Towards a bio-economic model of wetland protection on private lands*

Stuart Whitten and Jeff Bennett#

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School of Economics and Management, University College, The University of New South Wales, Canberra 2600.
Email: sm.whitten@adfa.edu.au, j.bennett@adfa.edu.au

Abstract

Wetlands on private land generate both private and social values. The nature of these values is dependent on the biophysical status of the wetlands. Changes in land management can alter the biophysical status of wetlands and hence the values generated by wetlands. Land managers change management according to the private values they receive from their wetlands. However land management changes also affect social values. Bio-economic modelling of changes to wetland management incorporates the biological and economic impacts at a landscape scale. In turn the bio-economic modelling can be used to determine appropriate incentives at the farm scale to facilitate wetland protection on private land. In this paper we discuss the development of a bio-economic model for two case study areas: the Upper South East of South Australia; and, the Murrumbidgee River floodplain between Wagga Wagga and Hay.

1 Introduction

A bio-economic model examines changes in the well being of society as a result of changes in the biological status of either a geographic area or an ecosystem. A bio-economic model of wetlands estimates the change in the net well being of society as a result of changes in the biological status of wetlands in a particular geographic area. The need for a bio-economic model arises from policy requirements relating to changes in wetland values over time.

Wetlands on private land generate both private and social values; that is, values that are of importance both to individual wetland owners and to the wider community. However, management decisions by wetland owners can alter both the private and social values generated by wetlands. Wetland owners make management decisions on the basis of the monetary and non-monetary trade-offs they face (that is, the private values drawn from wetlands). However, these decisions also alter the costs and the benefits of society as a whole. Hence society may wish to alter the framework within which these decisions are made in order to influence the nature and quantity of values drawn from wetlands.

Integral to the design of an appropriate decision framework is the prediction of the outcome of management changes. The development of a bio-economic model for wetlands facilitates prediction of changes in the biological status of wetlands, and, the resulting changes in the net well being of society. The ability to predict the likely change to society's well being provides a basis for designing appropriate policies. Appropriate wetland policies are designed to maximise the net well being of society. The nature of the costs and benefits incorporated into the bio-economic modelling process provide some guidance to the design of appropriate policy.

In this paper the development of a bio-economic model of wetland protection is explored with reference to two case study areas, the Upper South East (USE) region of South Australia (SA) and the Murrumbidgee River floodplain between Wagga Wagga and Hay in New South Wales (NSW). In the next section, the 'problem' is summarised for the two case study areas. In the third section the theoretical framework within which bio-economic modelling is undertaken is briefly defined. The development of the biophysical and economic components is discussed in the fourth and fifth sections respectively before being brought together as bio-economic modelling in part six of the paper. The paper concludes with a brief discussion of the policy implications of bio-economic models for wetland protection.

2 Setting the scene – case study areas

As part of the Private and Social Values of Wetlands research project, bio-economic models are being developed for two case study areas, the Upper South East region of South Australia and the Murrumbidgee River floodplain between Wagga Wagga and Hay in New South Wales (NSW). The approximate location of the case study areas is shown in Figure 1.

Figure 1: Location of case study areas

The Upper South East of South Australia

In the USE of SA large areas of wetlands have been cleared and/or drained and converted to pasture for agricultural production. 63,000 hectares of healthy wetlands, or less than seven percent of the original wetland area, remain in the USE region. The reduction in wetland area is further threatened by the impacts of dryland salinity. The dryland salinity has resulted from landscape scale replacement of native vegetation with lucerne and then, following the impact of the lucerne aphid in the late 1970's, annual pasture species.

The conversion of wetlands to pastoral production was motivated by the private values so obtained. However, the private and social values generated by natural wetlands in the region have been significantly reduced.[1] The issue is whether the balance between private and social values is optimal. If not, society may wish to encourage alternative wetland management practices that will lead to increased net benefit to society as a whole.

The Murrumbidgee River floodplain in NSW

Many wetlands on the Murrumbidgee River floodplain region between Wagga Wagga and Hay have been subject to degradation as a result of land and water management

[1] These values include drought refuge for waterbirds from South East Australia, bird breeding events and hunting.

practices. In the region relatively few wetlands have been drained, but many wetlands on the floodplain have been droughted while those closely linked with the river have been over-flooded as floodwater is stored and released for irrigated cropping and pasture production. Wetlands in the area have also been degraded by logging, grazing and to a lesser extent irrigation drainage management practices.

As in the USE region, the change in land and water management was motivated by private values generated from irrigation, grazing and timber production. However, unlike the USE region where the private values are confined to wetland owners, private values in the Murrumbidgee are divided between wetland owners (benefits resulting from grazing, logging and some irrigation) and irrigators downstream. The social values of wetlands have been reduced via reduced bird and fish breeding and reductions in water quality and wetland health. The community may wish to consider institutions and incentives that would alter land and water management practices and lead to increased benefit to society as a whole.

3 Theoretical framework

The concept of cost-benefit analysis underlies the development of a bio-economic model. This is because bio-economic modelling attempts to model the change in community welfare that results from changes to wetland management. Bio-economic modelling is a three-stage process:

1. Biophysical modelling – modelling changes in the biophysical status of wetlands;
2. Economic modelling – modelling community values associated with wetlands; and,
3. Consolidation into bio-economic modelling – modelling changes in community benefits as a result of changes in the biophysical status of wetlands.

Cost-benefit analysis compares the net social benefits of alternative courses of action (Department of Finance 1991, Turner, Pearce and Bateman 1994). There are three key elements to a cost benefit analysis (Department of Finance 1991):

- The benefits and costs evaluated relate to society as a whole rather than to particular individuals. Furthermore the benefits and costs extend to non-market transactions.
- Since costs are subtracted from benefits to assess the net benefit to society they must be comparable. Hence all costs and benefits are converted to monetary amounts. Where conversion is not possible the benefits or costs are defined and described in non-monetary terms for assessment by decision-makers.
- Costs and benefits occurring at different points in time are compared via discounting to a present value. This is necessary as resource use changes may take time to have an impact.

The practical application of bio-economic modelling to case studies requires development of an appropriate spatial context. The scale is chosen so as to encompass the area for which management changes are considered. At the same time, any impacts beyond the study area (externalities) must also be included within the model. The boundaries for the USE region was defined by reference to the Naracoorte fault line (the eastern boundary), the northern limit of widespread cropping (the southern boundary), the historic outfall of water to The Coorong (the northern boundary) and the Southern Ocean (western boundary). A similar strategy was followed in the Murrumbidgee. The northern and southern limits of the model area are constrained by the northern and southern limits of the largest mapped flood on record (1973). The eastern limit of the Murrumbidgee case study area is near where the floodplain broadens significantly and the western limit close to where the nature of floodplain wetlands changes and larger floodplain lakes and depressions become more common.

The three stages of bio-economic modelling are described in the following sections. Practical application of the three stages to case studies within the Private and Social Values of Wetlands research project are also presented.

4 Biophysical modelling

Biophysical modelling is the compilation of the biological information underlying each element of the cost-benefit analysis. Hence biophysical modelling has three main components:

1. The identification of the biological factors in wetlands that drive private and social values.
2. The prediction of the outcomes, in terms of changes to biological factors, under different landscape scale management strategies.
3. The prediction of the time taken and path of biological states to achieve each of the potential outcomes of different landscape scale management strategies.

In practice, it is difficult to distinguish step 2 from step 3. This is because wetlands, like all ecosystems, are in a continual state of change and flux. Hence outcomes will continue to change over time without changes to management and outcomes at different points in time will differ with changed management. In addition, potential physical changes to wetland management practices (such as additional fencing) are also defined during the second and third steps of the biophysical modelling.

Both the biophysical and economic modelling are based on the concept of the margin. Each of the management strategies that are defined as part of the biophysical analysis involves some change to landuse. However, the proportion of land that changes use is a relatively small proportion of total landuse. This relatively small proportion is referred to as ‘the margin’.[2]

Each of the elements of biophysical modelling will be demonstrated using the concept of the margin and with reference to either or both of the case study areas in the remainder of this section.

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[2] Definable impacts may occur beyond the area that has changed landuse, that is, beyond boundaries of changed landuse. These are ‘externalities’ of changes in land management and are also included in the analysis. For example downstream impacts of changed wetland management in the Murrumbidgee region. The difficulty of defining appropriate limits to analysis of changes is a potential weakness of the study.

Upper South East case study

As a precursor to the biophysical modelling, an extensive literature review of the information available relating to wetlands in the USE region and the values drawn from wetlands more generally was undertaken (see Whitten and Bennett 1998a). The literature review indicated an extensive array of values available from USE wetlands that can be divided between purely private values and values that are both private and social in nature. These values are indicated in Table 1. All of the purely private values involve some modification to the wetlands. Some of the social values, for example hunting, tourism and recreation, also involve wetland modification. However, the impacts of these (for example hunting and tourism) are markedly less than conversion for grazing production. Hunting, tourism and recreation appear on both sides of Table 1, as they can be purely private goods when participants are charged for participation but are social goods when available to the wider public. Other values commonly associated with wetlands, such as groundwater recharge, are either not associated with USE wetlands or less significant due to the nature and geographical placement of the of the wetland ecosystems within the catchment and relative to towns and industries.

Table 1: Array of values drawn from wetlands in the USE region

Pure private values	Private and social values
Grazing production	Flora and fauna values
Firewood and timber production	Ecosystem values
Water supply	Beautify the farm and regional landscape
Drainage storage/basin	Attract birds that help reduce pests
Tourism	Existence values
Recreation	Flood mitigation
Hunting	Water quality benefits
	Natural fire break
	Hunting and to a small extent fishing
	Public tourism and recreation

The biological factors that drive these values were also identified via the literature review and in consultation with scientists with expertise either in the region and/or in the types of physical relationships in the USE. The key biological factors can be summarised as the area (and type) of healthy wetlands and the area (and geographical relationship to wetlands and other remnant vegetation areas) of healthy remnant vegetation.

The second stage of the biophysical study was to identify the impacts of potential management strategies on the biological states driving wetland values. The base case in this type of analysis is usually continuation of current wetland management practices as a comparison for any change to management practices. However, in the USE case study this was not realistic as construction of a major scheme to manage flooding and dryland salinity had already commenced. Hence the USE ‘no change’ scenario is a shift to improved management of some wetlands as planned under the flood and salinity control scheme.

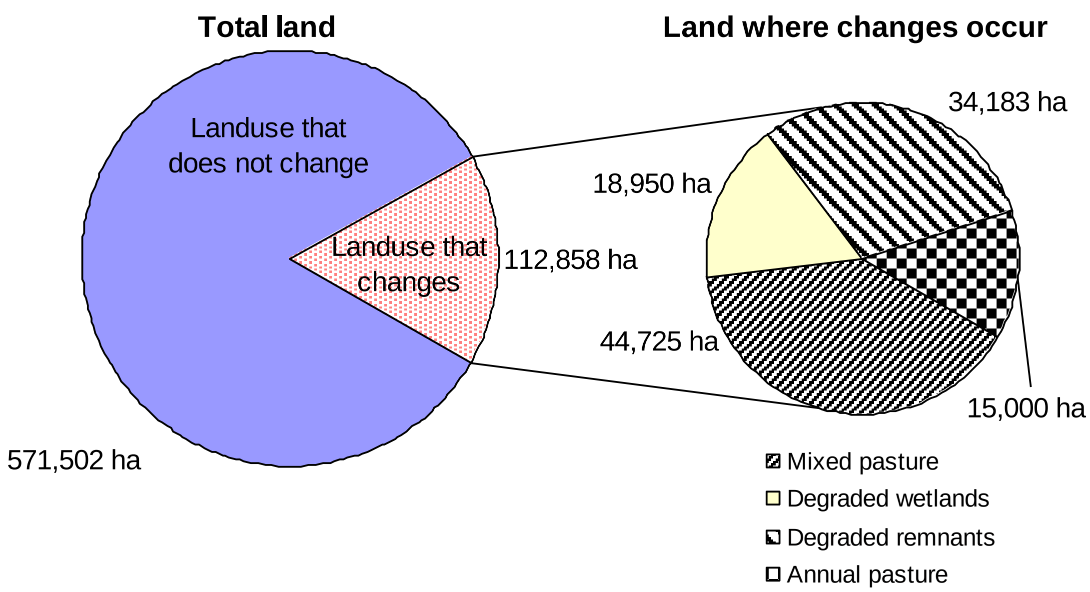
Once the comparison point is established, an array of potential management strategies can be considered. In the USE the strategies considered were:

- Improved management of existing wetlands;
- Improved management of existing remnant vegetation;
- Conversion of agricultural pasture to wetlands;
- Conversion of agricultural pasture to revegetation; and
- Large scale farm forestry and other deep-rooted perennial species.

Additional strategies were rejected on the basis that they would not have a significant impact on the biological factors that drive wetland values, or they were not sufficiently differentiated from one or more of the above set.

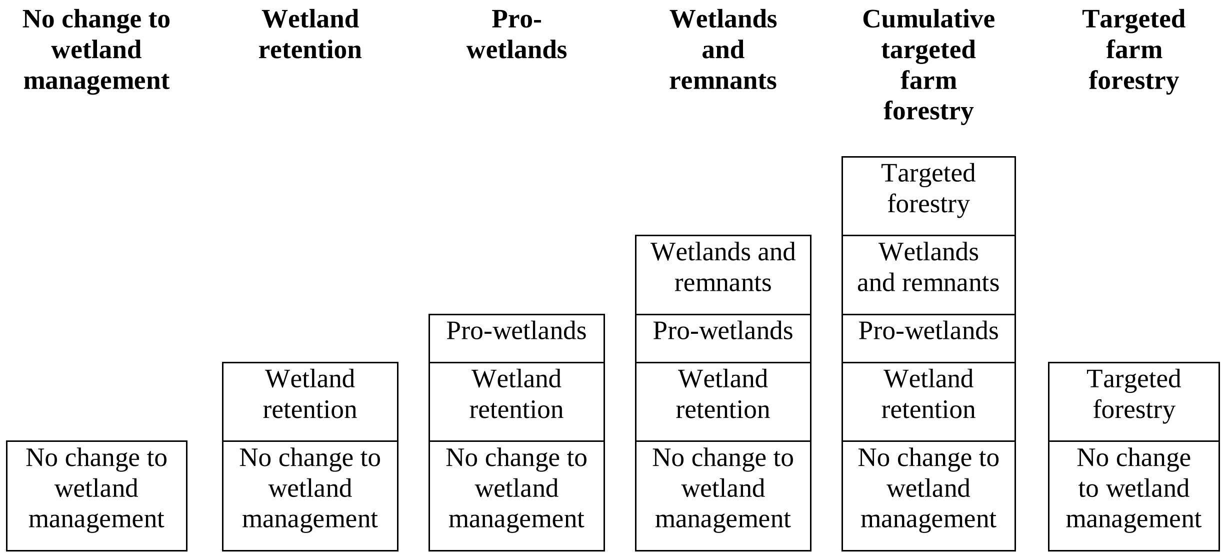
The next and final phase of the biophysical modelling was the definition of the likely impact of these strategies on the biological factors. The analysis of impact extended to the trade-offs that would occur as a result of changes in landuse under the strategies. The definable impacts were regarded as those that would occur over a 30-year period. The set of definable impacts can be defined as the margin as discussed above. In the USE, the margin was confined to changes in landuse as indicated in Figure 2 below.

Figure 2: Biophysical status of landuse at the margin in the USE region



Management strategies were grouped into a set of models as shown in Figure 3. The structure was designed to distinguish biological states that were significantly different from each other. In each case, the biological factors needed to be sufficiently well defined as to allow estimation of changes in the values (both private and social) reported in Table 1. This is the most complex phase of the biophysical modelling and required considerable input from scientists with expertise in the region. However, a considerable amount of uncertainty as to the biological outcomes remains and will need to be taken into account in later phases of the study.

Figure 3: Structure of USE modelling strategies



In Figure 4 and Table 2 the outcomes of the biophysical modelling for one[3] potential management strategy in the USE region – 'Wetlands and remnants' – are summarised.

Figure 4: Comparison of landuse under 'no change in wetland management' and 'wetlands and remnants' strategies in the USE case study area

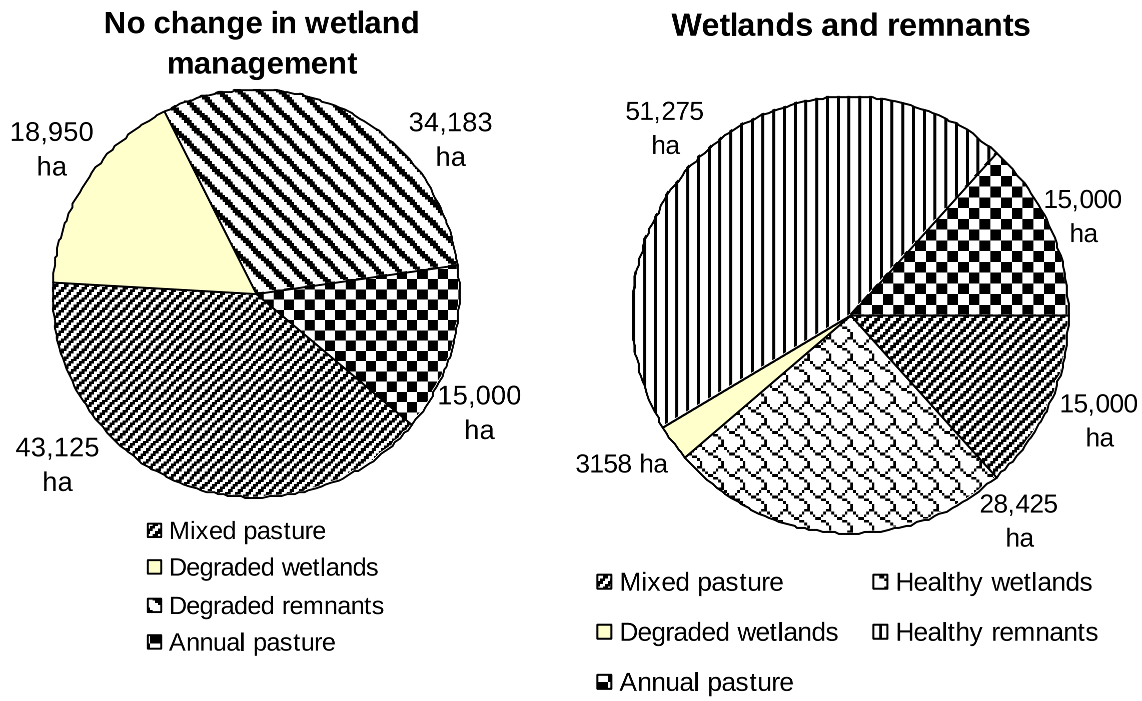


Figure 4 indicates that compared to 'no change in wetland management', the 'wetlands and remnants' management strategy would result in 28,425 ha of additional

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[3] For the other strategies see Whitten and Bennett (1999a) 'Potential Upper South East regional wetland management strategies'.

healthy wetlands and 51,275 ha of additional healthy remnants. However this gain is at the expense of 29,725 ha of agricultural pasture and the benefits of regular grazing of 15,792 ha of wetlands and 34,183 ha of remnants.

Table 2: Physical difference to land management/use between 'no change to wetland management' and 'wetlands and remnants'

Descriptive attribute	**Unit**	**Difference**	**Percentage difference**
Agricultural productivity	dse	-257,444	-7.7%
Area available for waterbird hunting	ha	28,425	144.5%
Area available for other hunting	ha	51,274	294.5%
Fencing distance required	km	2289	n.a.
Total tourist numbers	No.	35,150	553.5%
Fauna species with improved conservation status	No.	17	n.a.

Table 2 indicates the main physical impacts of implementing the management strategy. For example, 17 fauna species are likely to benefit, but annual agricultural productivity would be reduced by 257,444 dse.

Murrumbidgee floodplain case study

The same three biophysical modelling elements also comprise the Murrumbidgee floodplain study. However, unlike the USE study area where management strategies only relate to changes to land management, Murrumbidgee management strategies relate to changes to both land and water management. In the Murrumbidgee, two significant physical changes relating to the changes in the biological state of the wetlands extend beyond the study area. The impacts of riverine hydrological management extend above the study area while the impacts of healthy wetlands on the riverine ecology extend above and below the study area. However, changes to land management in these areas are not considered as part of the study. Hence the concept of the margin is applied to changes in water use as well as changes to land use.

5. Economic modelling

Whereas biophysical modelling is the compilation and analysis of the biological information underlying each element of the cost-benefit analysis, economic modelling is the compilation and analysis of the economic information required for a cost-benefit analysis. The economic modelling can be regarded as valuing the cost or benefit of each of the marginal changes in the biophysical factors.

It is important to recognise that the economic modelling component refers to the change in community well being that would result from each potential management strategy. The concept of economic modelling is based on the theory of economic surpluses. An economic surplus occurs where either the producer or consumer receives a net benefit. That is, a consumer surplus exists where consumers receive benefits in excess of the costs (monetary and non-monetary) while a producer surplus exists where the benefits of production (in terms of sale of goods and services and any other benefits) exceeds all costs of production (monetary and non-monetary).

The existence of both monetary and non-monetary values for wetland outputs further complicates the economic modelling. While monetary values are relatively easily estimated within the market place, non-monetary values are more difficult to estimate. In the Private and Social Values of Wetlands research project a variety of non-market valuation techniques are used to arrive at accurate estimates. In the remainder of this section the concept of economic modelling is illustrated with reference to the USE case study area.

Upper South East case study

Completion of the biophysical modelling component facilitates definition of the relevant physical 'margins'. The next phase of the case study is to value the relevant margins. To simplify the economic modelling most values to be estimated were divided into monetary and non-monetary values.[4] However, not all values can be strictly divided into monetary or non-monetary values. In some cases the producer surplus may be monetary while the consumer surplus is non-monetary. Hence some values (for example tourism) are part private and monetary (producer surplus from accommodation etc.) and part public and non-monetary (consumer surplus from wetland visitation). Table 3 shows the split of values used for the USE region.

Table 3: Value estimates in the USE case study economic model

	Pure private values	**Social values**
Monetary values	Lost grazing production net of reduced pasture costs Hunting Tourism Changed costs of wetland and remnant management	
Non-monetary values	Recreation Hunting Private values resulting from improved wetlands on farms	Existence values Hunting Public tourism and recreation Private tourism and recreation Flora and fauna values Ecosystem values Beautify the farm and regional landscape
Change to values not significant	Firewood and timber production Water supply Drainage storage/basin Fishing Attract birds that help reduce pests	Natural fire break Flood mitigation Water quality benefits Fishing Attract birds that help reduce pests

Some work remains before the economic modelling phase is completed for the USE study area. However the basic methodology for estimating each of the values listed in Table 3 has been finalised and is indicated in Table 4. As shown in Table 4, a range

[4] Note that some values were ignored (that is assumed zero or insignificant value change) on the basis that the marginal change was insufficient to impact on community well being. This assumption involves an element of judgement and may be regarded as a potential weakness of the study.

of monetary and non-monetary valuation techniques is used to assess the economic benefits to the community. In each case the methodology has been chosen based the trade-offs between the theoretical requirements for adequate estimation accuracy and the costs and difficulty of achieving estimates within budget and time constraints.[5]

Table 4: Estimation of economic values for economic modelling

Value	Method of estimation
Lost grazing production net of reduced pasture costs	Gross margin less labour costs (assuming sunk capital costs)
Hunting	Entry fee is producer surplus plus travel cost estimation of consumer surplus
Tourism	Producer surplus estimated via benefit transfer from input-output analysis, consumer surplus via benefit transfer from Hattah-Kulkyne National Park
Changed costs of wetland and remnant management	Estimated costs of fencing and revegetation from recent contracts let in region and management proxy from SA NPWS management costs
Private recreation, improve farm beauty and other non-market owner values of wetlands	Still under analysis – potentially a limited CVM type survey of farmers in the region
Non-owner non-use values comprising: existence values, beautify regional landscapes, flora and fauna values, and ecosystem values.	Choice modelling survey of USE, Adelaide and Interstate

Bio-economic modelling

Bio-economic modelling integrates the biophysical and economic modelling. Specifically bio-economic modelling facilitates comparison of alternative biological states in terms of the net benefit to society. Comparison is via aggregation of economic well being for each of the alternative management strategies developed within the biophysical modelling phase. The management strategy that would maximise community well being can then be found from the set of potential management strategies developed in the biophysical modelling phase. This phase of the Private and Social Values of Wetlands Project is yet to be completed however Table 5 shows the preliminary results in progress for the USE case study.

As indicated in Table 5 the consumer surplus for hunting and non-use values are yet to be finalised. Surveys to estimate these values (TCM and choice modelling respectively) will be undertaken in February 2000. All values in Table 5 are marginal. That is, all values are expressed in terms of difference in value between ‘no change to wetland management’ and the alternative management strategies at the

[5] Careful application of sensitivity analysis minimises the risk of poor or inaccurate estimates leading to invalid conclusions.

margin. It can be seen that in the USE the main costs of alternative management strategies relate to the loss of agricultural production and rehabilitation of wetlands and remnants.

Table 5: Preliminary results for bio-economic model of USE wetlands

	NPV	**NPV**	**NPV**
Additional Costs	***Wetland retention***	***Pro-wetlands***	***Wetlands & Remnants***
Fencing	$1,137,818	$2,438,181	$5,889,283
Wetland rehabilitation	$1,831,033	$7,682,930	$7,803,454
Remnant veg rehabilitation	$0	$0	$23,552,225
Total	$2,968,851	$10,121,111	$37,244,961
Costs saved			
Pasture renovation	$0	$1,332,743	$3,307,673
Total	$0	$1,332,743	$3,307,673
Producer surplus changes			
DSE changes	-$1,154,123	-$5,609,515	-$18,137,437
Tourism	$497,268	$1,240,156	$1,602,005
Hunting	$25,551	$82,336	$95,737
Total	-$631,304	-$4,287,024	-$16,439,696
Consumer surplus changes			
Tourism	$411,428	$748,592	$1,151,725
Hunting	Not available	Not available	Not available
Non-owner non-use values	Not available	Not available	Not available

As indicated previously, the biophysical and economic modelling phases are both subject to uncertainty. A key component of bio-economic modelling is the incorporation of uncertainty of outcomes via sensitivity analysis. A detailed sensitivity analysis, including the cumulative impact of uncertainty can help to determine the robustness of the optimal outcome. The robustness is important in determining the risks involved in attempting to reach the optimal outcome and the true expected benefit.

Sensitivity analysis is also a key tool in determining the potential value of additional biological or economic research. For example, if non-use values are uncertain as a result of inadequate biological or economic information, the potential for this uncertainty to lead to poor policy decisions can be assessed via sensitivity analysis. The sensitivity analysis can then be used in turn to indicate the expected benefits from additional research. Comparing the expected benefits with the costs of additional research gives an assessment of whether additional research is worthwhile.

Policy input and implications

Bio-economic modelling involves the assessment of the biophysical management strategy that will lead to the highest community benefits. Once an optimal strategy in terms of community well being is determined, questions relating to policy arise. The major policy question is how to get from the current situation that will result in the 'no change' outcome to the optimal outcome as indicated by the biophysical modelling. The nature of the bio-economic modelling process, in conjunction with economic theory, suggests some potential policy avenues for exploration. While exploration of these strategies is the final phase of the Private and Social Values of Wetlands research project some preliminary suggestions are drawn in this section.

The economic modelling estimates the values associated with changes in biological factors. However, while a change in management strategy may benefit society as a whole, the costs to wetland owners must exceed the benefits or the strategy would already be employed.[6] Hence there will be a need to transfer some of the benefits received by non-wetland owners to owners of wetlands in order to achieve changed wetlands management. The output from the economic modelling provides some guidance for developing policies to facilitate incentives for improved wetland management.

The main guidance from the economic modelling output is the nature and relative size of the social benefits and private costs from wetlands. The nature of the benefits is important as these determine whether particular incentives or policies are likely to be successful. The relative size of particular social values helps determine what degree of transfer is required to achieve adoption of the changed management strategy. Incentives for improved wetland management can be developed via three main paths:

- Changing property rights;
- Measures supplementing the market such as transfer via tax collection and re-allocation; and,
- Changing decision-making structures.

Each of these paths alters the structure of incentives facing wetland decision-makers. Changing property rights alters the decision framework facing the wetland owner and ranges from prohibition through to allowing private ownership and trade of particular rights relating to wetlands (for example the right to hunt). Granting property rights enables wetland owners to capture social benefits (and vice-versa). For example allowing wetland owners the right to lease out hunting rights provides an incentive to manage wetlands in ways that maintain production of hunting amenity. That is, social benefits are converted to private benefits (and vice-versa). The danger in removing property rights (via measures such as command and control legislation) is that wetland owners will continue to seek means of capturing such rights to the detriment of wetland ecosystems. For example, removing the right to clear may lead to less visible management strategies that are similarly or more destructive in the long run.

Changing property rights re-allocates benefits via the market in contrast to measures that supplement or change market outcomes via transfer of resources as incentives. For example allowing wetland owners to subdivide wetlands from larger property units facilitates a market for wetlands. In contrast, providing fencing materials or management assistance reduces the costs of maintaining wetlands and increases their net private benefits. Such incentives alter the outcome from that determined via the market.

The final option for incentive development refers to alternative ownership and decision-making structures that directly incorporate community (social) benefits.

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[6] The possibility also exists that owners are simply unaware of the benefits. An appropriate extension program is called for in this situation.

Such structures would allow social values to be expressed in the decision making process hence influencing outcomes. For example policies that make it easier for clubs or groups of people to purchase and manage wetlands could fall into this class. This type of strategy is potentially useful in conjunction with changing property rights.

The nature and mix of social values derived from economic modelling assists in determining the mix of incentive types that are most likely to achieve changed management. For example where latent recreation values are high, strategies that reduce the cost of tourism, hence increasing the net benefits of tourism to wetland owners, would be effective. Alternatively, where existence values are high and others lower, a transfer mechanism is difficult, redistributive incentives may be appropriate. The key, for optimal policy development, is to develop a set of incentives that move towards maximising community benefit at lowest cost.

In conclusion, development of a bio-economic model of wetland protection on private lands offers guidance for appropriate policy for the management of wetlands on private lands. Bio-economic modelling assists the wider community in developing appropriate goals for wetland management that will maximise community well being. It offers the community a rigorous method for comparing alternative future outcomes. Once a maximising outcome is determined, relative values for wetland outputs offers guidance to the development of policies incorporating institutions and incentives that will achieve the goals of the community.

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