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An evaluation of water management strategies in the Barmah–Millewa forest

Doug Young and Colin Mues
Australian Bureau of Agricultural and Resource Economics
GPO Box 1563, Canberra 2601

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Benefit–cost ratios are estimated for various water management options for the Barmah–Millewa forest.

Estimates are provided for a threshold annual value of the non-market benefits of the forest for which the benefit–cost ratio would equal one. Monte Carlo simulation techniques are used to assess the sensitivity of the estimated threshold values for various water management strategies to changes in key assumptions about the prices of water and timber products. The analysis is then conducted under alternative assumptions about the growth rate of the value of annual benefits from the environmental amenity of the forest.

ABARE project 32.009

Introduction

Spread over the flood plain of the River Murray between Echuca, Deniliquin and Tocumwal the Barmah–Millewa forest covers an area of approximately 70 000 hectares and is the most extensive river red gum forest remaining in Australia. It contains a large range of wetland habitats which support several hundred plant species and a large number of animal species.

Current uses of the forest include timber production, grazing, beekeeping and recreation. In addition the forest has important heritage, scenic, scientific, educational and wildlife values. The forest also serves a flood mitigation role during major floods since it stores large volumes of water.

For over a century there has been an increasing level of control over the water flow in the Murray and its tributaries to supply water for irrigation, domestic, stock and industrial purposes. However, this control has changed the timing of flooding and has reduced the frequency and duration of the flooding pattern on which the forest evolved and has consequently led to a deterioration of the forest vegetation. Examples of this deterioration include poor tree health and growth rates and changes in the types and numbers of plants and animals found in rushlands, grasslands and forests (Murray–Darling Basin Commission 1992).

The Murray–Darling Basin Commission has initiated a forest water management study to investigate ways of dealing with these problems. One of the initial steps in this investigation was to commission a consultant to develop a comprehensive water management plan that took into account the water needs of the flora and fauna of the forest.

The consultant identified five water management options for meeting the needs of the forest (Maunsell 1991). Each of these options necessitates the diversion of water from irrigators to the forest. These options were then assessed within a benefit–cost framework.

The economic analysis of the water management options was considered deficient in a number of areas (Murray–Darling Basin Commission 1992). First, no attempts were made to value the non-market benefits of flooding the forest. Rather, the total area flooded was taken to be a proxy for the extent of 'environmental improvement'. Since benefit–cost ratios for all of the management options were greater than one they were ranked according to the increase in the area of forest flooded. The option which produced the greatest level of flooding was identified as the best option with no consideration given to its ranking under benefit–cost criteria. Second, the prices used to value forest products included a contribution from value added activities which inflated the value of the extra wood production expected from the new flooding regimes. Third, the cost to agriculture of a reduction in the supply of irrigation water was considered to require further investigation.

The objective in the ABARE study is to apply an alternative benefit–cost method which incorporates explicit consideration of non-market attributes to the water management options for the Barmah–Millewa forest. The necessary extensions to the previous work are addressed in the process of conducting this analysis.

Economic evaluation of management options

Benefit–cost analysis

Benefit–cost analysis is a method of project evaluation in which the costs and benefits of a project can be compared directly. A project is considered viable when its benefits are greater than or equal to its costs and the return on the investment is equal to or higher than alternative investment opportunities. Where there are a number of options, these options may be ranked according to their benefit–cost ratios and considered in conjunction with any budgetary constraints that may exist.

Allocative efficiency is achieved in markets for goods and services when, among other things, pricing reflects the marginal costs of production. However, where institutional or other factors prevent markets from operating in this way, costs and benefits need to be priced at their opportunity cost — that is, at the value of the good or service in its best alternative use. As such, goods and services are valued according to the willingness of individuals to pay for the resources involved in their production and therefore reflect the best alternative use forgone (Department of Finance 1991).

Maunsell (1991) applied a standard benefit–cost model to estimate the market benefits and costs associated with each watering strategy for the Barmah–Millewa forest. The benefit–cost model used only took into account the opportunity cost of water, capital, operating and maintenance of the small scale works, and the benefit of increased wood production from increasing the area of forest flooded (see below). The forest responds quickly to changes in the flooding pattern, a conclusion supported by recent field trials conducted by the Forestry Commission of New South Wales, and can reasonably be expected to be sustainable given proper forest management. Consequently, the incremental yield is assumed to be independent of time.

$$B/C\ ratio = \frac{\Sigma_{t=0}^{\infty}(A * Y_{FP} * P_{FPt})/(1+r)^t}{K_0 + \Sigma_{t=0}^{\infty}(M_t + O_t + Q_w * P_{wt})/(1+r)^t}$$

where r is the discount rate; A is the incremental area of the forest flooded under the strategy (constant over time); Y_{FP} is the incremental yield of forest products under the new flooding regime (constant over time); P_{FPt} is the price of forest products in year t; K_0 is the capital cost of small scale works incurred in the initial year; M_t is the recurring maintenance costs of small scale works in year t; O_t is the recurring operating costs of small scale works in year t; Q_w is the average annual shortfall to irrigators as a result of adopting the strategy; P_{wt} is the opportunity cost of water in year t; and t is time in years.

The benefit–cost model did not take into acc[illegible]e increased potential for grazing and beekeeping under improved flooding strategies. However, there is only a small likelihood that additional permits for either activity would be issued as a result of the improved flooding strategies (Forestry Commission of New South Wales, personal communication, October 1992).

Five water management options for the flooding of the forest were considered.

- Constructing small scale diversion and impoundment works that can spread water in the forest when the flow in the Murray is relatively low.
- Creating a managed flood of 555 GL a month to be triggered by a flood in the Ovens River of 290 GL a month.
- Creating a managed flood of 912 GL a month to be triggered by a flood in the Ovens River of 290 GL a month.
- A combined option of small scale works and a managed flood of 555 GL a month.
- A combined option of small scale works and a managed flood of 912 GL a month.

Forest product prices

The value of additional forest products that would be produced through greater flooding of the Barmah–Millewa forest should be reflected in the price which sawmills would be willing to pay for logs, assuming a competitive market. In the study by Maunsell a price of \$112.56/m^3 roundwood was used. However, this was the price of the finished product and included value adding activities such as transport to mill and sawmilling.

Over time there has been considerable debate about whether log royalties charged by state forest agencies accurately reflect potential market prices for logs (O'Regan and Bhati 1991). In recent years, however, state forest agencies have made considerable progress in moving toward market based royalties. In addition, any disparities in prevailing royalties and potential market values for logs are likely to have been reduced in recent years because of the depressed state of the forest products market, which is likely to have led to a reduction in the potential market value of logs. Therefore, the current log royalty charge of \$32.50/m^3 roundwood was considered to be a reasonable estimate of the value of extra wood production from improved flood management.

As the market for forest products could improve with economic recovery, a higher royalty may be achieved in the future, and so its effect on the benefit–cost estimates should be examined. After discussions with the Forestry Commission of New South Wales about future prospects for the industry, an alternative royalty 20 per cent above the current level — that is, of \$39/m^3 — was also examined in this study (table 1).

Water

In the Maunsell study a water price of \$41/ML was used, compared with the current NSW Department of Water Resources charges for irrigation water in the Berriquin, Denimein, Deniboota, Wakool and Tullakool irrigation districts of \$9.19/ML and a delivery charge for irrigation water supplied by the Rural Water Commission of Victoria of \$15.35/ML for the Murray Valley Irrigation District. In both states, water is supplied at a cost which fails to fully cover the costs of infrastructure and delivery (Industry Commission 1992). As such there is an implicit subsidy for irrigation water use. The institutional arrangements which restrict trade between users both within the region and between regions also contribute to the lower price of irrigation water, as more profitable users of water are unable to vie for water that could be sold by the less profitable users. Therefore, observed prices of irrigation water are unlikely to fully reflect its true opportunity cost. A number of studies have attempted to estimate the opportunity cost of irrigation water in the Murray Valley.

A linear programming model of the Berriquin Irrigation District has been developed by ABARE (Poulter, Hall and Greer 1993). This irrigation district is directly north of the Barmah–Millewa forest and diversions to Berriquin occur upstream of the Barmah–Millewa forest. The model is based on gross margins and takes fixed or capital costs into account through depreciation. The model does not include urban or non-agricultural water demands. The opportunity cost of water generated by the model is around $17/ML. Although this value is at the lower end of previously published estimates it is consistent with prices at which water has recently been traded and has therefore been used as the most likely estimate for the opportunity cost of water in the sensitivity analysis (table 1).

The Victorian Department of Conservation and Environment (1991) has developed a model of the irrigated regions of Victoria's north to estimate the demand for water and its opportunity cost for irrigation regions in northern Victoria. The model is designed to maximise the total gross margin for the irrigation industries of northern Victoria in a typical year, and as such does not take into account fixed or capital costs. The model also fails to account for urban or non-agricultural water demands.

As the model is based on gross margins and does not account for fixed costs it could be expected to overestimate the shadow price of water. Conversely, by modelling only one enterprise unit and by excluding non-agricultural users, an underestimate of the shadow price could arise. This is because the model fails to capture competition between alternative users of the resource, both within and between regions and between sectors. Despite these shortcomings the results from the model provide a reasonable short run estimate of the opportunity cost of water for the irrigation areas close to the Barmah–Millewa forest. In the absence of a model that takes non-agricultural water demand into account, the shadow price generated by the Victorian model has been used in this study as the upper bound for the shadow price of water (table 1).

Because there is no clear argument for adopting a specific upper bound water price, the impact of adopting an upper bound of $41/ML was assessed. This was the water price used by Maunsell. Under this assumption the benefit–cost ratios were slightly higher but

Table 1: Range of prices to be used in benefit–cost analysis

	Unit	Lower bound	Most likely	Upper bound
Forest products	$\$/\text{m}^3$ roundwood	32.50	32.50	39
Water	$/ML	9	17	61

the overall rankings of the options were unchanged. Consequently it was decided to choose a higher upper bound for the water price, of $61/ML.

The current New South Wales charge ($9/ML) for irrigation water in the irrigation districts close to the Barmah–Millewa forest has been included as the lower bound for the price of water in this study.

Benefit–cost results

The results from a revised benefit–cost analysis of the five water management strategies identified in the Maunsell report are presented in table 2. For ABARE's analysis a discount rate of 8 per cent was used, a 3 per cent risk margin on top of a real risk-free rate of 5 per cent. This is recommended by the Department of Finance (1991) in circumstances where the project has an economywide perspective. The 'most likely' values for the prices of water and logs, shown in table 1, were used; all other data except for the discount rate were sourced from Maunsell (1991).

Prices of water and forest products can be expected to vary over time. However, given the similar time profiles for both benefits and costs for all projects being evaluated, it is the movement of water and forest product prices relative to one another that is important in

Table 2: Benefit–cost results for alternative management strategies

Strategy	Maunsell B/C ratio (most likely)	ABARE B/C ratios Lower bound [a]	Most likely	Upper bound [b]	ABARE estimate of net present value (most likely)
					$m
555 GL managed flood	1.53	0.30	1.07	1.28	0.089
912 GL managed flood	1.06	0.21	0.74	0.89	– 1.682
Small scale works	1.41	0.37	0.47	0.56	–6.2613
Combined option: 555 GL managed flood and small scale works	1.37	0.32	0.53	0.64	– 6.544
Combined option: 912 GL managed flood and small scale works	1.07	0.23	0.51	0.61	– 9.522

[a] Using the lower bound for timber prices and the upper bound for water prices. [b] Using the upper bound for timber prices and the lower bound for water prices.

ranking the alternatives. The presence of technical substitutes for both water and logs, such as irrigation technology and concrete sleepers, respectively, would offset the effect on prices of increasing scarcity. Consequently, the prices of water and forest products have been assumed to be constant in real terms over time.

With the exception of the 555 GL managed flood option, all benefit–cost ratios estimated are less than one. This differs from the results obtained by the consultant, whose estimated benefit–cost ratios were all greater than one, principally because of the value added component of the price of forest products used. The revised benefit–cost estimates imply that if only market factors are taken into account, only one of the proposed watering strategies produce a positive net social benefit. However, the low benefit–cost ratio for that strategy and uncertainty over key variables would not engender great confidence in this result.

In these circumstances the non-market benefits — principally comprising the improved quality and size of the environmental services from the forest compared with current practices — would need to have a positive value if the other water management strategies were to be acceptable under benefit–cost criteria.

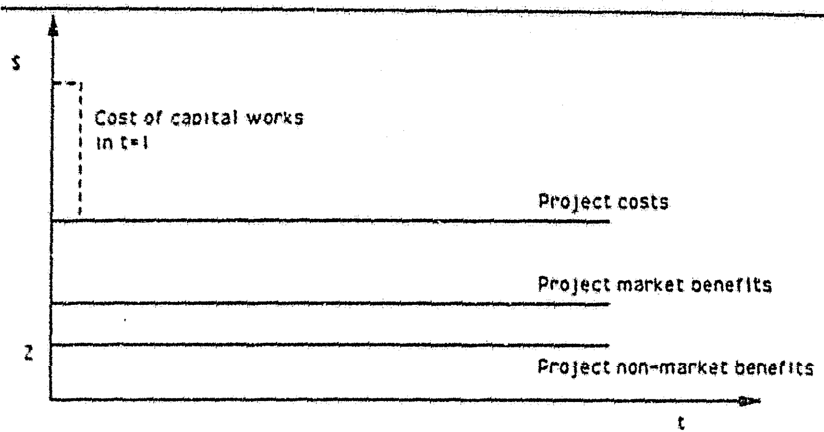
Estimation of the value of the environment

Commonly, non-market benefits are ignored in benefit–cost analysis — that is, non-market benefits are implicitly given a value of zero. Various approaches have been used in benefit–cost analysis where non-market benefits exist.

Recently, the use of empirical methods to quantify people's willingness to pay for particular non-market benefits has received considerable attention. Methods such as contingent valuation, the travel cost method and hedonic pricing techniques fall within this category. The problems with these methods are their expense in terms of time, data and money, and their susceptibility to various types of bias (Rose 1990; Young 1991).

An alternative approach is the 'threshold' approach applied to the Hell's Canyon project (Fisher 1981) and to the lower Gordon River hydroelectric development proposal (Saddler, Bennett, Reynolds and Smith 1980). The threshold approach involves estimating the value of non-market benefits, Z, in the initial year that would make the benefit–cost ratio of the project equal to one. Hence the threshold value is defined as the value of environmental benefits in the initial year — and which continues to exist in subsequent

Figure 1: Profile of project costs and benefits when value of environmental amenity is constant over time



years — required to equate the present values of the streams of project costs and project benefits.

The profile of the costs and benefits of the project, under the assumptions made for water and log prices, is depicted in figure 1. For a project that has no capital costs, the costs of the project are assumed to be constant over time. This is because water requirements, and operating and maintenance costs are recurring items. If the project has capital costs then these are incurred in the initial year, depicted by the dotted line. In the following year costs decline and then remain constant. Market benefits from increased wood production are also assumed to be constant through time.

The threshold approach involves estimating the value of non-market benefits, Z, in the initial year that are sufficient to make the net present value of costs equal to the net present value of total benefits. The value of Z will not simply be the difference between the net present value of costs and market benefits. Rather, the value of Z will be such that the net present value of the *stream* of benefits from the environmental amenity will be equal to this difference. This approach is used in ABARE's study to evaluate the five main water management strategies under the initial assumption that the value of environmental benefits remains constant over time relative to other goods and services.

Given uncertainty surrounding the true value of water and log resources, Monte Carlo simulation techniques were used in the benefit–cost analysis to assess the sensitivity of the estimated threshold values for each water management strategy. As mentioned by Treadwell, McKelvie and Maguire (1991) the advantage of the stochastic process is that it

Table 3: Threshold values for proposed water management strategies

Water management strategy	Incremental forest area flooded (compared with current practices)	Ratio of market benefits to market costs	Mean threshold value, Z, in the initial year for the benefit–cost ratio to equal one	Range of the value of Z [a]
	ha		$	$
555 GL managed flood	7 102	0.78	61 669	1 446 – 113 361
912 GL managed flood	15 191	0.54	471 672	185 224 – 713 295
Small scale works	7 267	0.47	542 946	487 897 – 593 672
Combined option: 555 GL managed flood and small scale works	21 723	0.49	681 898	526 258 – 815 711
Combined option: 912 GL managed flood and small scale works	27 291	0.43	1 204 282	815 706 – 1 540 091

[a] There is a 25 per cent chance of Z being below the lower figure and also a 25 per cent chance of it being above the higher figure. Thus, there is a 50 per cent chance of the value of Z being within the range shown.

produces the expected or mean value and also indicates the effect of uncertainty by providing a range of values with their probability of occurrence. The range of values for water and log prices in this analysis were given in table 1. In order to place more weight on the most likely value of the key variables a triangular distribution has been assumed. It has also been assumed that timber and water prices are independent of each other. The results of the simulation are presented in table 3.

The 555 GL managed flood leads to an improved flooding regime over 7102 ha of the forest. When estimated deterministically using the most likely values for water and logs this project had a ratio of market benefits to market costs of 1.07 (table 2). However, due to the skewed distributions assumed for the ranges of timber and water prices in the stochastic benefit–cost analysis, the mean benefit–cost ratio is reduced to 0.78, which is also reflected in the positive threshold value estimated. As this option has a high water requirement it is sensitive to the choice of the upper bound of the water price. However, selection of an upper bound which is significantly greater than the most likely value is justified because there is scope for upward movement of prices as pricing reform is instituted. There are a number of factors which may lead to significant price increases. One example could be a change in water pricing policy to fully recover costs including capital costs. Another is the possibility that a resource rent would be incorporated into the water price as a return to society for the use of this resource. Because the benefit–cost ratio has fallen below one this option is acceptable under expected benefit–cost criteria only if the improvement in 'environmental quality' of the forest amenity is worth at least $61 600, in aggregate, a year.

Similarly the small scale works lead to an improved flooding regime over 7267 ha of the forest. For this project to be acceptable under expected benefit–cost criteria the improvement in the quality of the environmental amenity must be worth at least $542 900, in aggregate, a year. The threshold values for the other water management options can be similarly interpreted.

The different options could be compared directly *only* if it is assumed that all parts of the forest are homogeneous with respect to the benefits to be gained from flooding.[1] If this were the case, the small scale diversions and impoundments option would seem to be much less cost effective than the 555 GL managed flood option. That is, for an extra 165 ha of forest flooded the cost is $2917/ha a year. If the two combined options were compared with one another the extra 5568 ha from the 912 GL combined option would cost an extra $522 400 a year or $94/ha. This compares with a threshold of only $9/ha under the 555 GL managed flood option alone, or $31/ha under the combined 555 GL managed flood and small scale works option.

Accounting for growth in environmental values over time

The analysis described above was conducted under the assumption that, over time, the value of environmental benefits remained constant relative to other goods and services. As such, it is implicitly assumed that the estimated threshold value of environmental benefits which occurs in the initial year would occur each year. That is, the annual value of environmental benefits remains constant, in real terms, over time.

It is possible, however, that the value of benefits of a specific environmental asset will increase over time. Saddler et al. (1980) attributed this increasing relative value to demand pressures caused by growth in both population and income and also to supply pressure resulting from the increasing relative scarcity of environmental amenities. Recently, arguments supporting this assumption were presented in the Resource Assessment Commission (1992) forest and timber inquiry. Particular attention was drawn to the

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[1] In the case of the Barmah–Millewa water management options, this is not the case. Different strategies have been developed to benefit different aspects of the forest. For example, the small scale works are aimed at maintaining wetlands whereas the managed floods are more beneficial to the red gum trees. The discussion which follows is presented for illustrative purposes.

increasing relative scarcity of forests, particularly native forests, both in Australia and globally. If these forests are considered to be environmental assets, they have no technical substitutes.

On the other hand, there may be some reasons for expecting declining demand for outdoor amenities, such as increasing levels of ultraviolet radiation and the increasing use of technology to simulate environmental amenities (see, for example, Dwyer 1992). However, these factors apply only to the 'use' values of the environment. The total value of an environmental asset includes a number of other aspects, such as bequest, option and existence values (Rose and Cox 1991), which may not be similarly affected by such factors.

In Saddler's basic model the present value of an environmental amenity was calculated as:

$$PV = \frac{Z * \sum_{t=0}^{\infty} (1 + w_t + c_t)^t}{(1+r)^t}$$

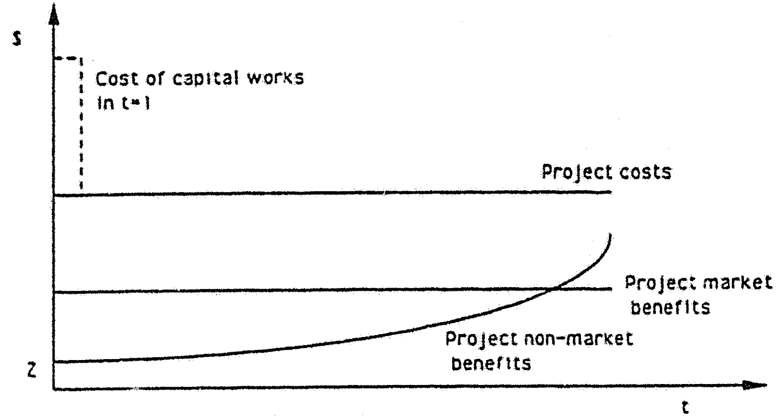
where PV is the present value of an environmental amenity; Z is the value of environmental benefits from the amenity in the initial year; w_t is the annual rate of growth of willingness to pay in year t; c_t is the annual rate of growth of consumption at given prices in year t; r is the discount rate; and t is time in years.

This initial model was then modified to take account of possible differences in the growth rate of environmental benefits over time and is further explained in appendix A.

For example, at a discount rate of 8 per cent an environmental amenity that yields benefits of $1 a year will generate a net present value of these benefits of $12.50 over an infinite period. However, if the value of the benefits are assumed to grow at an annual rate of 2.5 per cent, then its net present value would be $18.50.

A further simulation was undertaken to assess the sensitivity of the benefit–cost results to the assumption that the value of benefits from an environmental amenity would grow over time. The profile of the costs and benefits of the project under this new assumption is depicted in figure 2. The pattern of costs and benefits remains as explained previously. However, the value of the non-market benefits increases over time. Compared with the analysis under the previous assumption, the value of the environment in the initial year, Z, will be lower.

Figure 2: Profile of project costs and benefits when value of environmental amenity grows over time



The growth rate of benefits from the forest was assumed to have a triangular distribution around 2.5 per cent, with lower and upper bounds of zero and 5 per cent, respectively. The values of the key variables in the benefit–cost model were unchanged from the previous simulation. The results from the second simulation are presented in table 4.

The effect of incorporating an environmental growth factor into the simulation is to reduce the threshold value for each management strategy by approximately a third. While

Table 4: Threshold values for proposed water management options when environmental benefits increase in value over time

Water management strategy	Incremental forest area flooded (compared with current practices)	Ratio of market benefits to market costs	Mean threshold value, Z, in the initial year for the benefit–cost ratio to equal one	Range of the value of Z [a]
	ha		$	$
555 GL managed flood	7 102	0.78	41 655	1 815 – 75 330
912 GL managed flood	15 191	0.54	318 782	125 889 – 477 708
Small scale works	7 267	0.47	367 283	303 736 – 4 23 090
Combined option: 555 GL managed flood and small scale works	21 723	0.49	461 178	342 668 – 560 378
Combined option: 912 GL managed flood and small scale works	27 291	0.43	814 322	538 979 – 1 035 193

[a] There is a 25 per cent chance of Z being below the lower figure and also a 25 per cent chance of it being above the higher figure. Thus, there is a 50 per cent chance of the value of Z being within the range shown.

this affects the economic viability of each option, the relative merits of the options and interpretation of the results do not appear to differ. However, if the time profiles of benefits under each option had not been so similar the incorporation of an environmental 'growth' factor could be expected to have a greater impact on their relative merits.

Conclusion

In contrast to the Maunsell (1991) results, where all benefit–cost ratios were greater than one, the benefit–cost ratios obtained from this ABARE study are almost all less than one because of the different prices used for timber and water. Consequently, the value of non-market attributes are of much greater consequence.

Although no attempt to explicitly value the environment has been made in this study, the method provides decision makers with information on the value of non-market attributes necessary for a project to have a benefit–cost ratio equal to one. This approach to benefit–cost analysis is not new, but oddly it is not commonly used despite its potential to complement other methods of valuing non-market factors.

If the value of the annual benefits from the environmental amenity is considered to be greater than the threshold value estimated, the project will be acceptable under benefit–cost criteria. The estimated threshold values for the five water management strategies range from around $61 000 to $1.2 million. These values are estimated under the assumption of a zero growth rate in the value of annual benefits from the environmental amenity. The analysis also considers the impact of uncertainty surrounding the opportunity cost of water and timber.

The threshold value for each project was found to be sensitive to an assumed growth rate in the value of benefits from the environmental amenity. With a growth rate of 2.5 per cent the threshold value drops by approximately a third, to range between $41 000 and $820 000.

While the threshold or opportunity cost approach to benefit–cost analysis is sensitive to assumptions on the rate of growth of benefits from an environmental amenity, the approach has a far lower data requirement than explicitly valuing the environmental benefits using such methods as travel cost or contingent valuation. The threshold or opportunity cost method has the potential to be a cost-effective tool for assisting those who have to make resource use decisions where non-market benefits or costs exist.

Appendix A: Modified model

The modified form of the model is given by:

$$PV = \frac{Z * \sum_{t=0}^{k}(1+w_t+c_t)^t}{(1+r)^t} + \frac{Z * \sum_{t=k+1}^{m}(1+w_t+c_t^*)^t}{(1+r)^t} + \frac{Z * \sum_{t=m+1}^{70}(1+w_t+c_t^\#)^t}{(1+r)^t}$$
$$+ \frac{Z * \sum_{t=71}^{\infty}(1+w_t+c_t^\#)^{70-m}}{(1+r)^t}$$

where PV is the present value of an environmental amenity; Z is the value of benefits from the environmental amenity in the initial year; w_t is the annual rate of growth of willingness to pay in year t; c_t is the annual rate of growth of consumption at given prices, due to changing consumer preferences, in year t; c_t* is the declining value of c after the capacity constraint sets in; $c_t^\#$ is the population growth when t exceeds m; r is the annual discount rate; k is the year from which the capacity constraint has an effect; m is the year that c falls to equal the population growth rate; and t is time in years.

The first term of the modified model refers to the value of environmental benefits before a capacity constraint sets in after year k. During this period the benefits from the use of the area are assumed to grow at a constant rate determined by increasing incomes, population growth and changing consumer preferences. During this period consumer preferences are changing toward consumption of environmental amenities. The perceived use value of an environmental asset would decline if an excessive number of people went to the same area. In the case of the Barmah–Millewa forest, the marginal use value would decline if suitable camping spots became overcrowded.

The second term describes the period after the capacity constraint has an effect and the rate of growth of benefits declines until at year m it equals the sum of the rates of growth in population and income. During this period the move of consumer preferences toward consumption of the environmental amenity slows.

Saddler et al. (1980) assume that, at some time in the future, the individual preferences in society no longer change in the direction of environment but remain constant such that a fixed proportion of the increasing population consume the environmental benefits. The third term covers this period during which the benefit stream continues to grow at a rate given by the sum of the growth rates of population and real income. It is assumed that this period continues until year 70.

For simplicity it is assumed that in year 71 all growth factors cease to operate on the environmental benefit stream and consequently the environmental benefit stream remains at the level it reached at the end of year 70. The loss of accuracy caused by this simplifying assumption is negligible because of the effect of discounting to present values.

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