MODELLING THE ECONOMIC IMPACT OF ENVIRONMENTAL FLOW POLICIES ON THE MACQUARIE REGIONAL ECONOMY

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Abstract

New South Wales Government's 1995 water reform proposals included several environmental flow policies aimed at improving water quality and the river ecosystems. In evaluating these policies a number of different river flow objectives were considered some of which resulted in a reduction in the water availability for irrigated agriculture. This paper discusses the methodology and modelling framework adopted to analyse the economic impacts of environmental flow policies on the Macquarie regional economy of NSW.

An economic model (Catchment Economic Impact Model) was developed to estimate these impacts. This model combines hydrology, simulation, spreadsheet and linear programming applications. The objective function of the linear programming model is to maximise the total gross margins for the region. Constraints include prices, costs, land, labour and water availability. The model provides economic impacts in the format of descriptive statistics of total regional gross margin, total irrigated regional gross margin, present value of total regional gross margin over a 30 year period and changes in crop areas under different environmental flow objectives.

Four different river flow objectives represented by six hydrology scenarios were considered in this analysis. The results of the preliminary analysis of these objectives are also discussed in this paper.

KEY WORDS: Environmental Flows, Macquarie Marshes, Modelling, Linear Programming, Simulation.

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1. INTRODUCTION

In 1995 the New South Wales (NSW) Government introduced a water reform package. Two objectives of this package were to improve water quality and the natural habitat of river ecosystems. There are two stages of implementation of the water reform package. The first is to produce interim objectives (both water quality and River Flow Objectives) for all waterways, taking into account community preferences, current scientific knowledge and broad economic analysis. Stage 2 will involve an independent public inquiry process to help establish water quality objectives for priority catchments. These inquiries will involve detailed community consultation as well as the collection of scientific and economic information relating to catchments. Only by having this information and carrying out research can a better water policy be implemented.

In developing interim River Flow Objectives the following principles were adopted: adaptive management (flexibility); a total catchment approach; recognition of socio economic impacts; maintaining natural flow regime; higher level of protection for rivers which have not been seriously impacted by human use; and restoration of degraded river systems.

The major impacts of River Flow Objectives (environmental flow objectives) on the environment are improved water quality by reducing the incidence of blue green algae and diluting salinity in the water and maintaining suitable environment for fish migration and spawning. These improvements in the environment increase recreational opportunities Moreover, these flows may increase grazing land by increasing duration and frequency of wetting wetlands and consequently increasing income from grazing. However, identifying and quantifying the catchment specific effects of these improvements is difficult.

The main costs of water diversion from extractive users to the environment are impacts on the irrigated agriculture and town water supply. Reduced water availability encourages farmers to select different crop mixes and areas, modify irrigation intensity or methods or change the source of water. Such changes, particularly a change from irrigation farming to dryland farming will result in reduced agricultural income.

Empirical studies on estimating net benefit of environmental flows seems to be limited. A number of researchers have attempted to estimate recreational benefits of environmental flows, particularly benefits of recreational fishing. The impacts on agriculture have been studied by Bosch and Broomhall (1990) Jones et al (1992) and (Yatawara and Hill, 1996) by using statistical and linear programming approaches.

A number of River Flow Objectives were proposed to be implemented in controlled and uncontrolled inland river regions in New South Wales. The Resource Economics Unit of the Department of Land and Water Conservation (DLWC) was commissioned to carry out an

analysis of the economic impacts of implementing various environmental flow policies on regional economies. In order to analyse the impact of different River Flow Objectives on seven regional economies with different agricultural enterprises, a generic model was needed. For this purpose an appropriate modelling framework and subsequently the Catchment Economic Impact Model (CEIM) was developed.

This paper presents the modelling approach adopted for analysing the impact of different environmental flow policies on New South Wales regional economies. The CEIM was used to undertake a case study, the Macquarie region in NSW. The results of this case study are also presented and discussed in this paper.

2. MODELLING FRAMEWORK

Water prices and quantities have been so heavily regulated in NSW that econometric estimates derived from historical data are not that useful in evaluating the consequences of various water policies. The usefulness of linear programming for analysing this type of problems has been demonstrated in previous research (ABARE, 1986). This approach allows returns to the "most limiting" resource to be maximised. This approach also provides the most practical method for simultaneously determining those enterprises and technologies that are both technically and economically most efficient (ABARE, 1986). To determine the most profitable enterprises from a regional viewpoint, a regional linear programming approach was used in this analysis.

Since the water availability will be varied under different River Flow Objectives (hydrology options) it is important to determine the optimal return and production activities for these hydrology options. A linear programming model is used to estimate the optimal annual net returns (in terms of gross margins) from irrigated agriculture for different hydrology scenarios.

2.1. MODEL DESCRIPTION

The Catchment Economic Impact Model is a combination of hydrological simulation, spreadsheet and linear programming models. The objective function in the model is the maximisation of the total gross margin for the whole region for a given year subject to given resource availability (water, land, labour etc). The model is designed to ensure that the sequential impacts of long term weather cycles are reflected in the regional agricultural production patterns. Hence, the optimisation process is carried out for each year that corresponds to annual water diversions provided by the Hydrology Unit of DLWC. The optimisation process is carried out using *Whats Best!* software package.

The model is capable of analysing up to 14 crop types with varying proportions of irrigated and dryland crops, up to 13 environmental policy objectives (hydrology options) and up to 105 years of simulated hydrology data simultaneously.

The CEIM takes as part of its input the 102 year simulated hydrology data from the DLWC's Integrated Water Quantity and Quality Model (IQQM) for different water management

scenarios and analyses the economic impact of the changes in the scenarios. The simulated hydrology data has been obtained from the IQQM. The IQQM is a generalised hydrology simulation package which is capable of application to regulated and unregulated streams, and is designed to be capable of addressing water quality and environmental issues. The IQQM model operates on a continuous basis and can be used to simulate river system behaviour for periods ranging up to hundreds of years. It is designed to operate at a daily time step but some processes can be simulated at time steps down to one hour.

The major process simulated in the IQQM includes: Flow routing in rivers; effluent systems and irrigation channels; reservoir operation; resource assessment; irrigation; urban water supply and other consumptive uses; and wetland and environmental flow requirements.

The optimisation procedure in the model generates a series of total regional gross margins, total irrigated gross margins and cropping patterns. The output (series of regional gross margins) of the optimisation procedure becomes an input to a distribution model which generates probability distributions for respective outputs and assists in the analysis of the changes to farmer income and long term farm viability.

The model generates descriptive statistics for:

- total regional gross margins (dryland and irrigated)
- total irrigated regional gross margins
- changes in annual regional gross margins; and
- changes in enterprise mix.

Annual total regional gross margins are then analysed as a series of 30 year rolling cash flows discounted by the appropriate discount rates. The descriptive statistics and enterprise mix estimated in the absence of the proposed policy changes are compared to those that could occur with the introduction of a new policy.

The results of the model (value of lost agriculture) can also be used in Input/Output models to analyse the indirect (flow on) effects of these agricultural income losses on the regional economies. The structure of the CEIM is presented in figure 1.

Figure 1: Structure of the Catchment Economic Impact Model (CEIM)
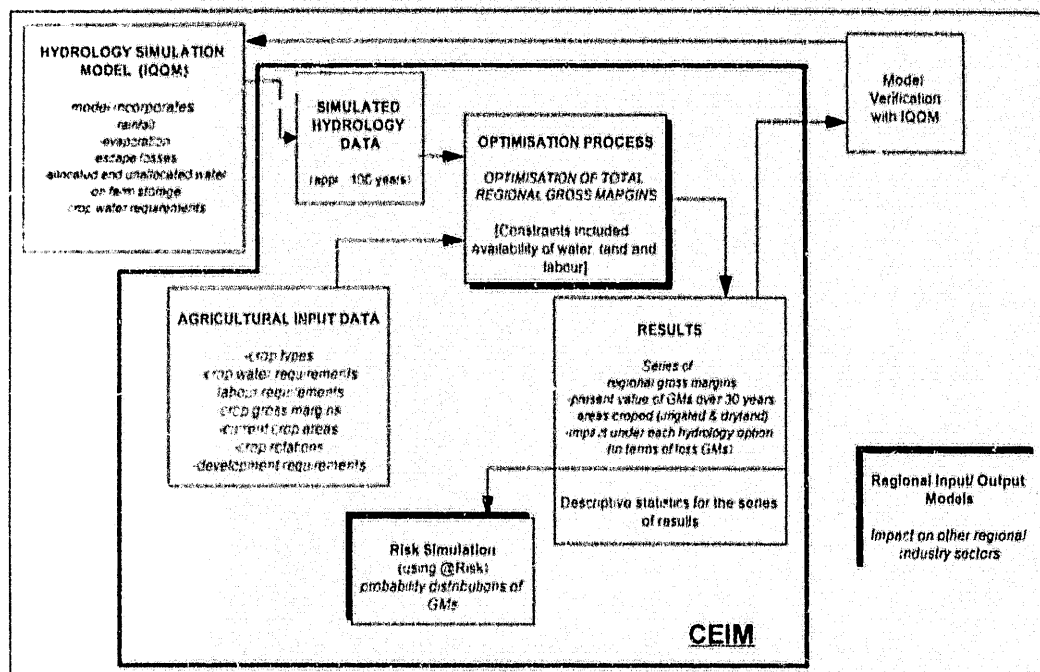
3. THE CASE STUDY: IMPACT ON MACQUARIE REGIONAL ECONOMY

3.1. CHARACTERISTICS OF THE REGION

The Macquarie Region (Catchment) is located in central to north-western NSW and is made up of the Castlereagh, Macquarie and Bogan River systems. The Macquarie Catchment encompasses the Australian Bureau of Statistics (ABS) statistical local areas of Dubbo, Narromine, Warren, Bogan, Bathurst, Orange, Bourke, Brewarrina, Coonamble, Gilgandra and Coonabarabran.

Currently about 4200 agricultural establishments are in the Macquarie Catchment. Grazing is the dominant land use in the table lands, hilly areas of the South and East and in the dry North-West. In the centre of the catchment both dryland and irrigated cropping constitute the agricultural activities. The area of irrigated agriculture during 1993 year was 92,370 hectares in the Macquarie Catchments. Irrigated cotton is the foremost irrigated crop type accounting for approximately 44% of total irrigated area. Other important irrigation activities include wheat, lucerne, pastures and vegetables.

The total value of agriculture in Macquarie Catchment in 1993, according to the ABS's IRDB Database, was estimated to be worth $785 million and accounted for about 12% of the total

agricultural production in New South Wales. The value of crops and pastures was approximately $447 million. Main contributors to the value of crop agriculture were cotton and cereals for grain.

There are two major dams in the catchment; Burrendong Dam on the Macquarie river and Windarmere Dam on the Cudgegong river. About 70% of the Macquarie river's flow are trapped or briefly detained by the Burrendong Dam. This causes a reduction in flood heights and the frequency of small to medium floods in the flood plains of the Macquarie and Bogan rivers and effluent creeks, including Macquarie Marshes. Inflows to Macquarie Marshes have been greatly reduced by diversions for irrigation of most of the stored water and some of the flows of uncontrolled tributaries. This has caused serious degradation of the wetlands and decline of wildlife populations. Several interim river flow were introduced with the aim of combating these problems. A base case, two River Flow Objectives and a combination of these two objectives were proposed for economic evaluation. These River Flow Objectives represented by six hydrology options including the base case. The River Flow Objectives included in the analysis are presented in the table 1.

Table 1. River Flow Objectives and Corresponding Hydrology Options Analysed

RFOs	HYDROLOGY OPTION	WATER MANAGEMENT RULES
Base Case (Current level)	Base Case	93/94 level of irrigation development and on-farm management. Storage's and weirs operated in accordance with the rules prior to the introduction of the September 1995 Water Reform Package provisions.
RFO 2 Protect flows during natural low flow periods.	Option 1	Burrendong Dam "transparent" * up to inflows of 75 ML per day during non-irrigation months (from June-October inclusive).
RFO 3 Protect or restore an appropriate proportion of freshes and floods.	Option 2	"Translucent" ** Burrendong Dam release rules - 100% of inflows passed in the specified range: No wildlife allocation is included because this option is an alternative to the Wildlife Allocation. Inflows into the storage that would, under natural conditions, provide Marshes inflows are passed through the dam with the addition of irrigation water orders.
	Option 3	93/94 level of irrigation development and on-farm management. System operated in accordance with the 1996 Macquarie Marshes Water Management Plan.
RFO 2 and 3	Option 4	Windamere Dam "transparent"* up to inflows of 1,200 ML per day during all months (irrigation releases are in addition to inflows' volume releases).
	Option 5	Windamere Dam "transparent"* up to inflows of 600 ML per day during all months (irrigation releases, are in addition to inflows' volume releases).

*Transparent Dam: Dam releases are equal to inflows (up to a defined threshold).

**Translucent Dam: Dam releases are proportional to inflows with a target range at the same defined down stream site.

3.2. MODEL INPUTS

The necessary data and information for this analysis were obtained from the DLWC, farm budget handbooks of the NSW Department of Agriculture (NSW Ag.) and IRDB database.

The simulated hydrology data for six different hydrology options were provided by the Hydrology Unit of the DLWC. The descriptive statistics for simulated hydrology data for Macquarie Catchments are presented in the table 2. The Base Case simulates the current conditions in the catchments. All other scenarios are compared to the base case.

Table 2 shows the summary statistics for total annual diversions to Macquarie Catchment irrigation under each hydrology option. These statistics show that option 2 has the largest negative impact on the amount of water available for irrigation, reducing the annual average amount of water available by 53,885 ML. or 14%. The least reduction in water available for irrigation will occur under Scenario 1 with a 725 ML. reduction in water availability. The standard deviation is very similar in all cases. However option 2 has the greatest standard deviation at 218,751 ML. and option 5 has the smallest with 196,559 ML.

Table 2. Descriptive Statistics of the Hydrology Data used in the Model, ML.

	Base Case	RFO 2	RFO 3		RFO 2 & 3	
Hydrology Options	Base Case	Option 1	Option 2	Option 3	Option 4	Option 5
Average	385,467	384,743	331,583	344,033	338,837	342,409
		(725)	(53,885)	(41,435)	(46,631)	(43,058)
St. Deviation	206,017	205,008	218,751	199,796	197,336	196,559
Minimum	36,329	35,457	38,264	36,576	37,402	38,004
Maximum	770,118	781,327	761,145	767,521	704,551	694,671

* The figures in the parenthesis are the differences from the Base case

Source: Hydrology Unit, Department of Land and Water Conservation

Extent of different crops and pastures, total crop and pasture areas and total labour availability in Macquarie Catchment were obtained from the IRDB. Other farm level data such as crop gross margins, crop water requirements, labour requirements and cost of labour were obtained from the Farm Handbooks of the NSW Agriculture. The DLWC provided the water charges for general irrigation security licences in the Macquarie Catchment.

4. RESULTS AND DISCUSSION

The CEIM provides graphs and tables of results with descriptive statistics for the options considered. For illustrative purpose only two indicators: change in irrigated areas; and changes in regional irrigated gross margins are discussed here.

4.1. TOTAL IRRIGATED AREA

The total irrigated area under each option resulted in the order of environmental flow options from least loss (cost) to highest loss (cost): option 1, option 3, option 5, option 4 and option 2 (Table 3). The maximum reduction in irrigated area from the Base Case was 6,812 ha, this occurred under option 2. Option 1 has the least amount of reduction in area irrigated with the average area irrigated being 68,990 Ha. Option 2 not only has the largest reduction in hectares but also has the highest standard deviation (highest variability) of 30,037 hectares.

Table 3. Area Irrigated under Different River Flow Objectives, Ha

	Base Case	RFO 2	RFO 3		RFO 2 & 3	
HYDROLOGY OPTIONS	Base Case	Option 1	Option 2	Option 3	Option 4	Option 5
AVERAGE	69,140	68,990	62,328	63,417	62,792	63,204
ST. DEV.	28,472	28,395	30,037	27,459	27,380	27,176
MINIMUM	16,805	16,696	17,047	16,836	16,939	17,014
MAXIMUM	110,252	110,252	110,252	110,252	110,252	110,252

4.2. TOTAL REGIONAL GROSS MARGINS

Figure 2 illustrates the importance of water availability to the model as it shows that the regional gross margins follow a similar pattern to the water diverted under the Base Case. This result shows that water is a scarce resource where any decrease in its availability will have a direct impact on farmer decision making and the returns from irrigated agriculture in the region.

Figure 2. Water Availability and Annual Regional Gross Margins under the Base Case
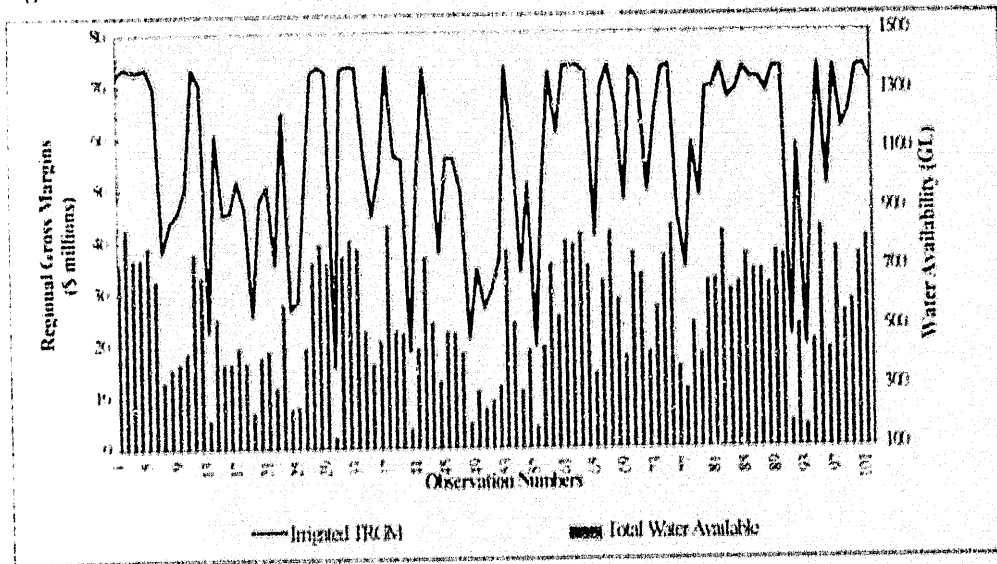
The descriptive statistics for annual regional gross margins in the Macquarie Catchment are presented in table 4. The irrigated regional gross margin for the Base Case in the catchments is $56.67 million. Option 1 in incurs the least cost to the catchment with a regional gross margin of $56.63 million. This option also has the lowest standard deviation indicating that returns to regional gross margins will remain relatively stable.

Table 4. Impact of Different river Flow Objectives on the Macquarie Regional Economy-losses in irrigated gross margins

($ millions)

	Base Case	RFO 2	RFO 3		RFO 2 & 3	
Hydrology Options	Base Case	Option 1	Option 2	Option 3	Option 4	Option 5
Average	56.67	56.63	51.48	53.53	53.16	53.52
		(0.04)	(5.19)	(3.14)	(3.5)	(3.15)
St. Deviation	17.10	17.10	18.67	17.68	17.77	17.61
		(1.62)	(6.68)	(4.28)	(4.65)	(4.07)
Minimum	15.95	15.85	16.18	15.98	16.08	16.15
Maximum	73.55	73.55	73.55	73.55	73.55	73.55

* The figures in parenthesis are the differences from the Base Case (impact on the Regional Economy).

Higher standard deviation indicates the higher farm income variability. Increase in the standard deviation between the base case and with the implementation of River Flow Objectives infers that introducing environmental flow policies would increase the likelihood of farm income variability. The decrease in the annual value of total regional gross margin of $5.19 million and an increase in the standard deviation to $6.68 million under option 2 shows that this option will have the greatest negative impact on irrigated agriculture for the Macquarie Catchments with the highest income variability.

The impacts of various options on the regional economy can also be illustrated on an average farm basis for the 4,168 agricultural establishments in the Macquarie Catchment. Implementation of options 2 may reduce the annual gross margin at farm level by $1245.20. Option 3 results in a reduction of $753.36 to the gross margin per farm. Similarly, Option 4 and 5 had reductions in the gross margin of $839.73 and $755.76 per farm respectively. However, these estimates may not show the true impact on farms of with varying sizes and financial situations. If different farm sizes and their financial situations were readily available, a more comprehensive farm level analysis could have been undertaken.

5. CONCLUSIONS

The Catchment Economic Impact model (CEIM) and the modelling framework presented in this paper provide a useful means of assessing the economic impact of different environmental flow policies (River Flow Objectives) on the regional economies. The CEIM is a generic model that can be used for similar policy analysis for different catchments/regions with varying agricultural enterprises. The model provides the impact of these policies on the regional economies in terms of loss or reduced regional gross margins and changed cropping patterns. The distribution graphs of gross margins which show the variability and the skewness is also a product of the model. These parameters are useful for identifying the income variability under different hydrology options of River Flow Objectives.

The model was used for a case study in the Macquarie Catchment. The descriptive statistics of total regional gross margins show that the largest negative impact to the Macquarie Catchment (region) was associated with hydrology option 2. The total irrigated area decreased under this option from the Base Case of 69,140 hectares to 62,328 hectares. This area was also lower than the estimate for option 1 (RFO 2) which was 68,990 hectares. It was also shown that if option 2 is adopted it will have an estimated cost of $5.2 million in terms of loss of regional gross margins in the catchment per annum. Thus, River Flow Objective 2 which is represented by the hydrology option 2 results in the least amount of loss to the agricultural industry in the Macquarie Catchment. Although the CEIM model is designed to analyse impact of environmental flow policies, it also provides a suitable avenue for addressing similar issues of water reform policies.

The results of the model can also be used in Input/Output models to analyse the indirect (flow on) effects of these agricultural income losses on the regional economies.

6. LIMITATIONS OF THE STUDY

One of the major limitations of this analysis is that it is not feasible to incorporate into the analysis the possible environmental benefits from the RFOs such as: controlling river algae blooms; stream salinity management; native fish management; and native water bird breeding.

The modelling framework discussed above is not specifically designed to cater for impacts on farms with varying sizes and financial situations. Hence, it has been considered to extend the current model to analyse farm level impacts in detail. In addition, the current approach could be developed further to incorporate the following aspects: yield responses to different water availabilities and soil types; changes in commodity and input prices over a time period.

REFERENCES

ABARE (1986) *A Model for Determining the Short Term Demand for Irrigation Water*, Discussion paper 86.4, Canberra

ABS (1996) *Integrated Regional Database version 96*, Australian Bureau of Statistics, Canberra.

Bosch, D. and Broomhall, D. (1990) *Estimating the Economic Costs to Irrigators of Alternative Minimum Instream Flow Standards*, Rivers, 1(1):51-61.

DWR (1995) *IQQM - Integrated Water Quantity and Quality Model*, Hydrology Unit, NSW Department of Water Resources, Parramatta, NSW.

Jones, R., Musgrave, W. and Bryant, M. (1992) *Water Allocation and Supply Reliability in the Murrumbidgee Catchments*, Review of Marketing and Agricultural Economics, 60(2):155-172.

NSW Agriculture (1993, 1994) *Crop Budget Handbook*.

Yatawara, T. and Hill, C. (1996) *Economics of Water Allocation for the Environment: A Case Study in the Gwydir Wetland*, NSW, paper presented to the AARES Annual Conference, University of Melbourne, 12-15 February 1996.