Economic valuation of ecosystem services from environmental flow provision in the Gwydir catchment, north-western NSW, Australia

F. Karanja[1,2,3], N. Reid[2,3] & O. Cacho[1]
Corresponding author E-mail: fkaranja@une.edu.au
Schools of [1]Business, Economics and Public Policy and [2]Environmental and Rural Science
University of New England, Armidale NSW 2351 Australia;
[3] Cotton Catchment Communities CRC, Australia

Abstract

Aquatic ecosystem services are threatened by river regulation, with diversion of water from rivers causing considerable environmental costs, particularly to floodplains and downstream wetlands. Increasing realisation that river regulation negatively affects aquatic ecosystems, compromising ecosystem services flow from these ecosystems, has led to proactive environmental flow management for ecological outcomes. Environmental flow provision in Gwydir Water Sharing Plan aims at improving wetland and aquatic ecosystems' health. However, irrigators are concerned that implementation of the Plan could lead to significant reductions in irrigation water. This research's aim was to value ecosystem services from provision of environmental flow. The present value economic cost related to provision of environmental flow (40 gigalitre), valued as the opportunity cost of foregone agricultural profit in Gwydir was A$15 million. The total economic value of four ecosystem services (waterbird-breeding events, habitat provision, improved wetlands grazing and biodiversity benefits (native fish species) totalled A$94 million, using NSW households. The NPV was A$79 million or an annual equivalent of A$160/ML/yr at a 7% discount rate.

Introduction

Restoration of the natural flow regime is seen as key to river ecosystem restoration (Frazier and Page, 2006, Kingsford, 2003). In NSW, the water sharing plans (WSPs) have been designed to redress—via partial restoration of the hydrological regime—some of the damage caused by river regulation that is thought to have been experienced by the associated floodplain wetlands and main watercourses (NSW DIPNR, 2004). The environmental flow allocation of each river aims to ensure that the long-term average volume of water available to the environment is maintained (Arthington and Pusey, 2003, Reid and Brooks, 2000). However, the ecological outcomes and benefits of environmental flows are not yet apparent in most aquatic ecosystems (Reid and Brooks, 2000, Pigram, 2006), and a poor understanding of the natural floodplain wetland inundation regime has hampered effective restoration management (Arthington and Pusey, 2003, Frazier and Page, 2006). While it is argued that an increase in environmental water allocation will realise environmental improvements, the irrigation industry is concerned about the lack of evidence, and the possibility that the reduction in wealth and wellbeing of catchment communities dependent on irrigated agriculture as a result of water cuts will be for nought (Reid *et al.*, 2006). Although most decisions on natural resource use are made on economic grounds (Emerton and Elroy, 2004), the economic values of water resources are seldom considered in such debates, despite accumulating evidence that wetlands are economically valuable (Kingsford and Halse, 1998, Woodward and Wui, 2001). This paper will endeavour to model and value ecosystem services from environmental flows to establish how their provision influences the flow of ecosystem services and its concomitant impact on economic sectors such as irrigation. The research's objective was to value ecosystem goods and services from the environmental flow provision in Gwydir catchment. The Gwydir catchment is located in the Murray–Darling Basin in north-western NSW and covers an area of 26 660 km^2 (Roberts, 2002). The Gwydir River's regulated sections are more than 700 km in length and include the Gwydir and Mehi Rivers downstream of Copeton Dam. Copeton Dam holds 1 366 400 ML (Kingsford, 2000). The Gwydir River empties into the Gingham and Lower Gwydir Watercourses

west of Moree. These two watercourses collectively comprise what are known as the Gwydir Wetlands, and are both Ramsar-designated sites (GCMB, 2003).

Methods

The assumptions and values used in valuing ecosystem services from environmental flow provision are summarised in Table 1. Morrison *et al.* (2002) applied choice modelling to Gwydir households and estimated the WTP for an increase in the frequency of waterbird-breeding events by 1 year to be A$19.70 per household. This WTP value was multiplied by the 2-year improvement resulting from provision of environmental flows (Table 1) and the total number of households where this WTP was assumed representative (i.e., 4333, 1.1 million for NSW and 3.4 million for Australia from Table 1) to derive the total WTP for waterbird breeding in the Gwydir catchment. The valuation of three ecosystem services from environmental flow provision—waterbird breeding events, increased wetland area, and biodiversity benefits (native fish species)—was conducted for the Gwydir catchment households, NSW and Australia. Gwydir Wetlands are a Ramsar site, giving it a national significance. Some of the hundreds of birds that breed at Gwydir Wetlands are listed under international agreements, adding to the Wetland's national importance. Similarly, the eight species of native fish that are likely to benefit from environmental flow provision are protected in NSW and nationally. The total WTP for an additional 2038 ha of wetland from provision of environmental flows was estimated from WTP values for the Murrumbidgee River floodplain (Whitten and Bennett, 2001). On average, respondents were willing to pay A$12.10 (as a one-off payment per household) for an extra 1000 ha of healthy wetlands (Whitten and Bennett, 2001). This value was multiplied by the increase in wetland area (divided by a 1000) and by the number of households willing to pay for environmental improvement in Gwydir, NSW and Australia to give the total WTP for wetland improvement in the catchment. The total grazing benefits derived from increased wetland area were estimated by multiplying the increase in wetland area (2038 ha) by the stocking rate of 1.8 DSE/ha in the Gwydir Wetlands. Returns from improved livestock production were calculated by multiplying the livestock yield by the profit at full equity (A$24.11; Table 1) for the Gwydir catchment. The 2038-ha increase in wetland area is a long-term annual average and it was therefore assumed that the grazing benefits would be available every year for 30 years. Morrison & Bennett (2004) applied choice modelling to value improved river health in NSW including the Gwydir catchment. They estimated the WTP (within-catchment estimates for Gwydir) to be A$2.25 per native fish species protected. Ecosystem services modelling revealed that eight native fish species would likely return to the catchment because of provision of environmental flows. The aggregate WTP for the increased number of native fish species was calculated by multiplying the mean WTP for native fish species by eight fish species by 4333, 1.1 million and 3.4 million households in the Gwydir, NSW and Australia, respectively, that would be willing to pay.

These ecosystem services come at a cost of reduced irrigation water, approximately 40 000 ML/yr. Irrigated cotton is the dominant component of irrigated agriculture in the Gwydir catchment and it was selected as the basis to assess the impacts of reduced irrigation water. It was assumed that, in the absence of irrigation water for cotton, the land would be used for cereal cropping (typically wheat) as the next best alternative. The opportunity cost of reducing irrigation water (40 000 ML) was calculated as the difference between irrigated cotton and dryland agriculture total profits. Irrigated cotton profits were calculated by multiplying the irrigated cotton operating profit per ML (Table 1) by 40 000 ML. The cotton area that would have been irrigated with 40 000 ML was calculated by multiplying 40 000 ML by the irrigated cotton water use (0.10 ha/ML; Table 1). Dryland agriculture profits were calculated by multiplying this derived area by the profit at full equity for wheat (Table 1). The net opportunity cost of reduced irrigation water was established by subtracting the realised profits through dryland agriculture from profits that would have been realised through a cotton crops. The effect of possible increases in water-use efficiency because of improvements in irrigation technologies and management techniques on crop water requirements were beyond the scope of this study and were therefore not considered.

Table 1. General assumptions, parameter descriptions, and values used in economic modelling of environmental flows provision

Variable	Unit	Value	Year	Inflator	A$2006	Source
Waterbird breeding events improvement from MDBC cap scenario to environmental flow (EF) provision scenario	yr	2				Karanja (2006)
WTP for waterbird breeding in Gwydir	A$/yearly waterbird-breeding event	15.18	1998	1.298	19.70	Morrison *et al.* (2002)
Habitat function improvement (increased wetland area)	ha	2038				Karanja (2006)
Mean WTP (implicit price) for wetland area	A$/1000 ha	11.39	2004	1.062	12.10	Whitten & Bennett (2001)
Improved grazing in wetlands	ha	2038				Karanja (2006)
Gwydir Wetlands stocking rate	DSE/ha	1.8				Keyte (1992)
Biodiversity outcomes: native fish species recovered in Gwydir River	Absolute	8				Karanja (2006)
WTP for native fish species	Per species	2.12	2004	1.062	2.25	Morrison & Bennett (2004)
Opportunity cost: reduced irrigation water	ML	40 000				Karanja (2006)

Results

The economic cost related to provision of environmental flow (40 GL), valued as the opportunity cost of foregone profits in the Gwydir catchment, were estimated at A$14.81 million (Table 2).

Table 2. Economic value (7% discount rate) of ecosystem services from environmental flow provision

	PV (A$million)			AEV (A$/ML/yr)		
Economic costs	**Gwydir**	**NSW**	**Australia**	**Gwydir**	**NSW**	**Australia**
Opportunity cost: lost agricultural production resulting from irrigation water reduction	14.81	14.81	14.81	29.84	29.84	29.84
Total economic costs	***14.81***	***14.81***	***14.81***	***29.84***	***29.84***	***29.84***
Ecosystem services economic value						
Waterbird breeding events improvement	0.17	44.67	135.41	0.34	89.97	272.81
Habitat provision function: increased wetland area	0.11	27.95	84.72	0.22	56.30	170.69
Improved grazing from increased wetland area	1.10	1.10	1.10	2.21	2.21	2.21
Biodiversity benefits: native fish species	0.08	20.42	61.90	0.16	41.14	124.71
Total economic benefits	***1.45***	***94.13***	***283.14***	***2.93***	***189.63***	***570.43***
Net present value (NPV)	***–13.36***	***79.32***	***268.33***	***–26.91***	***159.80***	***540.59***
Benefit–cost ratio (BCR)	***0.098***	***6.356***	***19.119***	***0.098***	***6.356***	***19.119***

The total economic value of ecosystem services from environmental flow provision was A$1.45 million, A$94.13 million and 283.14 million for the Gwydir catchment, NSW and Australian households, respectively (Table 2). Aggregate WTP for improved waterbird-breeding events made the highest contribution towards the overall economic value of environmental flow provision at A$0.17 million, A$44.67 million and A$135 million for the Gwydir catchment, NSW and Australian households, respectively (Table 2). The economic values translated to an annual equivalent value (AEV) of A$29.84/ML/yr in economic costs and A$2.93/ML/yr, A$189.63/ML/yr and

A$570.43/ML/yr for the Gwydir catchment, NSW and Australian households, respectively, for improved ecosystem services (Table 2). The NPV and net AEV for provision of environmental flows were negative for the Gwydir catchment households, and positive for NSW and Australia, when discounted at 7% (Table 2).

Discussion

Irrigation net revenue would be expected to decline if water for environmental flows is acquired through deductions in irrigation water allocations (Qureshi *et al.*, 2007). In Mooki sub-catchment of Namoi Valley in northern NSW, Aluwihare (2002) found that provision of environmental flows reduced the net farm income by up to 6%. Re-allocating River Murray Basin water from agriculture to the environment was predicted to reduce net irrigation revenue by A$75 million (Qureshi *et al.*, 2007). The findings of the present study found that the total economic cost of environmental flows provision (A$14.81 million). This estimated economic consequences of providing environmental flows in the Gwydir catchment tally with past economic assessments of the same area. ACIL Consulting (2002) predicted that the average extractive water loss following adoption of the surface water draft Water Sharing Plans (WSP) in Gwydir would be 7 GL/yr with an estimated economic costs of A$2 million in lost annual gross agricultural earnings and A$1 million in agricultural value added. Wolfenden & Gill (2001) indicated that net reductions in social benefit attributable to a 10% effective reduction in irrigation water of 34 GL (from 342 GL to 308 GL) could range between A$3 million and A$7 million per annum. The total loss in gross value of production of cotton for the same scenario would be around A$20 million, with the potential for the loss of 300 jobs (Wolfenden and Gill, 2001). Pigram (2006) predicted that reduced cotton production due to the provision of environmental flows, could cause annual losses of A$15 million in the local economy of the Gwydir catchment. This is very close to the economic costs of environmental flow provision A$14.81 million estimated in this present study.

However, Kingsford (1995) stated that approaches that translate loss of water to irrigation into direct economic impact and job loss are simplistic. The economic challenge for the irrigation community is to sustain growth using the same amount of water. Significant cost savings could be made by increasing water-use efficiency, such as by adopting drip irrigation (Kingsford, 1995, Reid et al., 2006)—this aspect is beyond the scope of the current study. In addition, such economic costs should be compared with economic benefits from ecosystem services provided by environmental flows which are substantial (Postel *et al.*, 1998). Unlike those past studies that focused on evaluating economic costs of environmental flow provision, our economic analysis revealed that the economic benefits outweigh the economic costs when the aggregate WTP for ecosystem services are calculated for NSW and Australian households.

The Benefit-Cost Ratios (BCRs) for ecosystem services from environmental flow provision for NSW and Australian households were 6.356 and 19.119 (Table 2), respectively. These BCRs were for ecosystem services only—waterbird-breeding events improvement, habitat provision, improved grazing and biodiversity benefits (native fish species). Wetlands provide many ecosystem services such as water quality improvement, flood mitigation and abatement, water conservation, carbon accumulation, and denitrification (Ewel, 1997, van den Bergh et al., 2004)). Barbier *et al.* (1996) pointed out that a major difficulty facing valuation of complex environmental systems such as wetlands is insufficient information on important ecological and hydrological processes that underpin the various ecosystem services generated by wetlands. Some ecosystem services provided by the Gwydir Wetlands that were not part of this study but with particularly large economic benefits include nutrient retention, flood control, groundwater recharge, and micro-climatic stabilisation, among others (Loomis *et al.*, 2000). If some of these additional ecosystem services were to be valued for the Gwydir wetlands above BCRs would increase even further. Restricting economic analysis of ecosystem services to Gwydir households returned a negative NPV (A$13.36 million) and a BCR less than one (0.098). However, as discussed in section 7.2.1, some of the ecosystem services modelled in this study such as waterbird breeding are of state, national, or international significance, and should therefore be valued

for NSW and Australian households. The net returns from environmental flow provision ranging between A$160 and A$540/ML/yr (Table 2) for NSW and Australian households provide economic justification for the continued provision of environmental flows in the Gwydir catchment.

Conclusion

This paper has valued ecosystem services and trade-offs from environmental flow provision and predicted net economic benefits from environmental flow provision. The economic valuation of environmental flow provision in this study went a step further than most studies which have focused on valuing economic costs (Qureshi et al., 2007, Aluwihare, 2002, Wolfenden and Gill, 2001) incorporating economic valuation of ecosystem services such as waterbird-breeding events, increased wetlands and biodiversity benefits (native fish species) which are key arguments for provision of environmental flows.

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