Optimizing Water-Energy Nexus for Sustainable Development

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Water Use Distribution

TOP 7 GLOBAL WATER CONSUMERS

1. INDIA 13%
2. CHINA 12%
3. UNITED STATES 9%
4. RUSSIA 4%
5. INDONESIA 4%
6. NIGERIA 3%
7. BRAZIL 3%

Rest of world 52%
Millennium Drought

Rainfall Deciles (AWA grids 1900-pres.)
1 November 2001 to 31 October 2009
Distribution Based on Gridded Data

https://www.bom.gov.au

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ID code: IMap/AWA/Deciles
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Drought Continues...

Rainfall Deficiencies: 30 months
1 October 2012 to 31 March 2015
Distribution Based on Gridded Data
Australian Bureau of Meteorology

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Murray-Darling Basin

- Over one million Sq. kilometre area
- Covers 14% of country’s area over 5 states
- 20 major rivers
- Only 6% of annual rainfall (165mm/year)
- 40% of country’s agricultural production
- 70% comes from irrigation
Salinity and Drainage Strategy (1989)
- In the mid-1980s more than 96,000 hectares of irrigated land in the Basin were showing visible signs of salinisation.
- It was estimated that the irrigation areas affected by high water tables could increase from 559,000 hectares in 1985 to 869,000 hectares in 2015.
- Increase in river salinity largely due to contributions from an increase in groundwater mounds under irrigation areas, and surface and sub-surface drainage from the high water table areas.
- Each State responsible for actions significantly affecting river salinity taken within its jurisdiction.
- Introduction of salinity register to maintain salinity credits/debits.
Cap (1997)

- Limit on the volume of water that could be diverted from the rivers in the basin for consumptive use (mainly irrigation) from 1997 after realizing that ongoing increase in consumptive use of water in the Murray-Darling Basin (MDB) was environmentally and socially unsustainable.
- This limit is called the cap and effectively limits the volume of water diversions to 1993/94 development level.
- No additional water could be diverted from the river for new developments.
- Positive outcomes:
  - River health,
  - impetus for water saving by improvement in water use efficiency, and water trading.
  - The improvement in irrigation efficiency helped control rising watertable in inefficiently irrigated areas
  - Made water available for new irrigation developments and
  - Water trading provided a market mechanism to temporarily shift water from low value to high value use.
- Discrepancies in Cap implementation and monitoring

- Agreed in 2004
- Under NWI, governments have made commitments to:
  - prepare comprehensive water plans
  - achieve sustainable water use in over-allocated or stressed water systems
  - introduce registers of water rights and standards for water accounting
  - expand trade in water rights
  - better manage urban water demands.

- 10 year 10 billion water for future program
- Federal government given more regulatory power to reform the Murray-Darling basin.
- Water charge and water market rules functions given to the Australian Competition and Consumer Commission.
- Functions in relation to water information given to the Bureau of Meteorology.
- Established Murray-Darling Basin Authority.
  - Responsible for overseeing water resource planning in the Basin
  - Basin Plan
Resent Policy Initiatives (cont’d)

- Water Act 2007 (2007) cont’d...
  - Basin plan
    - Sustainable diversions limit
    - Buyback
    - Supply measures
    - Efficiency measures
  - Water Trading
    - Improved market mechanism and transparency
  - Established the Commonwealth Environmental Water Holder
    - Manages Commonwealth’s environmental water portfolio.
Water Trading

- Water is a tradable commodity and has an economic value.
- One of the driving factors behind the trend for water use efficiency improvement.
- Institutional reforms:
  - creating water markets and regulatory framework
  - decoupling water and land property rights, and
  - allowing water to flow from low value uses to high value use with minimum of transaction costs.
- Water trade price has been as high as $1,062/ML during drought periods.
- The average water trade price from 2005-06 to 2010-11 in MIA: $271/ML
- Tradeoffs between water trading and environmental and equity goals.
Murrumbidgee Irrigation Area

- Total irrigated area: 3,624 sq. km
- Total surface water use for irrigation: 1,250 GL
- 8% of the area is covered by horticultural crops
- Average rainfall: 530 mm/year
- Average potential evapotranspiration is 1000 mm/year
Murrumbidgee Irrigation Area
- Over 3500 km of irrigation supply channels
- Only 250 km are lined and 100 km are piped
- Seepage loss as high as 20 mm/day
Irrigation Technology Adoption

- Shift in irrigation systems in MIA (% of total irrigated area)

![Pie chart showing irrigation technology adoption in 2003 and 2009.]

- In 2003:
  - 91.2% Drip
  - 0.7% Surface
  - 2.3% Fixed overhead sprinkler
  - 5.6% Moveable spray

- In 2009:
  - 52.9% Drip
  - 23.2% Spray
  - 17.2% Low head
  - 3.5% Furrow
  - 2.0% Sprinkler
  - 0.9% Overhead
  - 0.3% Travelling irrigator
An unintended consequence of technology adoption to achieve improved water use efficiency is the significant increase in energy use and energy cost and its long-term impacts on climate change.

Energy input in agriculture is directly related to the level of technology adoption and the level of production.
Underlying Objective

- Optimisation of water savings and energy consumption
Representative Area

- Schematic of 13 farm nodes and supply link
- Scenario 1: Furrow – gravity
- Scenario 2: Sprinkler with pressurised irrigation
- Scenario 3: Drip with pressurised irrigation
Node Link Model
Water Availability vs. Water Saving

- Climate_change
- Climate_shift
- Change_in policy_settings

Water_Availability → Water_Trade_Price

Water_Availability → Investment_on_Water

Water_Availability → Saving_Irrigation

Water_Availability → Irrigation_Water_Savings

Irrigation_Water_Savings → Water_savings

Water_savings → Water_savings_per_$_invested

Water_savings → Water_Availability
Water Savings vs. Energy Use

Irrigation_Water Savings

Net_Return from_Saved Water

Pumping Energy_Use

GHG Emissions_Tax

Water_savings per_$_invested

Energy_use_per ML_savings

Emissions_per KWh_energy_use
Water Use (ML/ha)

- Scenario 1
  - Citrus: 10 ML/ha
  - Stone fruit: 8 ML/ha
  - Wine grapes: 7 ML/ha

- Scenario 2
  - Citrus: 8 ML/ha
  - Stone fruit: 7 ML/ha
  - Wine grapes: 6 ML/ha

- Scenario 3
  - Citrus: 6 ML/ha
  - Stone fruit: 6 ML/ha
  - Wine grapes: 5 ML/ha
Scenario 1: Furrow – gravity (labour intensive)
Scenario 2: Sprinkler with pressurised irrigation
Scenario 3: Drip with pressurised irrigation

Energy Use (kWh/ha)
Water Savings Map for Sprinkler

Mia_water_savings_perha_sprinkler.shp
- 3.7 - 4
- 4 - 4.3
- 4.3 - 4.6
- 4.6 - 4.9
- 4.9 - 5.2

Mia_boundary.shp
Water Savings Map for Drip
Water/Energy Use vs Coverage

- Total water use - drip (ML)
- Total water use - sprinkler (ML)
- Total energy use - drip (MWh)
- Total energy use - sprinkler (MWh)
Adaptive management and policy responses to address the evolving water challenges.
Both water and energy have implications on sustainable development of agricultural production systems.
Water and energy use are strongly interlinked in irrigated systems.
Irrigation efficiency should be considered at system scale incorporating technical, economic & environmental aspects.
Need for finding an optimum level of adoption and appropriate mix of technology.
Thank You

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