Managing catchments for multiple objectives: the implications of land use change for salinity, biodiversity and economics

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Introduction

Natural resource management in Australia has tended to ignore, in practice, the interaction of ecosystem components and processes whose overall sustainability we seek to enhance. Operationally, natural resource objectives are often pursued independently, contrary to policy objectives which stress the development and implementation 'integrated catchment plans' (eg Anon, 2000). Since ecosystems constitute a set of interrelated processes that occur on different temporal and spatial scales such plans should require that catchment managers consider the impact of change on multiple systems components and the possibility of trade-offs between components (Yiridoe and Weersink, 1997).

In recent times government funding for the management of natural resources in rural Australia, under the National Action Plan for Salinity and Water Quality, has been contingent on the development of catchment management plans. These plans are required to specify the aim of management in terms of the change in resource condition, within a specified timeframe. These targets are underpinned by management targets which define the physical outputs, such as area of trees planted, that will eventually lead to a change in resource condition.

However, few, if any, catchment plans have been subject to a quantitative assessment of the impact of management changes on multiple catchment characteristics. Decision makers therefore remain unaware of the extent of trade-offs associated with proposed changes and the cost effectiveness of alternative strategies.

In this paper we assess the impact of alternative management strategies on the trade-offs between multiple catchment characteristics - biodiversity, stream salinity, stream yield, saltload, sequestration of carbon and farm profit - for a sub-catchment in NSW. The implications of the results for catchment management are discussed.

Method

Description of Little River Catchment

The scenarios modelled in this study encompassed a portion of the Little River catchment located south of Dubbo on the edge of the central west slopes, New South Wales. Cumnock lies in the heart of the catchment at 32.92 degrees South and 148.77 degrees East. The study area covers approximately 143,000 ha, extending from the Hervey Range in the west to the Catombal Range in the east. Topography is varied, with quite steep and divided terrain in the encircling ranges that reach an elevation of over 700 metres. Undulating hills cover much of the central part of the study area giving way to low-lying flats and flood plains in the northern part of the catchment adjacent to the Macquarie River. The average annual rainfall is between 580 and 700 mm and distributed evenly throughout the year.

The majority of the study area is used for agricultural production, including cropping and livestock grazing. Dryland salinity is an increasing problem with some areas affected by saline outbreaks and many of the watercourses exhibiting high levels of salinity. Much of the native vegetation has been cleared, particularly on the more fertile soils. Approximately 27 percent of the study area is covered with native woody vegetation restricted mainly to shallow, infertile soils. Ninety percent of woodland remnants are less than one hectare in area and isolated from areas of similar habitat (Seddon *et al.* 2002). They have little understorey and show signs of declining tree health.

Scenarios

In this study land use change scenarios focused on three areas: Biodiversity Investment (*BioInvest,* 2 levels); Salinity Management (*SaltInvest*, 2 levels); and Farming System Shift (*FSS,* 3 levels). These scenarios were evaluated by comparison with a *Status Quo* scenario representing the study area in 50 years time under current land use. The *BioInvest* and *SaltInvest* scenarios simulated the type and extent of on-ground revegetation, vegetation management, and pasture establishment typically identified in`investment plans of catchment management authorities (CMAs) in NSW. Farming system shifts focussed on establishment of 'alley farming' (alleys of old man saltbush with conventional crop-pasture rotations in the inter-row), as well as the introduction of 'pasture cropping', involving direct drilling of winter crops into (dormant, summer active) native pastures.

The *BioInvest1* scenario simulates investment in approximately 14,000 ha of land managed specifically for native vegetation outcomes, focused on communities of high conservation significance. *BioInvest2* was also evaluated in which these communities were revegetated to 30% of their pre-clearing extent or 30,700 hectares. The objective of the *SaltInvest* scenario was to reduce deep drainage on 15,000 hectares of high salinity risk landscapes, including 1500 ha of large woody interception plantings, enhancement of 7,500 ha of remnant vegetation, 100 ha of farm forestry plantings, and 5,000 ha of pasture cropping and alley farming (this does not add to 15,000). *SaltInvest2* assumed an additional 16,700 ha of interception plantings were established.

The Farming System Shift scenario focused on the adoption of alley farming and pasture cropping on 25%, 50%, and 100% of the area considered suitable by an expert panel. These were designated *FSS25*, *FSS50*, and *FSS100* respectively.

Estimation of Biodiversity Condition Score (BCS)

Changes in condition over time and under different land use scenarios were assessed using BioMetric (Gibbons *et al*. 2007), using data collected from a range of farming systems and native vegetation sites. The final BCS is expressed as the estimated mean condition of the catchment expressed as a percentage of the pristine condition. Seddon *et al*. (in prep) describe the methods used to assess biodiversity changes in greater detail.

Modelling of catchment responses

Bathgate *et al.* (2004) describe the model used to estimate the impact of land use change on stream flow, stream salinity, saltload and financial costs of these changes to consumers and industry that draw water from the Macquarie River downstream of the study catchment. Two additional modules were added to estimate change in farm profit and carbon sequestration over time. The model estimates the physical changes and the discounted financial benefits over a 50 year period.

Results and discussion

The most striking feature of the results (Table 1) is the large variation in total farm profit among scenarios compared to other catchment outcomes. Four of the seven scenarios assessed led to increases in farm profit, while three led to a reduction. Increases in the total farm profit were associated with insignificant shifts in other characteristics, such as biodiversity. More substantial improvements in the condition of the catchment achieved under the *SaltInvest2* and *BioInvest2* scenarios resulted in very large reductions in farm profit, which was $134m over 50 years for the status quo.

Water yield was reduced in all scenarios. The greatest reduction in water yield was 13% from 77 ML per annum to 67 ML per annum (*SaltInvest2*). These reductions led to a financial cost to downstream users in all but one instance. All scenarios produced financial benefits in terms of stream salinity. Total saltload was reduced by 19% from 31,700 tonnes per annum to 25,800 tonnes per annum for *SaltInvest2*. However the concentration of salt in-stream was only reduced by 7% at the confluence of the Little River and Macquarie River, and the net financial benefit of the reduction in salinity to downstream users of water was small relative to the change in farm profit.

The results indicate that broad scale changes to farm production methods with current technology are relatively ineffective in improving the condition of the catchment as measured in this analysis. The FSS100 scenario assumes land use change over 80,000 hectares, more than 30% of the study area. However, the net present value to consumers and industry of the financial benefits resulting from reduced stream salinity was less than $100,000. This benefit was more than outweighed by the cost of reduced water yield. The largest impact of this scenario was on carbon sequestration. However, this was less than 10% of the total benefit at the price of carbon credits assumed.

Table 1 Net change in catchment outcomes for 7 land use change scenarios. Financial benefits are expressed as the increase or decrease in net present value compared to the status quo over 50 years.

	FSS25	FSS50	FSS100	Bio Invest1	Salt Invest1	Bio Invest2	Salt Invest2
Total $ benefit ($m)[1]	7.64	20.78	53.38	-11.78	6.44	-42.73	-36.14
Change in farm profit ($m)	6.40	18.82	48.43	-12.17	5.10	-46.57	-37.11
Benefit of ↓ stream salinity ($m)	0.02	0.03	0.09	0.01	0.10	0.28	0.59
Change in saltload ('000's t)	-0.2	-0.3	-0.9	-0.1	-0.9	-3.6	-5.8
Cost of ↓ Water yield ($m)	-0.06	-0.08	-0.24	0.02	-0.18	-0.89	-1.11
Carbon income ($m)	1.28	2.02	5.10	0.37	1.42	4.44	1.47
Increase in BCS (pp)[2]	0.5	0.4	0.1	2.5	2.5	7.7	4.0

[1] – Includes only those benefits that have been assigned a financial value

[2] – Regional biodiversity condition score in percentage point increases compared to the status quo

Broad scale revegetation with woody perennial plant species will be required in order to have a substantial impact on the condition of the catchment. However this will result in a substantial reduction in both farm profit and total financial benefit to the catchment. Such action would only be justified if a very high value were assigned to the environmental value of changes in stream salinity, saltload, terrestrial biodiversity and stream flow. This conclusion is consistent with Pannell (2001) who argues that investment should be directed at high value assets, rather than spread thinly across a broad area.

The fact that optimal catchment management depends on an understanding the environmental impact of these factors poses a conundrum for researchers and policy makers as there is a paucity of empirical data in this area. Moreover, collecting such data is costly, problematic and needs to be undertaken over a long timeframe. The lack of data is particularly pertinent to the management of stream salinity, given the trade-off with water yield and the apparent trade-off between water yield and biodiversity. Whilst the financial consequences of these trade-offs are small it is unclear that the environmental costs of reducing streamflow will be outweighed by the gains of reducing stream salinity. Nor is it clear that potential gains in biodiversity should be sacrificed in order to focus onsalinity. Yet the management of dryland salinity in Australia has been largely pursued with little if any consideration of the loss in stream yield and independently of the management of biodiversity. Maximising the benefits of catchment management requires the development of integrated strategies based on consideration of their multiple outcomes.

The large private benefit (to farmers) of changing production methods, say by increasing the area of perennial pasture (Scenarios *FSS25, FSS50* and *FSS100*) and the small impact on the condition of the catchment indicate that there is little or no role for government in providing incentive payments to farmers for such a shift. Equally, profitable land management changes for farmers will not produce substantial improvements in biodiversity although *SaltInvest* is the best compromise. Rather the focus should be on subsidising changes in land use that are not profitable but deemed to have a large environmental benefit. Pannell (2001) also argues there is a role for government in providing R&D to identify and develop profitable production methods that have environmental benefits.

Carbon sequestration

The relatively small impact of land use change on income obtained from carbon sequestration is noteworthy. In recent years there has been increasing interest on the capacity of farm businesses to benefit from the introduction of a carbon trading scheme in Australia. Yet the potential returns to farmers, relative to the returns (or costs) of land use change, are such that they are unlikely to influence production decisions. This is coupled with the potential risks associated with maintaining sequestered carbon and the likely long term nature of such a commitment, thus limiting choice of future production options.

Efficient outcomes from land use change

The results of the analysis of three scenarios in Table 1 highlight an important aspect of the need for quantitative analysis of potential land use strategies aimed at improving the resource condition of the catchment. Scenarios *FSS100* and *SaltInvest* achieve the same saltload while the total financial benefit to the catchment is substantially different. Similarly, the *BioInvest* and *SaltInvest* scenarios achieve the same change in biodiversity condition while the catchment benefit for each is very different. Alternative strategies may thus be employed to achieve a given outcome, and the cost of these alternatives can differ quite markedly. Maximising welfare of society will depend on achieving specific outcomes at the lowest cost and this requires an assessment of costs and benefits that are derived from the impact on multiple catchment characteristics, not just the expenditure incurred in the of implementation of the strategy.

Conclusions

Substantial improvements in the resource condition of the catchment, according to the results of this analysis, can only be achieved by incurring large reductions in the farm profit through revegetating a significant proportion of the catchment. The extent to which this is justified will depend on the perceived value of environmental impacts of changing catchment characteristics, given that the financial impacts on all but farm profit are small. There appears to be little justification for subsidising farmers to alter production methods, given the small effect of these changes on resource condition.

Maximising the benefits of catchment management depends on understanding the effects of change on a range of catchment characteristics, possible trade-offs and their environmental impacts.

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