envir & Consv 2009). In addition, the Department's budget for Managing Wildlife Habitat was $3/ha with actual expenditure of $4/ha. 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 7%.

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

Parameter	Symbol	Estimate
Value environmental benefit ($/yr)	v	40
Opportunity cost of labour ($/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^m	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	
Final payment ($)	b	
Functions		
Environmental benefit	w	
Landholder profit	π	
Cost of payments	c	
Quality of vegetation	s_t	

The landholder's ability to change the biodiversity condition (a) and natural rate of change in unmanaged vegetation (r) are estimated from remote and field assessments of biodiversity condition change in NEWROC (White *et al.* 2008). The biodiversity condition for 70 managed and unmanaged remnant vegetation sites was estimated each year from 2003 to 2007. Managed remnant vegetation sites were part of the Auctions for Landscape Recovery scheme. The biodiversity condition was scored on a scale from 0 to 1, with 1 being a pristine vegetation community and 0 being severely degraded. In NEWROC eucalyptus bushlands, this would be interpreted as 1 being bushland with a generally intact shrubby understorey, a heterogeneous litter layer, and friable, porous soil with possibly some annual weeds. A biodiversity condition score of 0 would be the equivalent of agricultural land, with rotations of annual crop and/or pasture species (Yates and Hobbs 1997).

The average change in the quality of managed and unmanaged bushland in NEWROC is shown in Figure 4. The two 'bumps' of the managed distribution indicate the distinction between management to maintain the biodiversity condition of the bushland, and management to improve its condition. This is in line with ecological studies in Western Australia that have found intensive management is more effective in achieving successful restoration, while minimal efforts such as fencing to reduce grazing have limited effect (Yates *et al.* 2000a; Yates *et al.* 2000b).

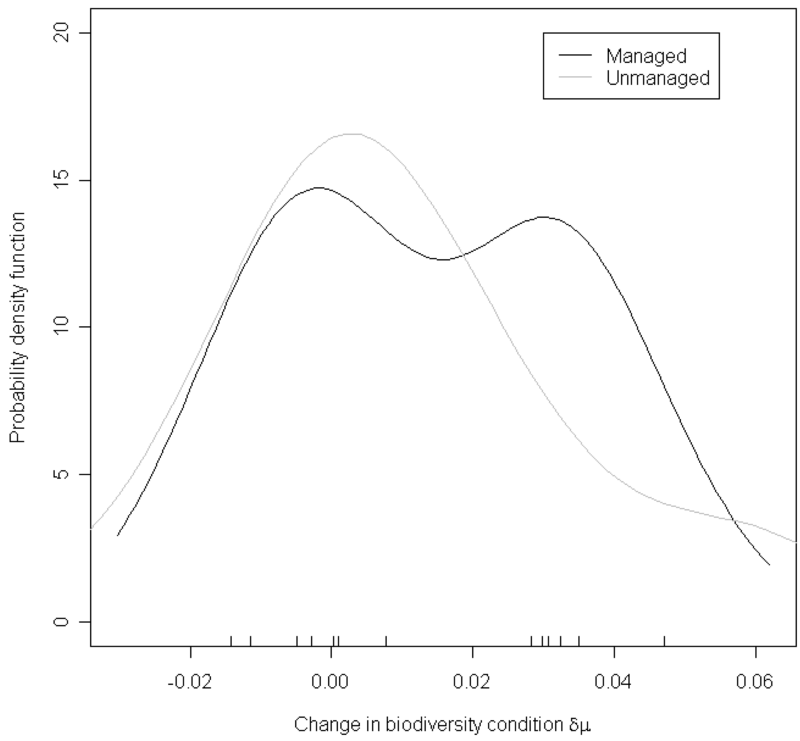

FIGURE 4 AVERAGE BIODIVERSITY CONDITION SCORE OF MANAGED AND UNMANAGED BUSHLAND IN NEWROC (WHITE *ET AL.* 2008).

The impact of management on the biodiversity condition score is related to the landholder's labour effort. It is estimated that management to improve remnant native bushland over the three years, of the comparable Auctions for Landscape Recovery contracts, required approximately 1 hour of labour per hectare each year (Gole *et al.* 2005). The biodiversity condition score for managed sites increased by 0.03 on average from 2003 to 2007 (White *et al.* 2008). The efficiency of labour is calculated as approximately 0.007 points of the biodiversity condition score per hour of labour effort per hectare each year (a). The biodiversity condition of unmanaged land (r) does not improve or decline, a natural rate of change of 0. The initial biodiversity condition score (s_0) is estimated to be 0.6, the average for remnant bushland included in NEWROC.

The cost of labour effort is estimated from a recent survey of NEWROC landholders and State Government Award rates. Survey results indicate landholder's value their own labour and contract labour for revegetation work at approximately $25/hour. The shadow price of landholder labour for conservation work (g) is estimated to be $58 per day, or approximately $7/hour (White *et al.* 2008). Both results are similar to the Farm Employee Award casual labour rate of $17.30/hour for work such as driving machinery or working on sheep. In this study the opportunity cost of landholder labour is assumed to be $10/hour.

The assessment techniques available to the conservation agency are assumed to be field assessment by a local expert, and remote assessment via satellite imagery. The field assessment has an accuracy (m) of 95% at a cost (o) of $10/ha (Gole *et al.* 2005). The remote assessment has a lower accuracy of assessment (m), 0.7, but is also lower cost (o), $1/ha (Peterson *et al.* 2002; Zha *et al.* 2003). Assessment takes place in the final year of the contract, year five.

Results and discussion

Results and anlysis for the conservation contract with perfect and costless assessment are presented, then for the use of remote and field assessment of the final biodiversity condition. An analysis of contracting when the timing of landholder labour during the contract cannot be observed is then given. The model was solved and analysed using Microsoft Excel.

Contracting for biodiversity condition

The conservation agency would not contract the landholder to improve the biodiversity condition of bushland in NEWROC with perfect and costless assessment given the assumptions described above. Contracting the landholder to improve the vegetation condition would have a net cost to society. Sensitivity analysis of individual parameters was performed to determine when contracting with the landholder would be desirable, i.e. return a net benefit to society of at least $0/ha.

The agency would contract the landholder once the value of pristine bushland was above $270 per hectare per year. When the bushland is worth $270/ha/yr the landholder is contracted for 120 hours of labour effort in the initial period and none in any other period. The final biodiversity condition is 1. The payment to the landholder at the completion of the contract ($\delta_t b s_{\mathrm{T}}$) is has a net present value of $1,140/ha, being a final payment (b) of $1,600 scaled by the biodiversity condition score of 1.0 (s_5) and the discount factor of 0.71 (δ_5). The landholder's individual rationality constraint is binding, so $1,140/ha is their labour cost and their expected profit is $0.

Sensitivity analysis was also conducted into the landholder characteristics that would make the contract attractive to the conservation agency. The conservation agency would contract with the landholder when the cost of labour (g) is below $1.5 per hour or landholder efficiency (a) is greater than 0.05 per hour. When labour is $1.5/hr, the landholder is contracted for a single period of 120 hours of labour effort in the first period to provide the maximum change in biodiversity condition. The final payment (b) is $240/ha, which has a net present value to the landholder ($\delta_t b s_{\mathrm{T}}$) of $170/ha. When the landholder increases the biodiversity condition score by 0.05 for each hour of labour, their labour efficiency, they are again contracted for 120 hours in the initial period. They are paid (b) $110/ha, having a net present value to the landholder ($\delta_t b s_{\mathrm{T}}$) of $80/ha. The profit of this contract to the landholder remains $0/ha.

TABLE 3 SENSITIVITY ANALYSIS RESULTS OF MINIMUM PARAMETER VALUES REQUIRED FOR CONTRACTING WITH THE LANDHOLDER TO BE FEASIBLE, CONTRACT IS A SINGLE PERIOD OF LABOUR EFFORT UNDER PERFECT AND COSTLESS ASSESSMENT (PER HECTARE).

Parameter	Symbol	Value for contracting to occur
Value of vegetation ($/yr)	v	270
Opportunity cost of labour ($/hr)	g	-1.5
Landholder efficiency (biodiv score/hr)	a	0.05

The values provided by the sensitivity analysis for a feasible contract are very unlikely to occur. The increase in the valuation of the bushland is nearly 600%. For a comparison, a study in northern Queensland valued teatree woodlands at $18/ha/year and wetlands at $2812/ha/year (Mallawaarachchi *et al.* 2001). The value to society for the improvement of bushland in NEWROC to be feasible would only occur if it were a very rare or endangered site, or provides other very unique environmental services. A cost of labour of $1.50 per hour is effectively equivalent to $0, which would only occur if the landholder themself valued the improvement in the biodiversity condition above their opportunity cost of labour. The landholder's ability to increase the biodiversity score by 0.05 per hour of their labour is practically impossible, requiring significant assistance to meet the work rate.

Contracting with inaccurate assessment of environmental benefits

The conservation agency does not contract with landholders under the NEWROC scenario presented, regardless of the assessment type. The impact of assessment accuracy and cost can only be investigated in situations when contracting would occur: high bushland value, low labour cost or high labour efficiency. Table 4 summarises the breakeven points for the conservation agency to contract the landholder to improve biodiversity condition when using field assessment. Table 5 gives the breakeven value for a contract with remote assessment.

Inaccurate and costly assessment raises the value of pristine bushland required for the conservation contract to be feasible. The required value of bushland is higher as it increases to match the higher minimum payment for the landholder to enter the contract. The inaccuracy of assessment increases the payment required by the landholder to rationally enter and comply with the contract (Equation 7). Therefore, the valuation of bushland required for the contract to be viable also increases. For the conservation agency to enter into a contract with field assessment the value of pristine bushland (v) must be great than $290/ha/yr (Table 4). The expected payment required by the landholder ($\delta_t s_{\mathrm{T}} b_2$) is $1,170/ha. This payment provides the landholder with an expected profit of $40/ha. The $40/ha expected profit from the contract to ensures landholder compliance, by matching the return from non-compliance. Were the landholder to enter the contract and not comply their expected profit is $40/ha.

The value for the contract to be feasible is higher with remote assessment than field assessment as the higher inaccuracy of the assessment technology increases the landholder's profit required to comply with the contract. A contract with remote assessment is only feasible if the value of bushland is above $430/ha/yr (Table 5). The minimum valuation for pristine bushland is higher as the cost of the contract is higher. The cost of the contract is higher as the landholder requires a higher payment to enter the contract. The reduction in the cost of remote assessment compared with field assessment is less than the impact on the minimum landholder payment. The expected payment for the landholder to enter the contract is $1,530/ha, providing a profit of $390/ha to ensure compliance. The landholder's profit from entering and not complying with the contract is $390/ha. With remote and field assessment the landholder is contracted for 120 hours in the initial period to improve the biodiversity condition by the maximum possible. With inaccurate and costly assessment the compliance constraint becomes binding. The compliance constraint requires a higher payment than the individual rationality constraint, meaning the individual rationality constraint is not binding. The compliance constraint alters the landholder payment requirements and consequently the investment decision of the conservation agency.

Inaccurate and costly assessment also lowers the maximum labour cost and raises the landholder efficiency required for the contract to be feasible. When allowing for field assessment, to contract the landholder, the landholder labour cost (g) must be $1.4/hr or below, or their efficiency (a) 0.06/hour or above (Table 4). When the landholders labour cost is $1.4/hour, or their efficiency

0.06/hour, profit from the contract is $5/ha. With remote assessment the landholder labour cost must be less than $0.9/hr, or their efficiency greater than 0.07/hour (Table 5). The landholders expect profit is $39/ha when their cost is $0.9/hour or efficiency 0.07/hour. The landholder is always contracted for the number of hours required to achieve the maximum biodiversity condition of 1.0. Field monitoring has a smaller impact than remote assessment on the payment required and feasibility of the contract.

TABLE 4 SENSITIVITY ANALYSIS RESULTS OF MINIMUM PARAMETER VALUES REQUIRED FOR CONTRACTING WITH THE LANDHOLDER TO BE FEASIBLE, CONTRACT IS A SINGLE PERIOD OF LABOUR EFFORT WITH FIELD ASSESSMENT.

Parameter	Symbol	Value for contracting to occur
Value of vegetation ($/yr)	v	290
Opportunity cost of labour ($/hr)	g	-1.4
Landholder efficiency (%/hr)	a	0.06

TABLE 5 SENSITIVITY ANALYSIS RESULTS OF MINIMUM PARAMETER VALUES REQUIRED FOR CONTRACTING WITH THE LANDHOLDER TO BE FEASIBLE, CONTRACT IS A SINGLE PERIOD OF LABOUR EFFORT WITH REMOTE ASSESSMENT.

Parameter	Symbol	Value for contracting to occur
Value of vegetation ($/yr)	v	430
Opportunity cost of labour ($/hr)	g	-0.9
Landholder efficiency (%/hr)	a	0.07

The conservation agency is seen to have a preference for field over remote assessment as the impact of the inaccuracy of field assessment on the landholder payment is less than the higher cost incurred. The landholder requires a higher expected profit to comply with a contract assessed remotely compared with assessed on-ground. The high inaccuracy of remote assessment is a greater cost to the conservation agency than the cost saving from using a cheaper technology.

TIMING OF LABOUR EFFORT AND BIODIVERSITY CONDITION CHANGE

Potentially, the conservation agency is unable to observe the timing of the landholder's labour effort across the 5 years of the contract. Rather, they are only able to observe the finally biodiversity condition the landholder achieves. If this matches what they have been contracted to supply then the landholder would still receive the payment. The landholder will structure the timing of their labour effort to maximise their profit $\pi(l_t, b)$, not the conservation agency's social welfare function. Delaying their labour effort is optimal due to the discount rate for labour effort in the future. The delay in landholder labour effort will delay the improvement in biodiversity condition, and so the value of bushland improvement $w(l_t)$ and overall social benefit of the contract $Z(l_t, b_2)$.

Table 6 shows the impact of the landholder changing the timing of their labour effort over the 5 years of a contract with perfect, field or remote assessment. The bushland is assumed to have a high conservation benefit (v), $500/ha/yr, as this ensures contracting with all assessment types. The landholder increases their profit by delaying their labour effort to the end of the contract. The landholder delays their labour effort, reducing the present value of its cost. They still receive the standard payment, however, as the conservation agency observes the contracted biodiversity condition at the end of the contact.

The net benefit of contracting with perfect and costless assessment decreases by 38% when landholder labour effort cannot be observed. The landholder is contracted to achieve a biodiversity condition of 1.0 in year five for an expected payment of $1,140/ha. The landholder delays their 120 hours of labour effort from year one to year five. The delay increases their expected profit from $0/ha to $270/ha. The net social benefit of contracting when the landholder applies their labour effort at the beginning of the contract is $1,080/ha, and at the end $670/ha. The delay reduces the social benefit of the contract by $410/ha. The net benefit with delayed labour remains positive, so contracting is still preferred to not contracting with the landholder in high value bushland.

The reduction in net benefit from contracting when labour is unobservable is greater when the inaccuracy and cost of assessing biodiversity condition is incorporated. With field assessment and unobservable labour effort the landholder is able to increase their expected profit for achieving a biodiversity condition of 1.0 from $40/ha to $310/ha by delaying their labour effort. A delay in labour effort decreases the net benefit of the contract by 41%, from $1,000/ha to $590/ha. The net benefit with delayed labour effort is positive, so contracting still provides a better outcome than not contracting in this situation.

Contracting with remote assessment when landholder labour is unobservable reduces the net benefit of the contract below zero, making it infeasible. The landholder's delay in labour effort increases their expected profit from $390/ha to $660/ha. The delay in labour and consequently the benefits of improved bushland decreases the net benefit of the contract 128%, from $320/ha to $-90/ha. The contract is then providing a net benefit less than $0/ha, the return for not contracting. When the conservation agency is unable to observe the timing of labour effort, and is using remote assessment, it is preferred not to contract rather than allowing the delay in labour effort and benefits.

TABLE 6 IMPACT OF LABOUR COST AND VALUE OF PRISTINE BUSHLAND ON OPTIMAL CONTRACTED LABOUR EFFORT, FINAL PAYMENT WITH INACCURATE AND COSTLY REMOTE ASSESSMENT (PER HECTARE).

Assess type	Labour eff (hr) l_1, l_2, l_3, l_4, l_5	Landh Profit ($) $\delta_5 m s_5 b_2 - \sum \delta_t g l_t$	Veg qual (%) s_5	Net benefit ($) Z
Perfect				
Standard	120,0,0,0,0	0	1.0	1080
Labour unobs	0,0,0,0,120	270	1.0	670
Field				
Standard	120,0,0,0,0	40	1.0	1000
Labour unobs	0,0,0,0,120	310	1.0	590
Remote				
Standard	120,0,0,0,0	390	1.0	320
Labour unobs	0,0,0,0,120	660	1.0	-90

CONCLUSIONS

The paper provides an investigation of the feasibility of conservation contracts for environmental services considering assessment accuracy and cost. The model presented extends the existing literature and the empirical analysis illustrates some key contracting issues. It is only feasible for the conservation agency to contract private landholders in NEWROC Western Australia to improve the biodiversity condition of native bushland when the value of the vegetation is high, the cost of landholder labour effort is very low or the landholder labour is particularly efficient at producing environmental services.

Assessment technologies are unable to perfectly determine whether a landholder is compliant with the contract. The inaccuracy and cost of assessment increases the payment required by the landholder to improve the biodiversity condition of bushland, as well as adding directly to the cost of the scheme. In the case of NEWROC, the increase in costs can noticeably increase the minimum valuation of bushland, maximum labour cost and minimum labour efficiency for the contract to be feasible. The negative impact of imperfect assessment technology is much greater for remote sensing than field assessment. Comparing the impact of remote and field assessment, the greater inaccuracy of remote assessment increases the payment required by the landholder more than field assessment. The higher payment is not offset by the lower cost of remote assessment to field assessment.

If the conservation agency is unable to observe the timing of labour effort by landholders the net benefit of the contract is reduced. In the case of prefect and costless assessment of high value bushland this is 38%, field assessment 41% and remote assessment 128%. Contracts with perfect and field assessment remain viable, with a positive net benefit. However, contracts with remote assessment are not feasible, with a net benefit below zero. In general, the conservation agency should employ field over remote assessment, particularly if they are unable to observe when landholders undertake conservation work.

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