Towards Achieving Water Security in a Changing World

Presented at International Water Resource Economics Consortium
World Bank, Washington DC
12 September 2016
Quentin Grafton

Email: quentin.grafton@anu.edu.au
Overview

(1) Water Security versus Water Scarcity
(2) Trends and projections
(3) Demand-based responses
(4) Supply-based responses
(5) Environmental water
(6) Concluding remarks
(1) Water Security and Water Scarcity
## Dimensions of Water

<table>
<thead>
<tr>
<th>Rivalry</th>
<th>Excludable</th>
<th>Less or not excludable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Good</td>
<td>(bottled water)</td>
<td>Common-pool Resource</td>
</tr>
<tr>
<td>(aquifer, water in stream)</td>
<td></td>
<td>(aquifer, water in stream)</td>
</tr>
<tr>
<td>Club Good</td>
<td>(community irrigation)</td>
<td>Public Good</td>
</tr>
<tr>
<td>(flood control)</td>
<td></td>
<td>(flood control)</td>
</tr>
</tbody>
</table>
Physical Measures of Water Scarcity

(1) ‘Water Stress Index’ or Falkenmark Indicator:
If less than 1,700 Cu.M/capita then experiencing water stress
If less than 1,000 Cu.M/capita then experiencing water scarcity

(2) OECD Criticality Ratio based on ratio of freshwater withdrawals to annual water availability:
10% water stress is low
10-20% water stress is moderate
40% < water stress is severe

(3) IWMI’s with **economically water scarce** (unable to meet future demands in the absence of investments) and **physically water scarce** (unable to meet future demands even with investments)
Groundwater Footprint
Economic Measure of Water Scarcity

![Graph showing water supply and demand with MB $ on the Y-axis and Water Supply on the X-axis.]

- Water Demand
- MB $:
  - a
  - b
  - c

- Water Supply

The graph illustrates the economic measure of water scarcity, with the blue lines representing the demand curve and the red lines representing the supply curve. The points a, b, and c indicate different levels of water scarcity or abundance.
Water Security Elements

- **Good Governance**: Adequate legal regimes, institutions, infrastructure, and capacity are in place.
- **Economic Activities and Development**: Adequate water supplies are available for food and energy production, industry, transport, and tourism.
- **Transboundary Cooperation**: Sovereign states discuss and coordinate their actions to meet the varied and sometimes competing interests for mutual benefit.
- **Drinking Water and Human Well-Being**: Populations have access to safe, sufficient, and affordable water to meet basic needs for drinking, sanitation and hygiene, to safeguard health and well-being, and to fulfill basic human rights.
- **Ecosystems**: Ecosystems are preserved and can deliver their services, on which both nature and people rely, including the provision of freshwater.
- **Water-Related Hazards and Climate Change**: Populations are resilient to water-related hazards including floods, droughts, and pollution.
- **Financing**: Innovative sources of financing complement funding by the public sector, including investments from the private sector and micro-financing schemes.
- **Peace and Political Stability**: The negative effects of conflicts are avoided, including reduced water quality and/or quantity, compromised water infrastructure, human resources, related governance, and social or political systems.
“The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution, and water-related disasters, and for preserving ecosystems in a climate of peace and political stability.”

UN-Water (2013)
Global Risks: Next 10 Years

For the next 10 years

<table>
<thead>
<tr>
<th>Risk</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water crises</td>
<td>39.8%</td>
</tr>
<tr>
<td>Failure of climate-change mitigation and adaptation</td>
<td>36.7%</td>
</tr>
<tr>
<td>Extreme weather events</td>
<td>26.5%</td>
</tr>
<tr>
<td>Food crises</td>
<td>25.2%</td>
</tr>
<tr>
<td>Profound social instability</td>
<td>23.3%</td>
</tr>
</tbody>
</table>
## Water Security Risks

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hazard</strong></td>
<td>Water-related phenomena with potential to cause harm</td>
</tr>
<tr>
<td><strong>Exposure</strong></td>
<td>The people or assets that are in harm’s way</td>
</tr>
<tr>
<td><strong>Vulnerability</strong></td>
<td>The susceptibility to incur loss, should a hazard materialize</td>
</tr>
<tr>
<td><strong>Adaptation responses</strong></td>
<td>The steps that have been taken to reduce risk</td>
</tr>
<tr>
<td><strong>Impacts</strong></td>
<td>The actual losses that have occurred (realised risk)</td>
</tr>
</tbody>
</table>

- **Droughts and water scarcity**
- **Floods**
- **Water supply and sanitation**
- **Environmental impacts**
Responding to Risks
Food Security
Food and Water Security
(2) Trends and Projections
Chronic Water Shortages

2050: Probability number of people with chronic water shortage increasing by more than 10%

2100: Probability number of people with chronic water shortage increasing by more than 10%
Climate Change and Water Stress in 2050
Exposure to River Flooding in 2050
Water Scarcity and GDP in 2050
(3) Demand-based Responses
Pricing Water

(1) Market price:
- Who trades? What is traded? How is it traded?

(2) Regulated price:

**Efficiency**
- First Best (MB = LRMC)
- Second Best (Coasian and Ramsey pricing)
- Dynamic (scarcity) pricing

**Equity** (across current users and over time)

Versus
- Price Cap (UK),
- Cost of Service (most countries)
Market Prices and Water Supply ($/ML)
### Dynamic Volumetric Pricing in Sydney

<table>
<thead>
<tr>
<th>Elasticity</th>
<th>60% (in %)</th>
<th>55% (in %)</th>
<th>50% (in %)</th>
<th>45% (in %)</th>
<th>40% (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.536</td>
<td>67.96</td>
<td>47.01</td>
<td>29.83</td>
<td>15.55</td>
<td>3.56</td>
</tr>
<tr>
<td>-0.446</td>
<td>86.95</td>
<td>59.11</td>
<td>36.89</td>
<td>18.89</td>
<td>4.12</td>
</tr>
<tr>
<td>-0.352</td>
<td>120.32</td>
<td>79.64</td>
<td>48.48</td>
<td>24.21</td>
<td>5.00</td>
</tr>
<tr>
<td>-0.258</td>
<td>192.59</td>
<td>121.52</td>
<td>70.88</td>
<td>33.78</td>
<td>6.57</td>
</tr>
<tr>
<td>-0.165</td>
<td>436.90</td>
<td>246.96</td>
<td>130.85</td>
<td>57.58</td>
<td>10.03</td>
</tr>
</tbody>
</table>
Costs by Water Source (47 countries, 93 places)
Volumetric Water Costs to Consumers
(4) Supply-based responses
Infrastructure and Water Risks

Storage per capita, institutional capacity vs. CV of monthly runoff.
Optimal Time to Invest

Lifetime of the augmented water supply

Premature Net Loss =

Annual Benefit

Annual Cost

$
Optimal Supply Augmentation in Sydney
(5) Environmental Water
Net Benefits of Water Reallocation

Graph showing the relationship between drought cost to the environment, price for irrigation water, and irrigation net profit. The graph illustrates how different flood conditions (moderate and big floods) affect the time from the previous flood and the net profit from current irrigation diversion and volume.
Gain Optimal *versus* Actual Allocations: Murray River 2002-2009

\[
\begin{align*}
&a = 20 \text{ yr}, \ b = 30 \text{ yr} \\
&$0.620 \text{ billion}
\end{align*}
\]

\[
\begin{align*}
&a = 15, \ b = 25 \\
&$1.71 \text{ billion}
\end{align*}
\]

\[
\begin{align*}
&a = 12, \ b = 20 \\
&$2.67 \text{ billion}
\end{align*}
\]

\[
\begin{align*}
&a = 10, \ b = 15 \\
&$3.52 \text{ billion}
\end{align*}
\]

Increasing environmental costs

\[\text{a} = \text{Number of years until environmental costs of drought add up to 50\% of PV of net profits in irrigated agriculture.} \]

\[\text{b} = \text{Number of years until environmental costs of drought add up to 100\% of PV of net present in irrigated agriculture.}\]
Valuing Stream Flows

**Step 1. Hydro-ecological modelling**
- Climate sequence and river management scenarios
- IQQM hydrology model
  - Daily time-series of river flow and inundation area
- IBIS DSS
  - Definition of flood events
    - Flood duration
    - Flood depth
    - Flood timing
  - Interflood dry period
  - Rate of fall
- Ecological response models (habitat suitability)
- Change in habitat suitability from baseline to alternate watering regimes

**Step 2. Stated preference valuation**
- Choice experiment
- Value transfer
- Primary survey
- Willingness to pay for ecological attributes (Economic value of a unit change of an ecological attribute)

**Step 3. Integration**
- Marginal value of water (Economic value of an additional unit of water)
Benefits of Increased Stream Flows
Marginal Benefit and Costs of Environmental Flows

- \( MB_U(\lambda=0) \)
- \( MB_L(\lambda=0) \)

- Entitlement Price

Price (mn AUS/GL) vs. Year (2007-08 to 2012-13)
Concluding Remarks

Many ‘dollars on the sidewalk’ (multiple of billions) that can be picked up if used:

(1) Efficient (and equitable) pricing
(2) Efficient (and equitable) supply augmentation
(3) Economic valuation to consider trade-offs

BUT can only realized if systematically overcome:
- ‘institutional constraints’ whereby decision makers are ill or poorly informed (need for better measurement, tools and also risk processes)
- vested interests ‘trump’ the public good (need greater transparency on benefits and costs and citizen engagement).
References


King D., D. Schrag, Z. Dadi, Q. Ye and A. Ghosh. Climate Change A Risk Assessment, Centre for Science and Policy, University of Cambridge.

Palmer, M.A et al. Climate change and the world’s river basins. Frontiers in Ecology and the Environment

