

Integrated systems evaluation of climate change and future adaptation strategies for the Lower River Murray, Australia

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Abstract

Australia's Murray Darling Basin is experiencing climate change, leading to a hotter and drier climate and declines in basin inflows. There is also a significant salinity issue in this region that arises because highly saline groundwater is hydraulically connected to the river. This article reports on an assessment of future conditions likely to arise in the region under alternative assumptions about climate, markets, and policy to influence environmental conditions.

The analysis involved an integrated systems model accounting for impacts of climate on water availability, adaptive response of the irrigation sector to changing water availability, market prices and policy settings. Irrigation water balance implications and river salinity and floodplain ecological health consequences of futures are assessed. Several policy opportunities to reduce potentially adverse impacts of climate change are identified; merits and tradeoffs involved are discussed.

Keywords: Adaptive response, catchment scale integrated assessment, climate change, economics, policy, salinity, water quality.

Introduction

The MDB is Australia's most significant basin in terms of irrigation, producing 41% of Australia's gross value of agricultural production and also a source of and municipal industrial water for a significant population. The system is highly allocated so that the median annual flow to the sea is now only 27 per cent of the natural (pre-development) flow on average. As a result of high allocation levels the environmental health of the River Murray system is in decline (MDBC 2001). In addition, there is evidence that climate change is leading to a hotter and drier climate in Southeast Australia with declines in basin inflows a likely consequence (AGO, 2007).

The focus of analysis reported on here is the Lower reaches of the River Murray, Australia. There is a significant salinity issue in this region that arises because highly saline groundwater is hydraulically connected to the river. Even before irrigation, considerable quantities of saline groundwater seeped into the Murray. Because irrigation has replaced native vegetation along a considerable area of the Lower Murray banks, much greater volumes of drainage now percolate into groundwater. This results in elevated groundwater levels that create gradients forcing saline discharge to the River and floodplain. Results include yield losses for crops irrigated with saline water, damage to municipal and industrial water infrastructure and reduced health of significant floodplain and estuary ecosystems.

This article reports on a project undertaken for local environmental management agencies to assess future conditions likely to arise in the region under alternative assumptions about climate, markets, and policy to influence environmental conditions. The analysis involved an integrated systems model accounting for impacts of climate on water availability, adaptive response of the irrigation sector to changing water availability, market prices and policy settings, irrigation water balance implications and river salinity and floodplain ecological health consequences.

Methods

Future scenarios for the Lower Murray River Corridor

The futures analysis methodology used in this study involves policy options conceived of as plausible arrangements of natural resource management actions in the landscape given assumptions about policy and external drivers. Options are selected to represent the bounds of the range of alternative actions that are possible to address the relevant NRM issues. This methodology enables evaluation of costs, benefits and trade-offs related to alternative approaches to address NRM. The two policy options evaluated in the river corridor component are summarised in Table 1.

Futures are modelled as policy options evaluated under external condition scenarios representing alternative assumptions about external climate and market conditions. As can be seen in Table 2, four scenarios are modelled representing assumptions about impacts of temperature, average annual basin inflows (and implications for water allocation levels), water and crop prices. This allows assessment of robustness of policy approaches to assumptions about external conditions and allows deeper appreciation of how future conditions beyond the control of those setting policy are likely to influence key environmental outcomes.

Table 1 Policy options modelled in river corridor component of the Lower Murray Landscapes Futures Project

Policy option	Short Description
Irrigation Efficiency	Complete adoption of high efficiency irrigation practice across the region and continuation of current NRM policy as in the Baseline scenario.
Low Impact Irrigation	Reduction by 20% of irrigation in high salinity impact areas through cessation of irrigation or relocation to low impact areas. Again continuation of current NRM policy as in the Baseline scenario is assumed.

Table 2 Summary of climate, water allocation, water and commodity price assumptions defining Lower Murray Landscape Futures, river corridor scenarios

	S0 – Baseline	S1 – Mild Climate Change	S2 – Moderate Climate Change	S2 – Severe Climate Change
Temperature	Historical Mean	1°C	2°C	4°C
Average Annual Rainfall	Historical Mean	5% decrease	15% decrease	25% decrease
Average Annual Basin Inflow	1975 – 2000 25 year reference sequence levels	13% decrease	38% decrease	63% decrease

River Corridor Integrated Systems Model

The river corridor systems model developed for this project is a synthesis framework that brings together findings from a set of connected biophysical and socio-economic models. The integration allows representation of the key natural and human elements of the river corridor system and their interactions. A brief overview is provided here. More detail on component models is reported in Connor *et. al*, 2008. The interrelated biophysical and economic processes synthesised for the analysis include:

A basin water availability model - Climate change, resultant basin water yield and water allocation process models determine the level of rainfall in the basin, resultant levels of inflow into basin water storages, water availability for irrigation, and river flow levels;

Irrigation economics, water and drainage models - Irrigated crop production economics and water balance is modelled including spatial representation of irrigation water use and drainage depth. This

includes accounting for economic responses by irrigators to policy and external water availability, irrigation water salinity and water and crop price changes;

A groundwater salinity process model simulates the spatially heterogeneous processes that determine how irrigation water drainage influences saline groundwater tables and consequent accessions of saline groundwater base flow to the River and floodplains;

A floodplain health model assesses changes in ecological risks from floodplain water table level changes in response to changes in drainage and actions to mitigate risks including engineering to intercept groundwater flow and other actions such as drainage reduction to control water table level.

A River salinity model represents processes including the processes that determine seasonal and annual flow variation and variation within and across seasons in salt concentrations in river water, given modelled groundwater salt inflows.

Salinity damage and salt interception models – A salinity damage model estimates irrigated crop and water infrastructure salinity damage and damage costs. A salt interception model determines engineering intervention investments required to offset all growth in salt accessions with by pumping saline groundwater baseflow away from the river's edge.

A regional socio-economic impact model estimates regional income, employment and population changes in response to irrigation sector economic impacts of responses to NRM policy and investments and changes in external conditions such as water allocation levels, crop and water prices.

Conclusion—key policy implications of findings

One key finding is that given current basin scale water sharing rules, reduced inflows consistent with moderate and severe climate change scenarios result in more variability across the year in allocation levels and more years of greatly reduced or zero water allocation. Water price rises in response to increasing water scarcity were another key feature of response to the lower water allocation levels associated with warmer climate scenarios identified in the assessment.

A further conclusion from modelling of irrigation sector adaptation to single years of low allocation was that only moderate reductions in revenue and profit were likely from allocation levels down to 60% of entitlement. Opportunities exist to adjust such as improved irrigation efficiency and slightly water-stressing crops that don't involve large yield and hence revenue loss for allocation reductions in this range. At very low allocation levels (30% or less), severe economic losses are estimated because there is not enough water to protect permanent plantings from sustaining long-term reduced yield potential in future years.

The overall conclusion from the assessment of the potential impacts of climate change on Lower Murray floodplain health is that local adaptation to increased water scarcity consistent with climate change may have a positive NRM impact in the form of less groundwater discharge to floodplains than would otherwise result. This, in turn, is likely to lead to less risk from elevated floodplain water table than would otherwise be experienced. However, maintaining healthy floodplains requires inundation as well as reduced rates of saline groundwater flow to floodplains. The reduced river flows predicted for climate change scenarios are likely to be inconsistent with provision of inundation required to maintain ecological health for most of the floodplains in the region. Providing sufficient inundation would require altering current basin level water allocation, rules and environmental flow management practices.

The overall conclusion from the benefit cost analysis of irrigation efficiency and location policies was that there are likely to be significant opportunities to improve irrigation efficiency and location in the Lower Murray that can be justified on a benefit cost basis. This is concluded despite the finding that the monetised benefits considered are not estimated to exceed the costs when the usual market interest discounting is used in benefit cost analysis.

There are three reasons for this conclusion: 1) The monetary value of reduced floodplain health deterioration were not counted in the benefit costs analysis while available evidence suggests Australian highly value River Murray floodplain health both intrinsically and for recreational, amenity purposes. 2) The values in the benefit cost analysis were on average across multiple irrigation areas. Benefit to cost ratios would be considerably greater for policy better targeting sites where salinity impacts of irrigation are greatest. 3) The use of a market rate of interest in discounting time lagged benefits that underpins the baseline benefit cost analysis, is not universally accepted by economists. Some economist argue that a lower discount rate is more appropriate for discounting when comparing dollar costs incurred by the current generation with future generation environmental benefits. When the monetised benefits and costs considered here are compared with a reduced discount rate, benefits exceed costs of irrigation efficiency and location policy, regardless of assumptions about future climate.

A final conclusion was that the futures approach, offered insights with respect to interactions between biophysical system behaviour and adaptive responses by human actors that would not have been obvious in absence of an integrated systems view. For example, futures modelling provided important insight regarding the relative influence of actions that can be taken locally and climate and water allocation factors determined that would not have been easily understood in absence of a highly integrated evaluation. Most notable is the conclusion that salinity outcomes in the Lower Murray system as a whole and especially in South Australia are fundamentally determined by factors outside of regional control. The combined adverse impacts on river salinity of time delayed salt load growth and concentration increases that could result from reduced flow, were estimated to be much greater than positive impacts estimated to result from regional irrigation efficiency and location.

References

AGO Adapting to Climate Change: Australia's Settlements and Infrastructure - Impacts of Climate Change <http://www.greenhouse.gov.au/impacts/settlements.html>

Connor, J., Doble, R., Walker, G., Stenson, M., Elmahdi, A., Ferris, M.M., Jolly, I., Kaczan, D., Morrison, J.B., King, D., Pickett, T., Petit, C. Lower Murray Landscape Futures Final Report: Volume Four Analysis of Regional Plans and Landscape Futures for the River Corridor CSIRO: Water for a Healthy Country National Research Flagship, Canberra.

MDBC 2001 MDBC (2001). Integrated Catchment Management in the Murray-Darling Basin 2001-2010: Delivering a Sustainable Future. Murray-Darling Basin Commission, Canberra.