Sustaining Healthy Rivers with Climate Change: Murray-Darling Basin

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Overview

• State of the Basin
• Climate Change Scenarios
• Climate Change:
  - Temperature Increases
  - Water planning/management
  - Irrigated agriculture
• Changing Business as Usual
State of the Basin
Murray Mouth Flows 1963-2009

No flows 1% pre-development, 40% current development
Millennium Drought

40% decline in runoff 1997-2008 in southern MDB
Environmental Impacts

• 20 or 23 river valleys in Basin in poor or very poor health
• Maximum period between floods at least doubled (6 to 29 years for Chowilla Floodplain) and average annual flood volumes one quarter of pre-development conditions along Murray River.
• 80% of river red gums in southern Basin floodplains are in stress or degraded.
• Low or zero flows at Murray Mouth:
  - 1% time pre-development
  - 40% time based on long-term averages (47% median climate change)
  - 80% during Millennium Drought
Climate Change Scenarios
The pattern of water availability

Average Annual Streamflow without Extractions

Source: CSIRO 2008
Median climate change impact

Source: CSIRO 2008
Change in Annual Runoff

Source: CSIRO 2008

1996-2007 climate
Climate Change:
Temperature & Diversions
Surface Water Diversions

Long-term average surface water diversions 11,327 GL/year

Source: CSIRO 2008
Diversions versus Flows

Under 2030 median scenario across Basin:
- 11% fall in mean surface water availability
- 4% fall in extractive use
- 24% fall in end-of-system flows

Source: Young and Chiew 2011
# Changes in Temperature on Daily Flows on Murrumbidgee River 1910-2005

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimated Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.001**</td>
</tr>
<tr>
<td>$\Delta y_{t - 1}$</td>
<td>1.865***</td>
</tr>
<tr>
<td>$\Delta y_{t - 2}$</td>
<td>-1.514***</td>
</tr>
<tr>
<td>$\Delta y_{t - 3}$</td>
<td>0.798***</td>
</tr>
<tr>
<td>$\Delta y_{t - 4}$</td>
<td>-0.196***</td>
</tr>
<tr>
<td>$\Delta y_{t - 365}$</td>
<td>-0.020***</td>
</tr>
<tr>
<td>$d_{1950}$</td>
<td>0.022***</td>
</tr>
<tr>
<td>$d_{1952}$</td>
<td>0.007**</td>
</tr>
<tr>
<td>$d_{1956}$</td>
<td>0.025***</td>
</tr>
<tr>
<td>$d_{1974}$</td>
<td>0.015***</td>
</tr>
<tr>
<td>$\Delta F_t$</td>
<td>-0.004***</td>
</tr>
</tbody>
</table>
Temperature and Flows

- Based on Murrumbidgee model of daily water flow that separates trend from drought, we project a one degree Celsius increase in temperature will reduce water flow by 842 GL (based on average flow) or about 20% of current long-term average flow.

- Estimate for MDB are that:
  - +1 Celsius reduces run off by 13%
  - +2 Celsius reduces run off by 38%
  - +3 Celsius reduces run off by 63%

- Decadal increase in temperature of 0.2-0.3 °C since 1960
Murrumbidgee Inflows, Outflows & Extractions

ML

- Inflow
- Outflow
- Irrigation

## Murray River: Annual Diversions

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Net Inflows (GL)</td>
<td>7,928</td>
<td>12,822</td>
<td>9,181</td>
<td>9,932</td>
<td>4,449</td>
</tr>
<tr>
<td>Diversions (GL)</td>
<td>3,119</td>
<td>3,465</td>
<td>4,025</td>
<td>4,351</td>
<td>3,368</td>
</tr>
<tr>
<td>Diverted (%)</td>
<td>39%</td>
<td>27%</td>
<td>44%</td>
<td>44%</td>
<td>76%</td>
</tr>
</tbody>
</table>

Upstream consumption has **reduced** mean annual streamflow by 61%. Annual streamflow at Murray Mouth is 16% river inflows.
Climate Change: Irrigation
# 2030 Climate Change Effects Relative to Long-term Average, Irrigation

<table>
<thead>
<tr>
<th>Murray-Darling Basin</th>
<th>Median 2030 Scenario</th>
<th>1997-2006 Climate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Use Change (%)</td>
<td>-4%</td>
<td>-13%</td>
</tr>
<tr>
<td>Land Use Change (%)</td>
<td>-5%</td>
<td>-10%</td>
</tr>
<tr>
<td>Profit Change (%)</td>
<td>-1%</td>
<td>-5% (7% with NO regional trade)</td>
</tr>
</tbody>
</table>
Water Planning, Climate Change & End-of-System Flows

**Scenario one**: 30% reduction in inflows and water planning rules remain unchanged
- 63% reduction in flows at lower lakes
- 16% reduction in water use

**Scenario two**: 30% reduction in inflows but equi-proportional reduction to extractions and environmental flows
- 47% reduction in flows at lower lakes

Value added in irrigation **falls by 3%** in scenario two versus scenario one.
## Actual GVIAP Changes

<table>
<thead>
<tr>
<th>Year</th>
<th>Surface Water Use (GL)</th>
<th>GVIAP ($ millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-01</td>
<td>10,514</td>
<td>5,085.4</td>
</tr>
<tr>
<td>2007-08</td>
<td>3,142</td>
<td>5,078.9</td>
</tr>
</tbody>
</table>

Source: Australian Bureau of Statistics 2010
Findings

(1) Under normal inflows the reduction in net profits would be much less than the decline in extractions;

(2) Under climate change, a policy response that ensures the environment and irrigated surface water extractions decline by the same proportion has only a small effect on value added in irrigated agriculture relative to the case where the environment bears most of the reduction in inflows.
Changing Business as Usual
Dynamic Tradeoffs

\[
\pi(L, e, i) = \frac{\varepsilon \gamma}{1 - \varepsilon} i^{1-\varepsilon} - \alpha \times \max(L, 0)^\beta
\]

- State (+ or -)
- Env. releases
- Diversions
- Elasticity
- Environmental cost coefficient
- Environmental elasticity
Optimal Environmental Releases

![Graph showing TL over time for dry and normal years.](image)
Gain Optimal \emph{versus} Actual Allocations: Murray River 2002-2009

\begin{align*}
  a & = 20 \text{ yr}, \quad b = 30 \text{ yr} \\
  $0.620 \text{ billion}$ \\
  \hline
  a & = 15, \quad b = 25 \\
  $1.71 \text{ billion}$ \\
  \hline
  a & = 12, \quad b = 20 \\
  $2.67 \text{ billion}$ \\
  \hline
  a & = 10, \quad b = 15 \\
  $3.52 \text{ billion}$
\end{align*}

\begin{itemize}
  \item $a$ = Number of years until environmental costs of drought add up to 50\% of PV of net profits in irrigated agriculture.
  \item $b$ = Number of years until environmental costs of drought add up to 100\% of PV of net present in irrigated agriculture.
\end{itemize}
Concluding Remarks

Sustaining healthy rivers can be achieved at relatively small cost. A minimum requires that:

(1) Water extractions, on average, do not exceed the flows required to ensure the sustainability of key environmental assets mitigate effects of climate change;

(2) Water users have appropriate economic incentives to be water use efficient; and

(3) Water planning must account for variability of inflows and climate change and the trade-offs across competing uses (extractions and *in-situ*).