Ricardo Energy & Environment

Improving Irrigation Systems through Smart Technology

Dr. Mohsin Hafeez
Principal Consultant (Water Management) –Technical Business Manager (Water and Environment)

12th March 2018

Presentation Outline

- Introduction to Ricardo Energy and Environment
- Personal Experience
- Grand Water Management Challenges and Water Reforms Journey in Australia
- Water Management across Multiple Scales (Continental, River and Irrigation System)
- Learnings and Opportunities from Australian Experience
- Case Studies from Selective Countries (Philippines, China & Uzbekistan)
- Issues and Opportunities for Water Management in Asia
- Insight
- Way Forward

Ricardo Energy & Environment: Our Heritage

- **Internationally - renowned consultancy**
- **Heritage of world-leading scientific/technical capability since 1915**
- **Part of Ricardo PLC**

1954
1st UK Sulfur Dioxide and Black Smoke Monitoring Network

1973
1st UK Atmospheric Emissions Inventory

Created UK Renewable Energy R&D Programme

1989
Created UK's Energy Efficiency Best Practice Programme

1994
Created UK's resource efficiency programme – Envirowise

1997
1st UK National Air Quality Strategy

1st UK Greenhouse Gas Inventory

1998
Authority and Negotiator for Industrial Energy Saving Agreements

2002
Developed the UK's Quality Assurance for Combined Heat and Power programme

2004
Advised on UK's National Allocation Plan for the European Union Emissions Trading Scheme (EU ETS) Phase 1

2005
Lead Adviser to European Environment Agency on Air and Climate

2008
China's largest climate adaptation project

Chosen as Key Technical Adviser on UK Carbon Reduction Commitment

2010
Envirowise delivers over £2 billion of savings to industry

2012
Acquired by Ricardo plc

2013
Expert adviser to developing countries on international climate reporting

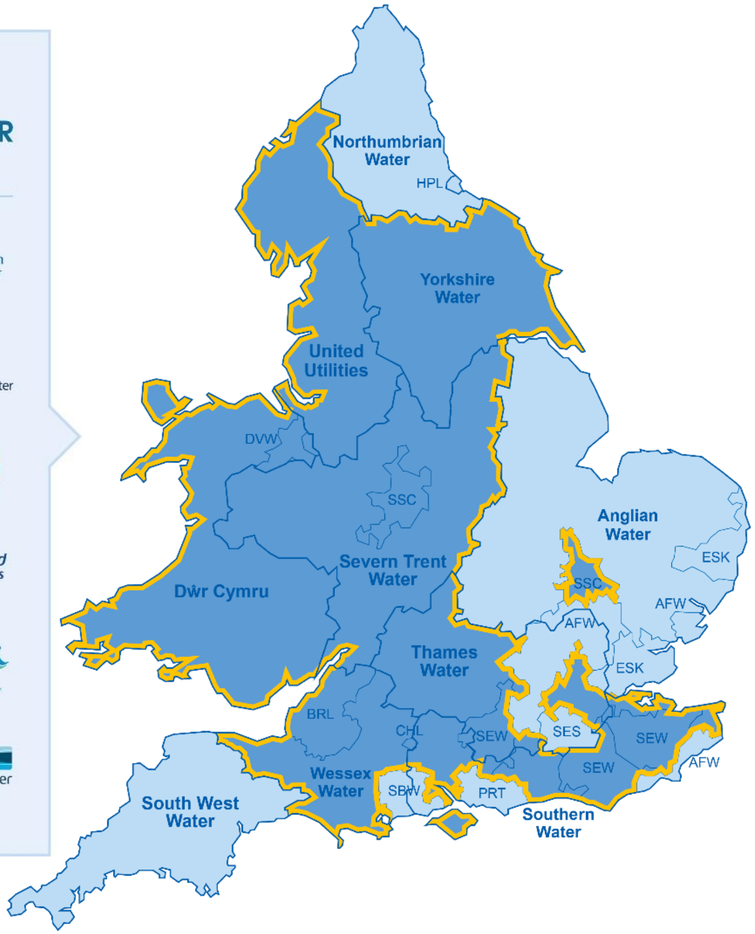
2014
Acquired PPA Energy, providing a valuable extension to the group's energy sector capability

2015
Acquired Cascade Consulting providing additional capability in water, ecosystem services and environmental impact assessment

2017
Supports 14 UK water companies to develop water resource management plans

Ricardo - UK Market Leader in Water Resources Management

We work with most of the major water companies in England & Wales.



Some examples of our Water Resources service offerings



- Water Resources Management Planning
- Water Policy and Strategy Development
- Strategic Environmental Assessment and EIA
- Climate Change Impact on Water Resources
- Water Use Efficiency Strategy & Advice
- Innovation & Strategic Thinking
- Drought Planning
- Water Resources Environmental Assessments

Currently accounts for ~45% of our water & environment practice revenue

Ricardo Supported > 30 ADB Projects across Asia

India

Kolkata Environmental Improvement Investment Program - Solid Waste Management

Azerbaijan

Preparing an Enabling Environment for Private Sector Participation in Azerbaijan's Power Sector Implementation

China

Air Quality Action Plans (AQAP) for cities in China

- Developing Cost-Effective Policies and Investments to Achieve Climate and Air Quality Goals in the Beijing-Tianjin-Hebei Region

AQAP for Chinese Cities Phase 2

- Major study into improving air quality in three cities

Nauru

Technical Assistance to identify the options for increasing the power supply capacity and reliability in Nauru while increasing power generation efficiency

Cambodia

Preparation of the Project Performance Audit Report to the Special Rehabilitation Assistance Project for Cambodia. Responsible for assessing the power and irrigation sectors, including reassessment of the economic analysis

Vietnam

- Establishing the Wholesale Electricity Market 1 Viet Nam Wholesale Electricity Market
- Harmonizing the GMS Power Systems to Facilitate Regional Power Trade
- Investigation and feasibility studies to determine the viability of several prospective small hydropower sites in Lai Chu, Dien Bien, Quang Nam and Hue provinces

Federated States of Micronesia

Defining possibilities for the combination of solar energy technologies with existing diesel power plants so that diesel consumption can be reduced

Personal Experiences Prior to Joining Ricardo

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- Personal Insights
- Way Forward

Grand Challenges of Water Management in Australia

Increased urban demand

Drying and warming climates

Growing irrigation requirements

Over extraction and opportunities with untapped resources and managed aquifer recharge

Expanding plantations

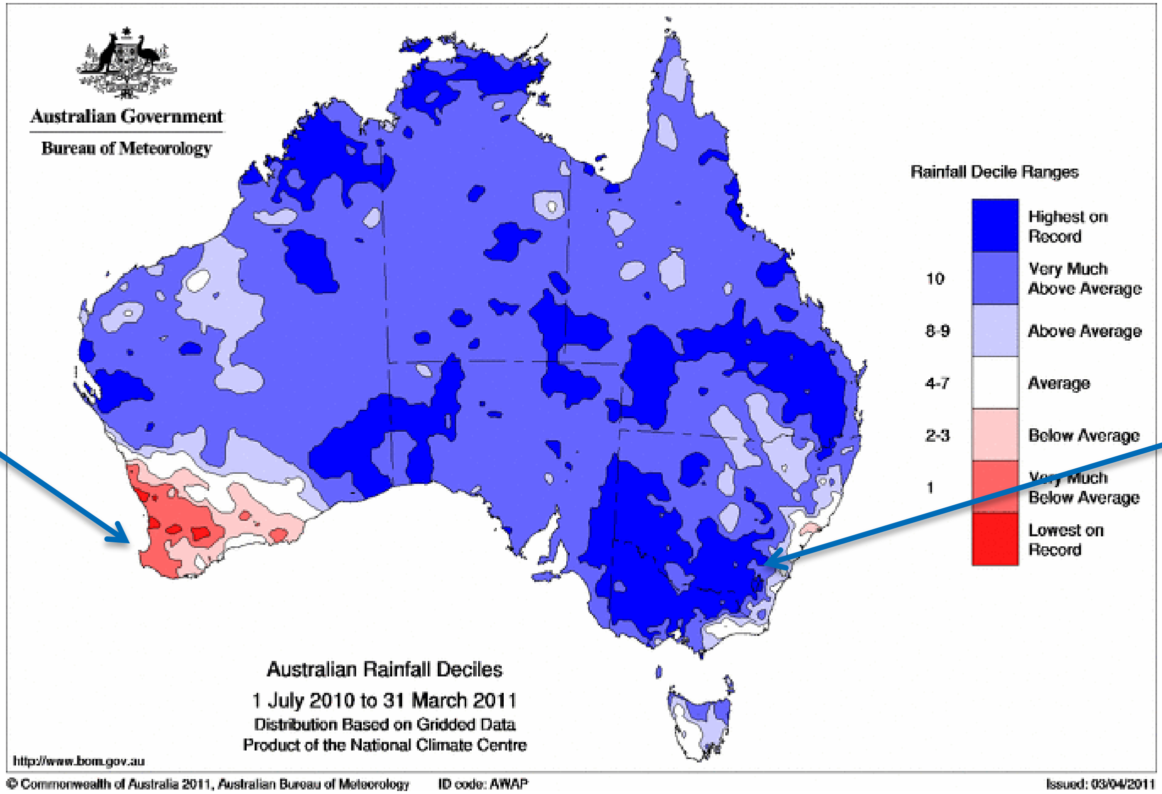
Expanding farm dams

Bushfire recovery

The environmental flows imperative

Managing Water Resources in a Changing Climate

Record dry



Record wet

One of the strongest La Nina events observed (records dating back to the 1800s) produced well above average rainfall – except in Southwest Western Australia.

BoM (2016)

Australia Water Reform Policy Journey

RICARDO

- **Development decades – 1880’s to 1980’s**
- **Water reform Journey from 1980’s**

1984
Victorian Parliamentary Review of water management

1985
MDB Govts endorse Salinity & Drainage strategy

1994
COAG endorses the National Water Reform Framework

1995
Extractions capped in the Murray Darling Basin

2004
MDB Govts endorse 500GL to be returned to environment and invest $500M

Millennium Drought

2004
COAG endorses National Water Initiative Australian Government Water Fund $2 billion

2008
Water Act 2007
Water for Future
- $13B

2012
Murray Darling Basin plan commenced

Ackn: Prof. Jane Doolan (2017)

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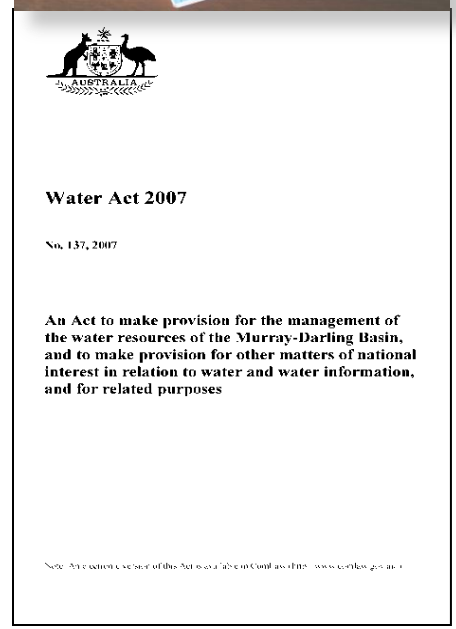
New Bureau Water Information Service – *Water Act 2007*

Water Act 2007

to ***collect, hold, manage, interpret and disseminate*** Australia's water information.


AUSTRALIA

Water Act 2007

No. 137, 2007

An Act to make provision for the management of the water resources of the Murray-Darling Basin, and to make provision for other matters of national interest in relation to water and water information, and for related purposes

The Bureau's NEW responsibilities :

- issuing national water information standards
- collecting and publishing water information
- **conducting regular national water resources assessments**
- **publishing an annual National Water Account**
- providing regular water availability forecasts
- giving advice on matters relating to water information
- enhancing understanding of Australia's water resources.

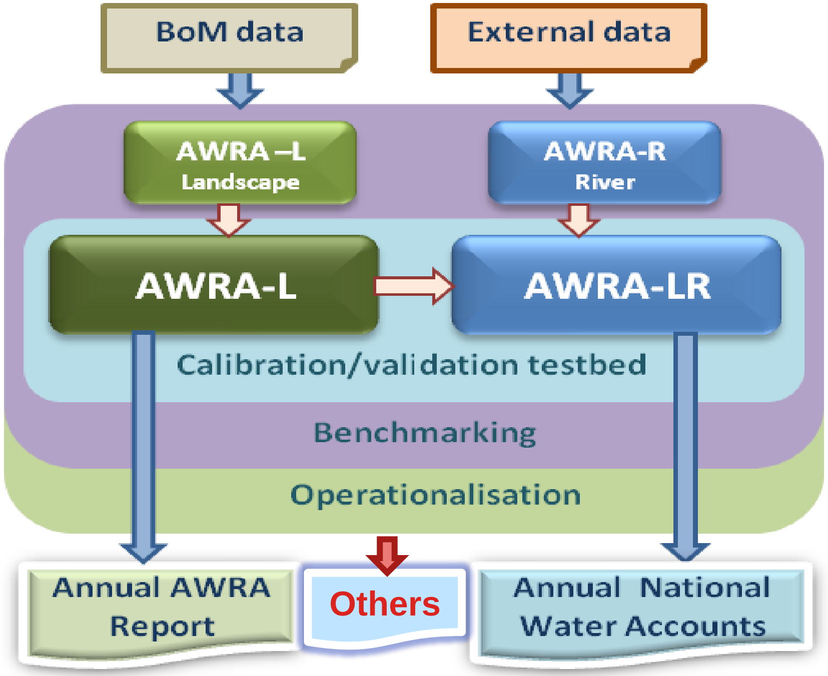
Australian Water Resources Assessment (AWRA) Modelling System –WIRADA (BoM & CSIRO)

Objective:

- To provide seamless water balance information and data for the nation for the past and present, using observations where available, and modelling otherwise.

Outcomes:

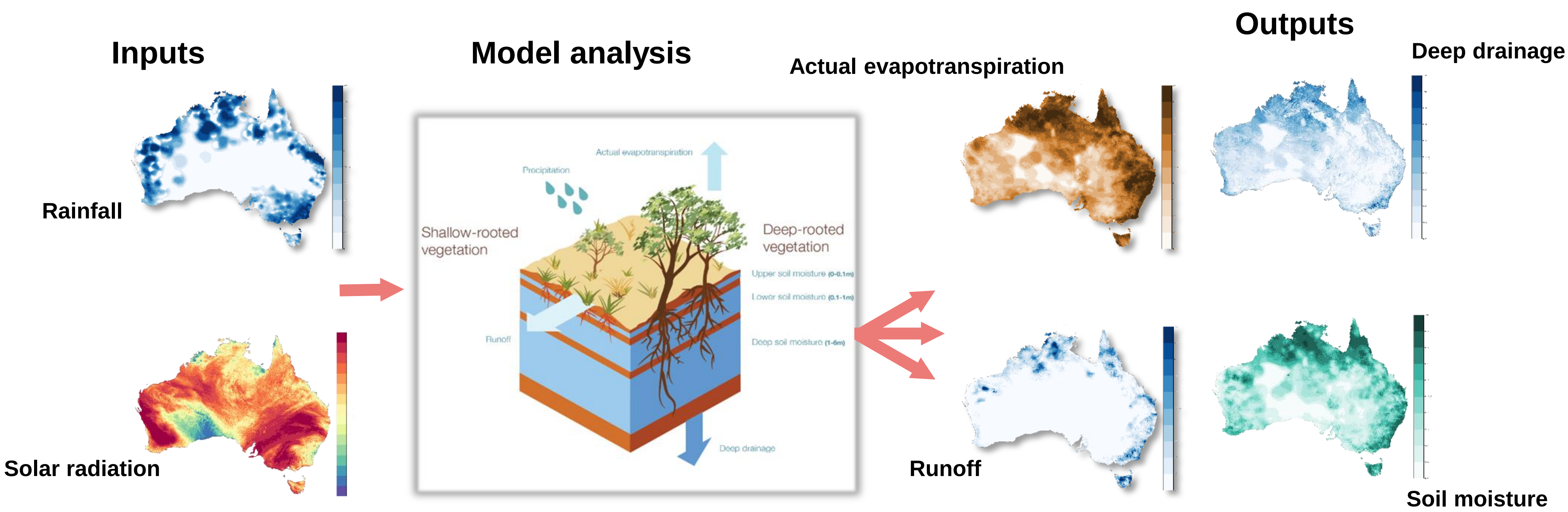
- Consistent, accurate and robust continental and regional scale modelling.



Hafeez et al., (2016)

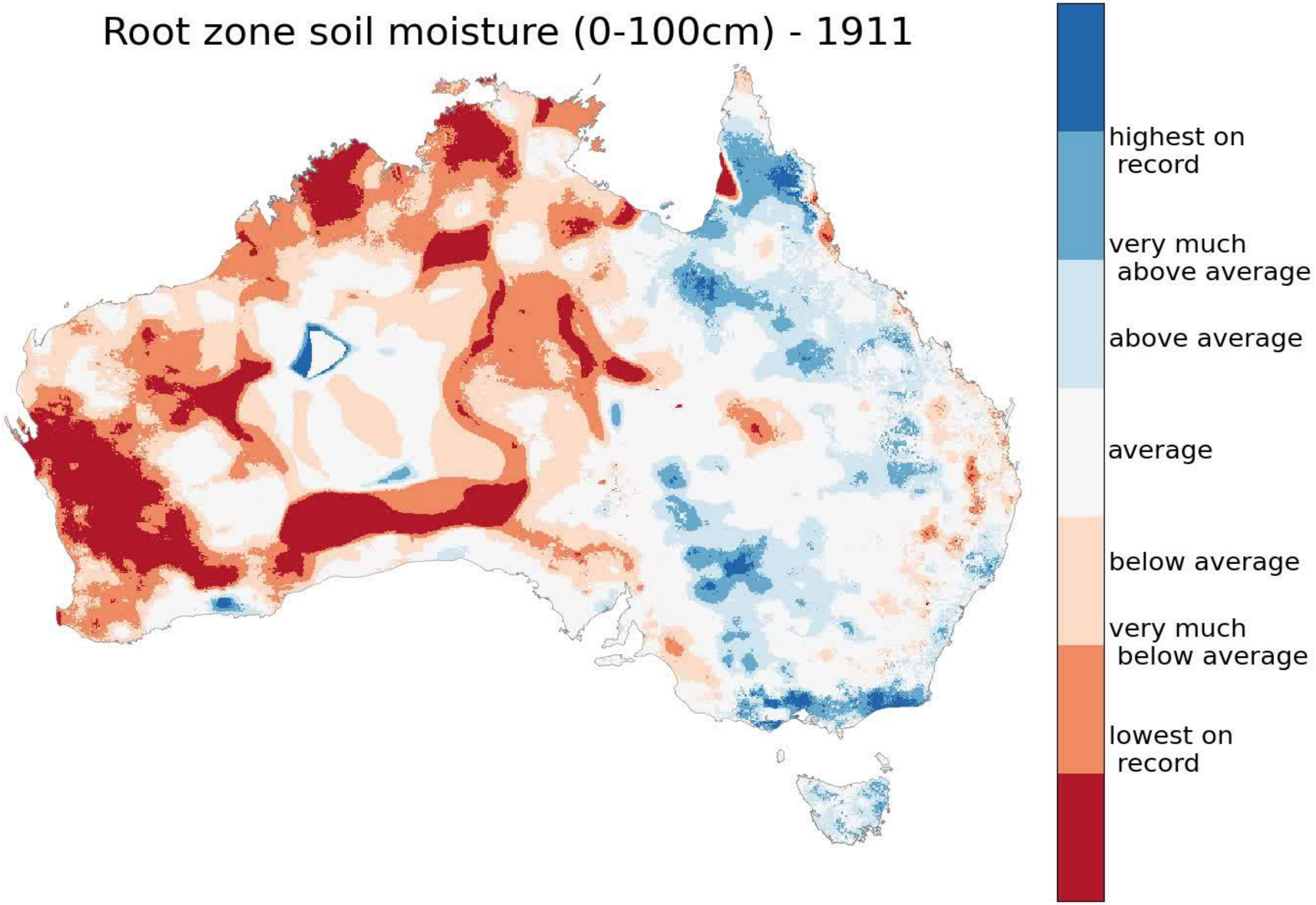
Operational continental landscape water balance model

AWRA-L: national, daily time-step, 5 km resolution



Hafeez et al., (2016)

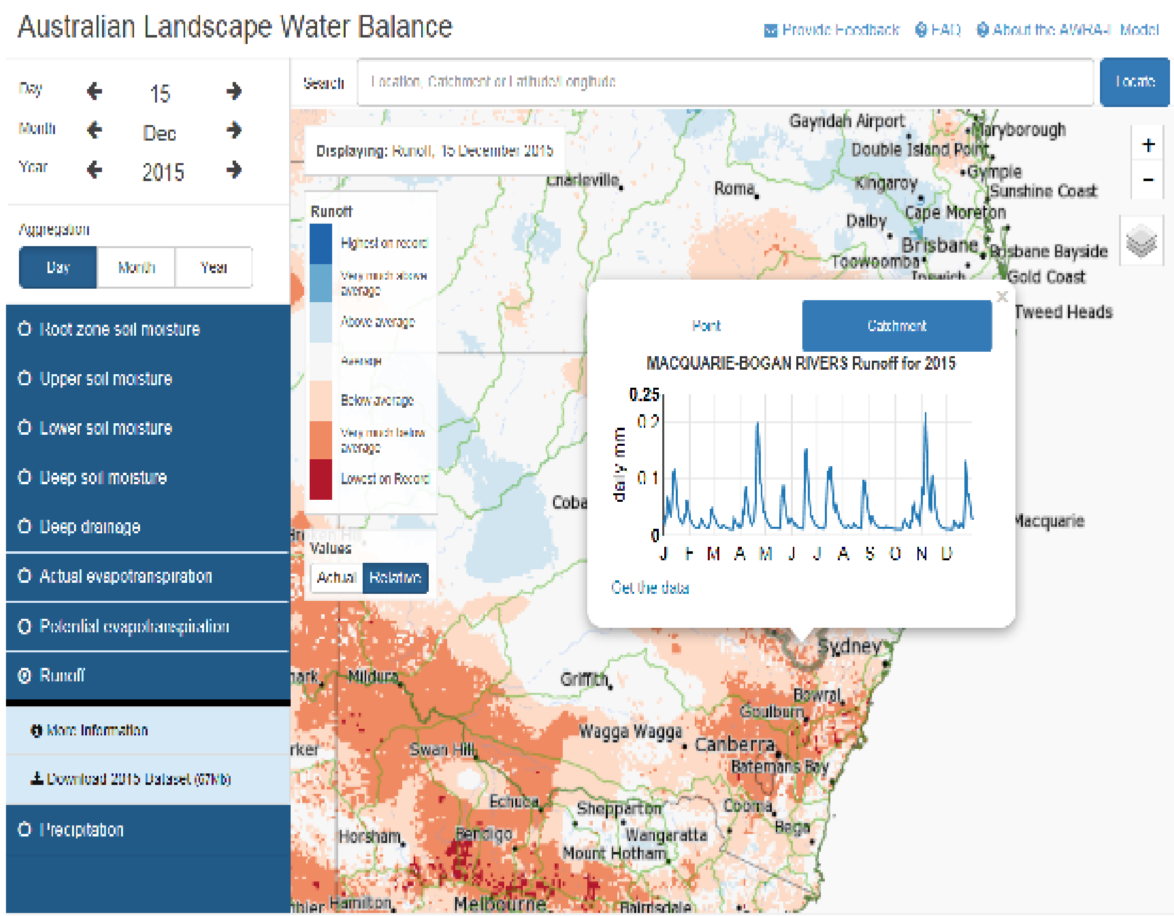
105 year simulation of landscape water balance



Hafeez et al., (2016)

Australian Landscape Water Balance web application

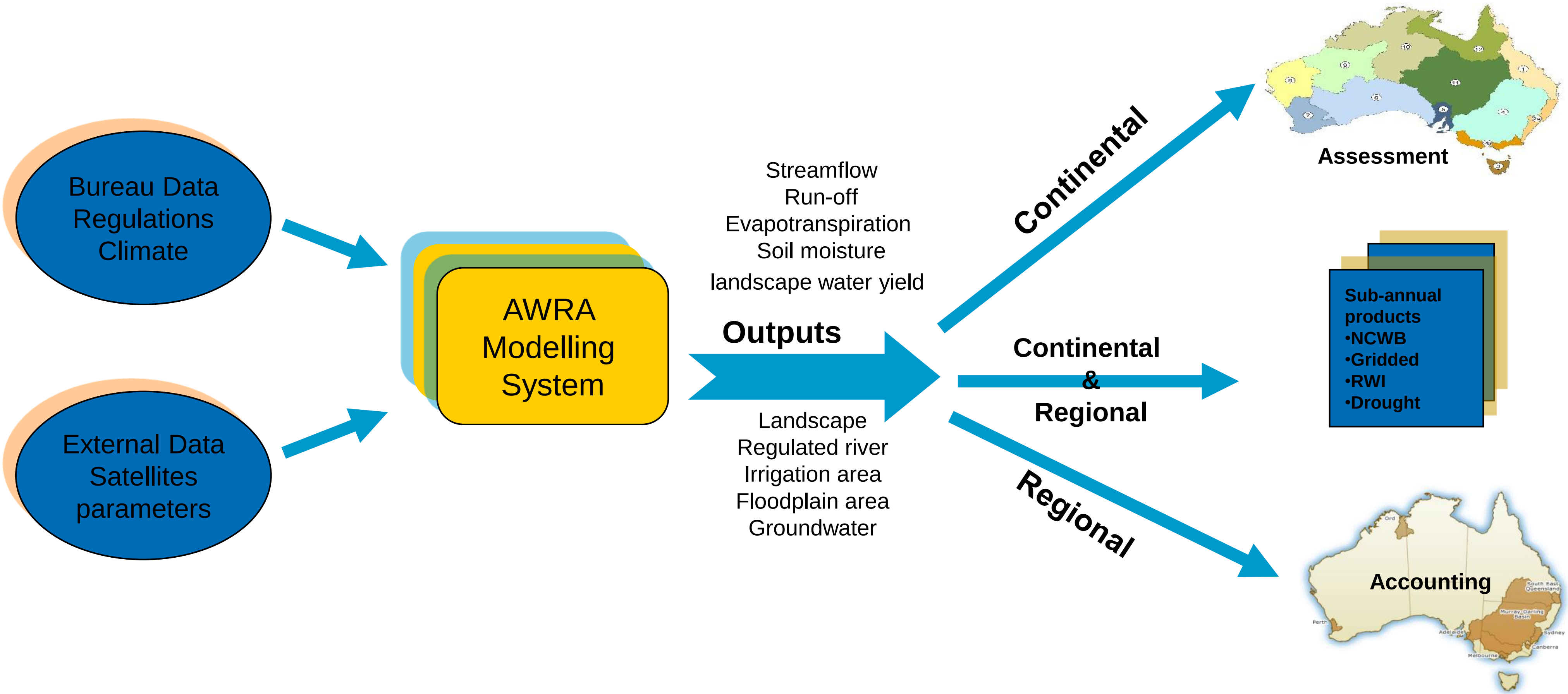
- A unique service!
- Updated daily
- See all variables at daily, monthly or annual time slices
- Download the grids at a resolution of 5km x 5km
- Past 10 years data available to all
- Registered users access >100 years and tailored products



http://www.bom.gov.au/water/landscape

Hafeez et al., (2016)

Applications – Water Resources Management and Water Accounting



Hafeez et al., (2016)

Melbourne Water use of AWRAMS outputs:
Monthly Percentiles at Melbourne Water Storage Level

Impact Pathways

- AWRA-L model provides better water balance fluxes compared with peer hydrology models.
- AWRA-L modelled data outputs has been used for all reporting in water products as well as in national climate and water briefings.
- Agricultural and water stakeholders has been actively using the modelled outputs to make sound water management decisions.
- The AWRAMS has offered incremental improvement to national water resources modelling platform across Australia
- Through release of AWRA-L as a community model, the model has been enhanced significantly through future developments for
  - Water Resources Assessment and Planning community
  - Agriculture and Natural Resources Management community
  - Flood Modelling community
  - Groundwater community

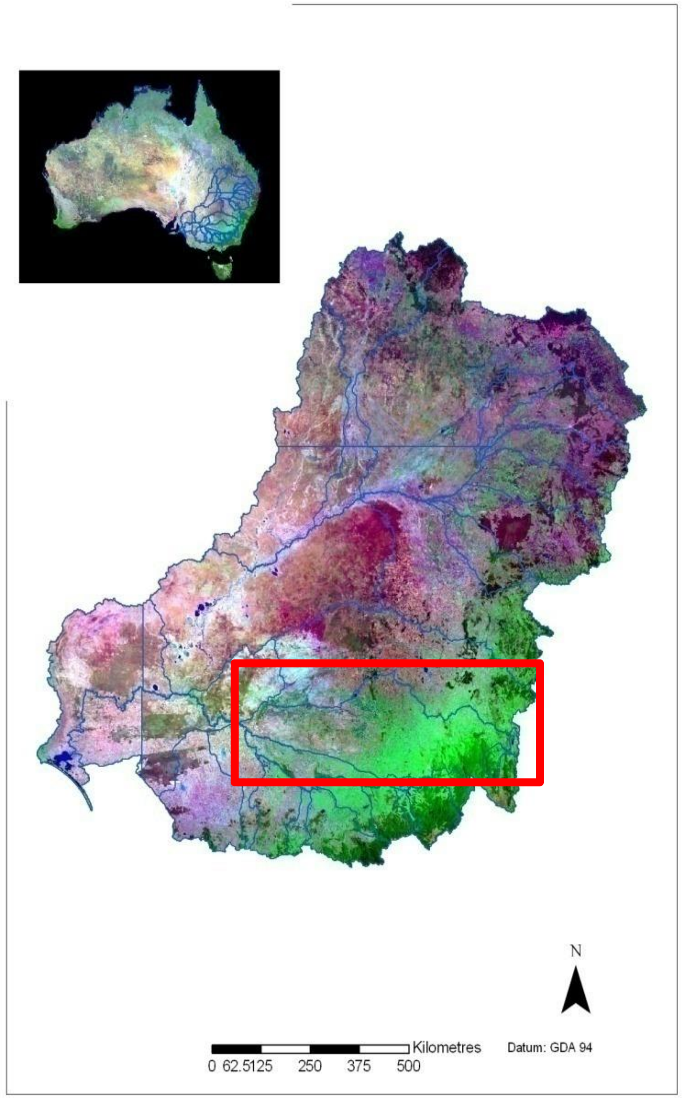
Scientific Recognition

- 2015 AWA ACT Award
- 2016 CSIRO Chairman Gold Medal Award for research innovation in water management
- 2017 Bureau of Meteorology CEO Award

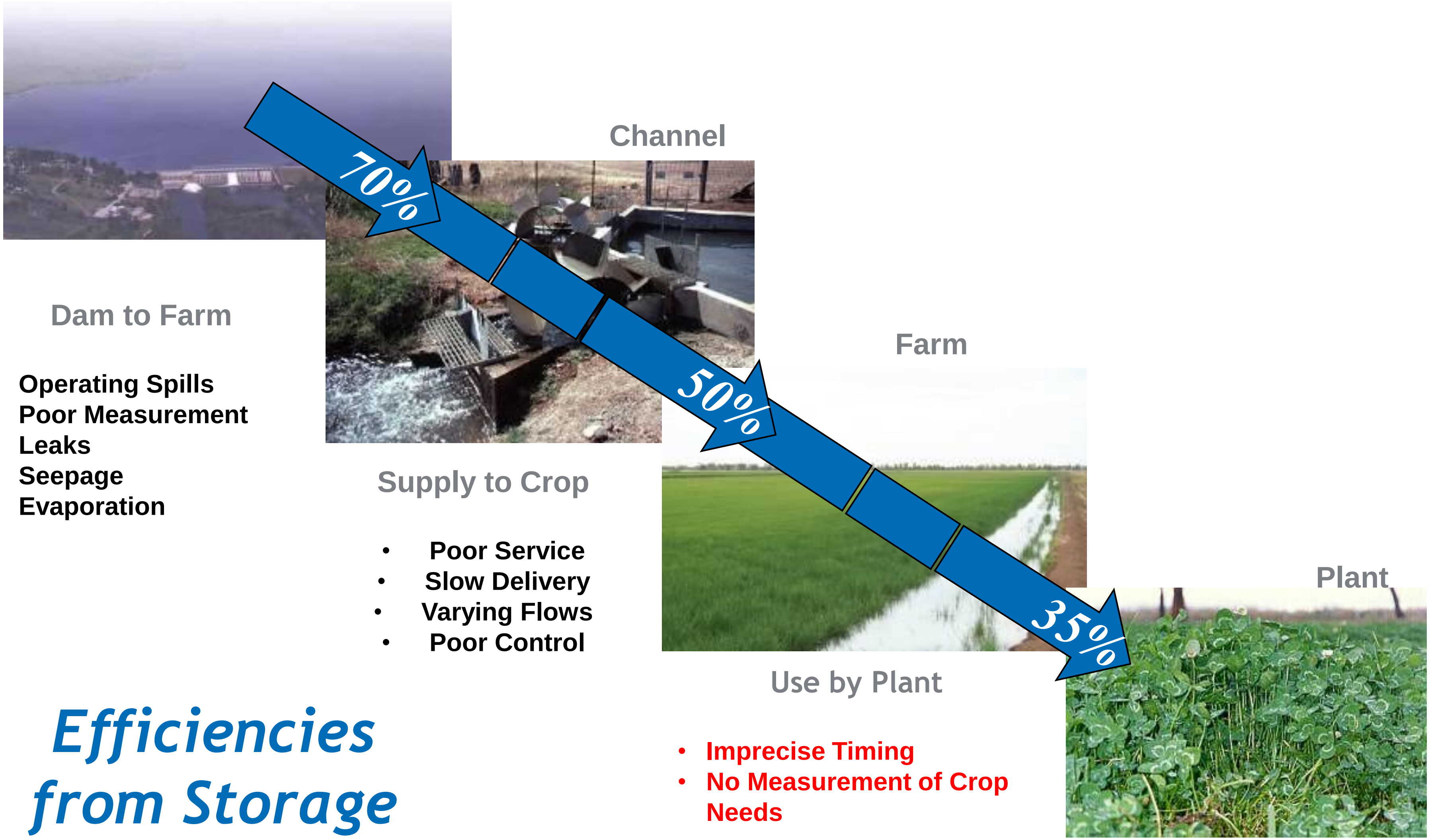
Hafeez et al., (2016)

Irrigation Sector in Australia

- Total irrigated area 2,506,000 ha
- Proportion of Agricultural area < 1%
- Proportion of world irrigation area 1%
- Water diverted 16,660 GL
- Irrigated farm gate revenue $9.6 billion
- Proportion total agriculture production 28%
- Irrigated farm profit/total agricultural profit 51%



Irrigation – a managed Cycle



Dam to Farm

- **Operating Spills**
- **Poor Measurement**
- **Leaks**
- **Seepage**
- **Evaporation**

Supply to Crop

- **Poor Service**
- **Slow Delivery**
- **Varying Flows**
- **Poor Control**

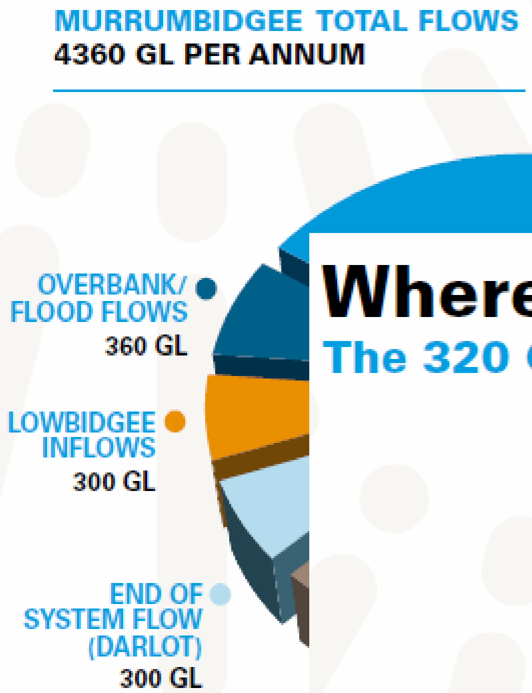
Use by Plant

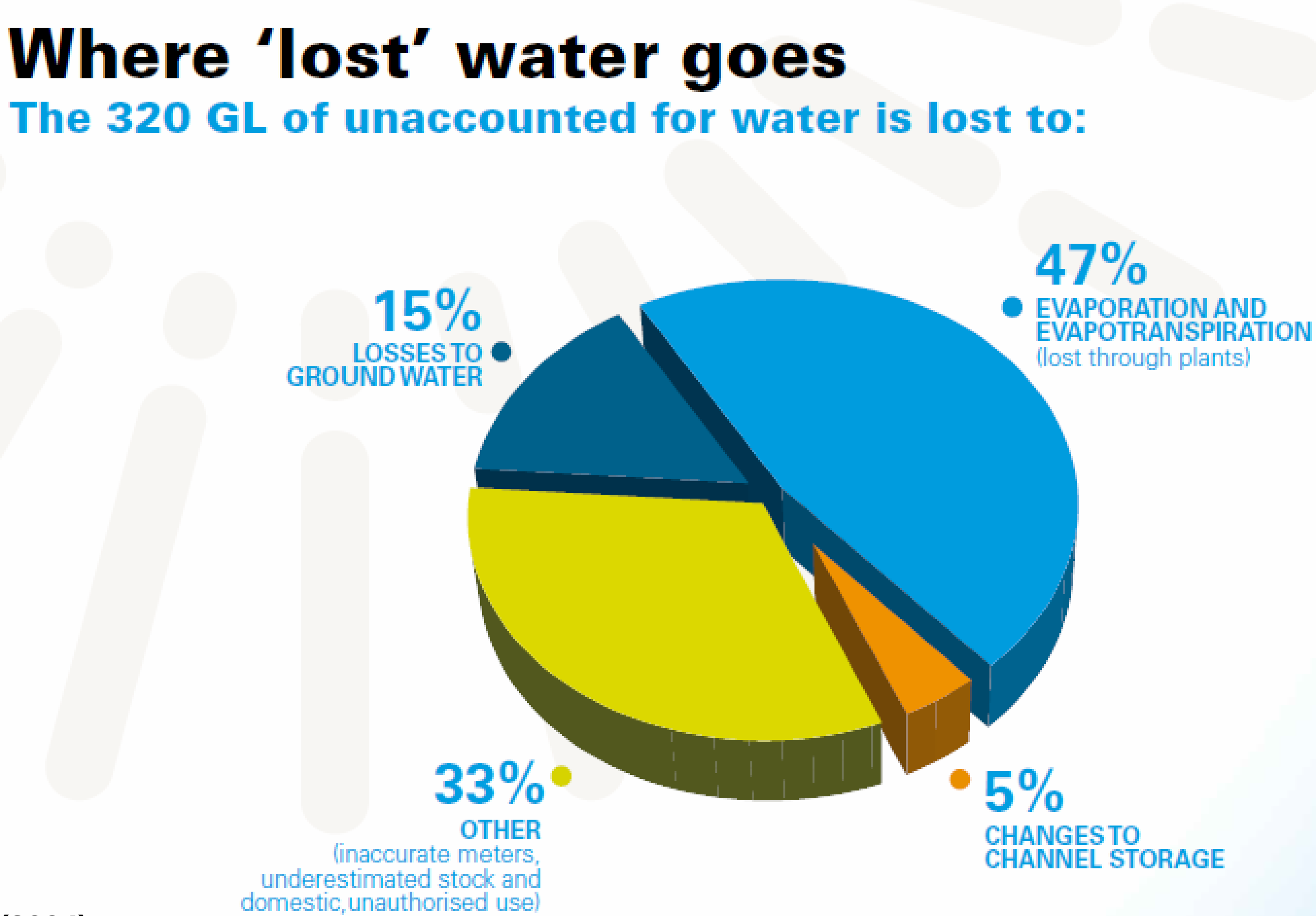
- **Imprecise Timing**
- **No Measurement of Crop Needs**

Efficiencies from Storage

Khan et al., (2004); CSIRO (2004)

Water in the Murrumbidgee system





Khan et al., (2004); Pratt Water (2004)

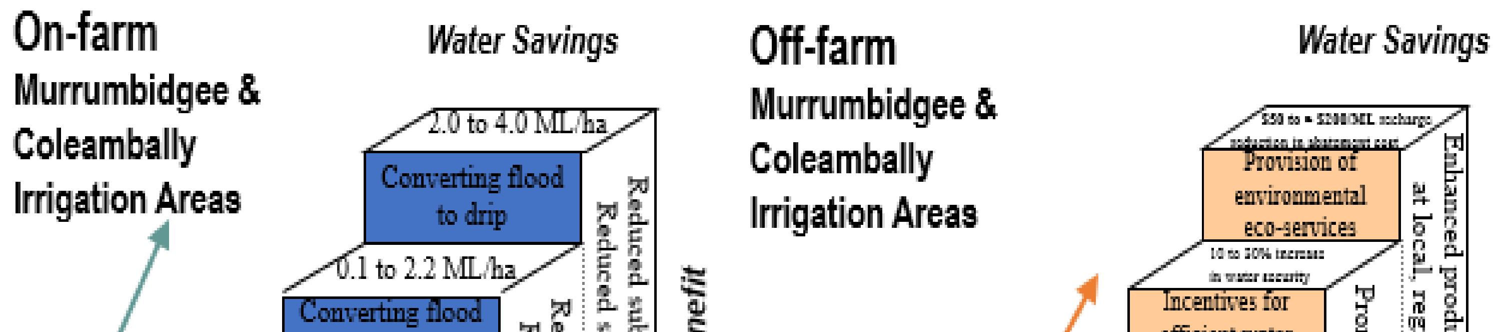
Accounted Water Losses

Component of System	Accounted and Identified for Water Savings (GL)			
	Near-Farm		On-Farm	
	Previous Knowledge	New Assessment	Previous Knowledge	New Assessment
Coleambally Irrigation				
a. Seepage	15	30-45	4-16	4-16
b. Deep percolation			29-41	29-41
c. Evaporation	15	15		
d. Irrigation technology conversion				15-74
Total	**30**	**45-60**	**33-57**	**48-131**

Component of System	Accounted and Identified for Water Savings (GL)			
	Near-Farm		On-Farm	
	Previous Knowledge	New Assessment	Previous Knowledge	New Assessment
Murrumbidgee Irrigation				
a. Seepage	21	42 -63	9-36	9-36
b. Deep percolation			74-101	74-101
c. Evaporation	62	62		
d. Irrigation technology conversion				70-86
Total	**73**	**104-125**	**83-137**	**153-223**

Khan et al., (2004); Pratt Water (2004)

Water Savings in Murrumbidgee Catchment



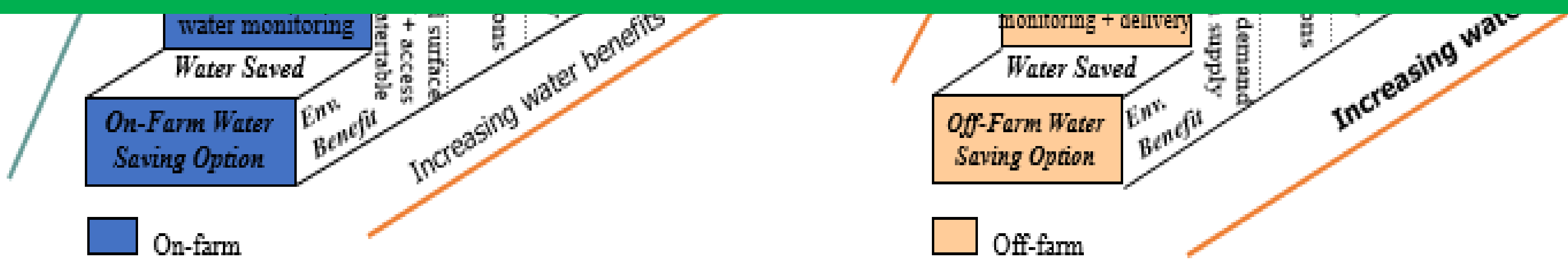
Impact Pathways of Pratt Water Project

Scale : On-farm and off-farm

- **Provided first time assessment on potential water-saving and economic benefits of water-saving by conducting hydro-economic modeling. The modeling results have been extensively used in Australian water policy.**

Scientific Recognition

- **2007 CSIRO Chairman Gold Medal for Research Achievement in Irrigation Management**
- **2007 Land & Water Australia's Eureka Award for Water Research and Innovation "Australian Oscar of Science"**
- **2007 CRC for Irrigation Future award for research innovation in irrigation management**

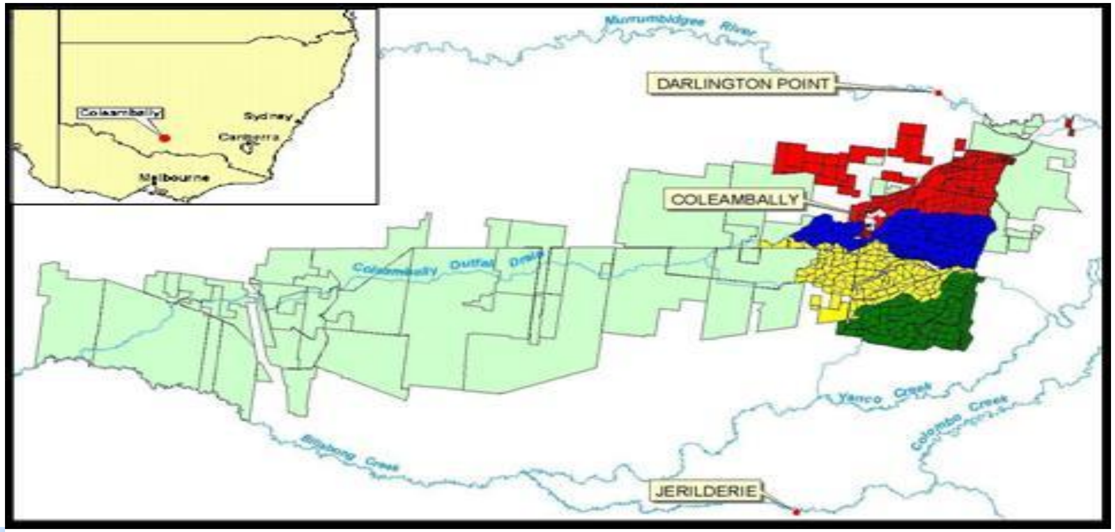


Khan et al., (2004); Pratt Water (2004)

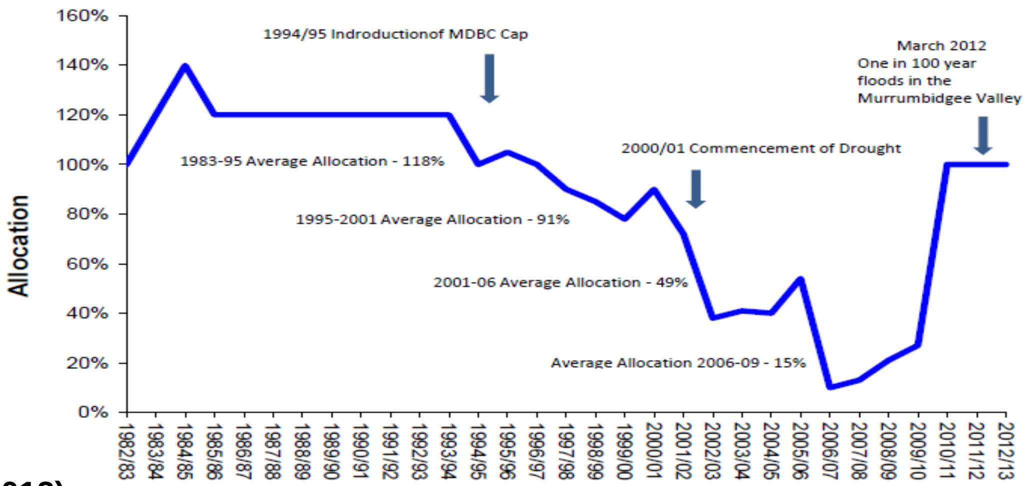
Coleambally Irrigation Area-Near Real Time Irrigation Water Management

Scale: Field, Farm, Sub-irrigation and Irrigation System

- **Built 1950s - 1970s**
- **79,000 ha Irrigated Area**
- **477 Farms**
- **396 mm Rainfall**
- **1800 mm Evaporation**
- **518 km Channels**
- **734 km Drains**
- **Annual Bulk Entitlement ~ 630 GL**



Water Allocation Trends



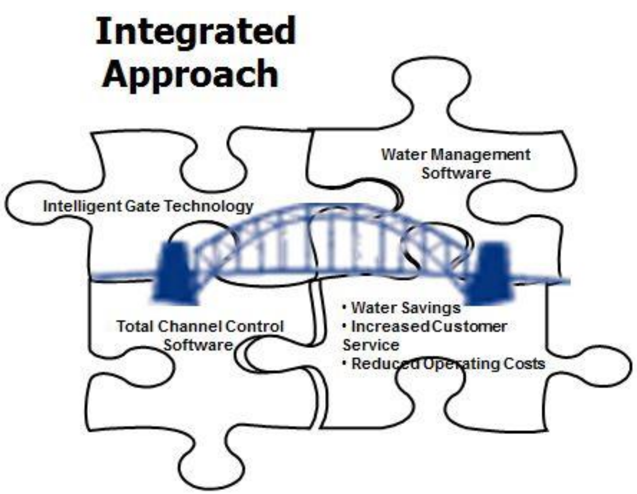
(CICL, 2012)

Irrigation Modernisation

Dethridge Wheel

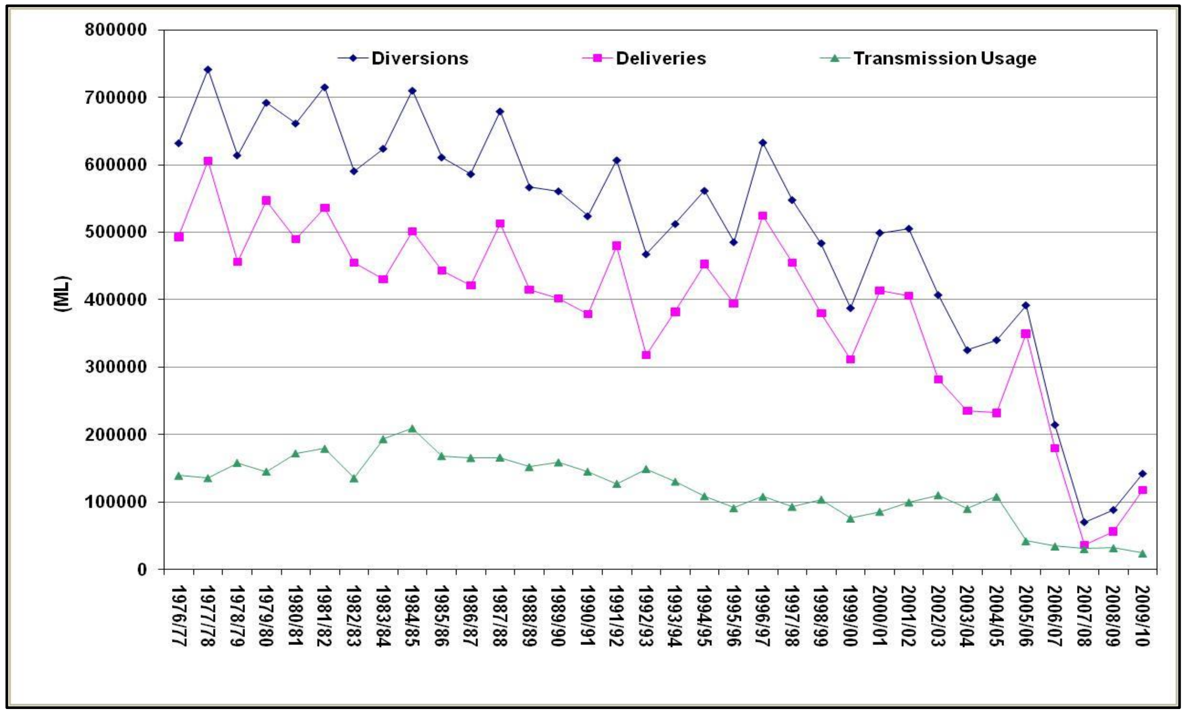
Integrated Approach

Flume Gates

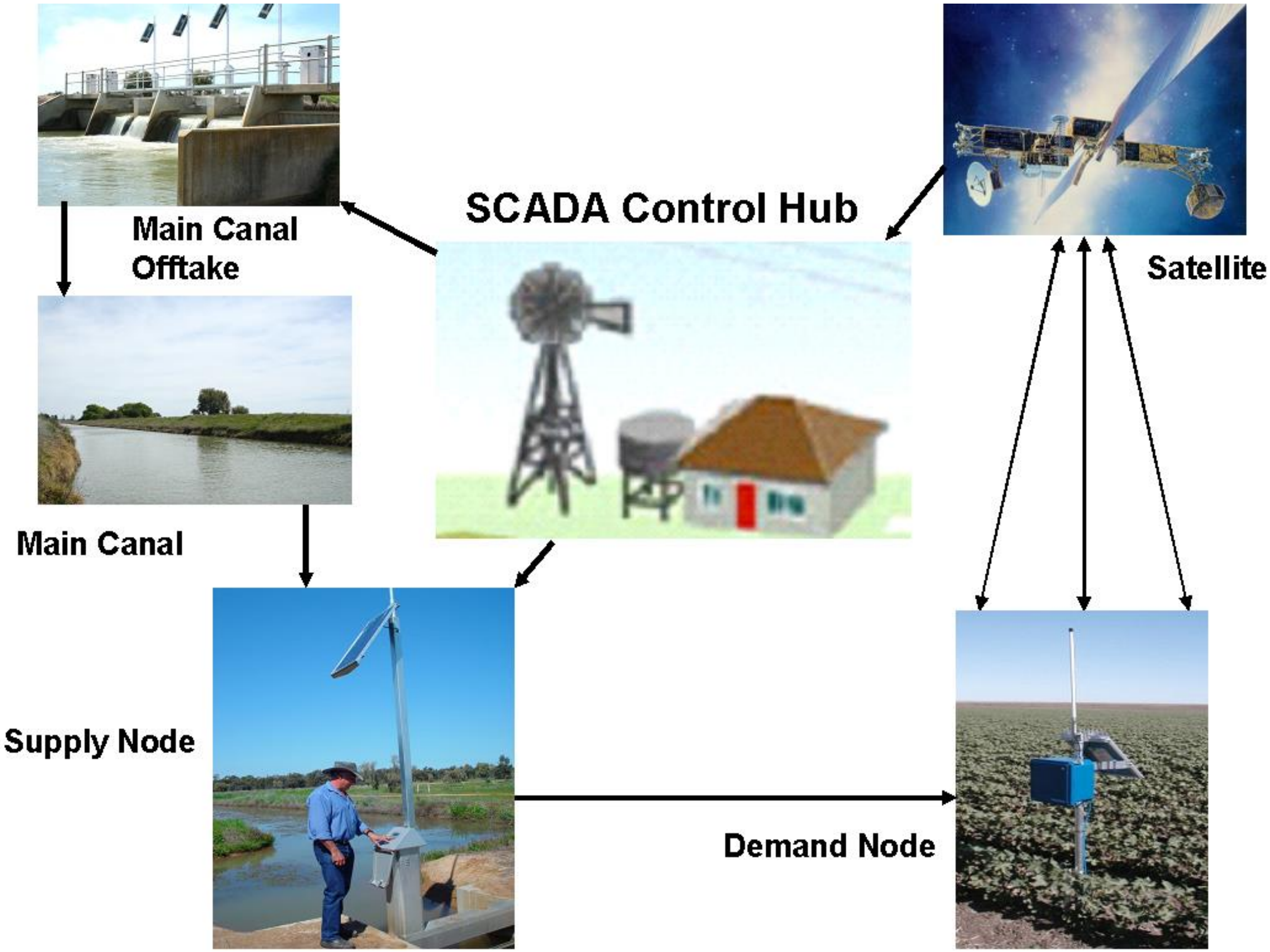


(CICL, 2010)

More water for Farmers

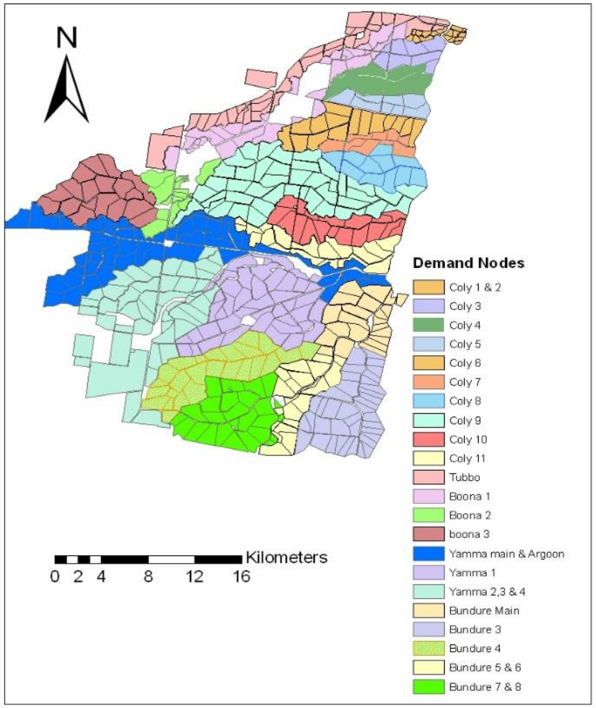


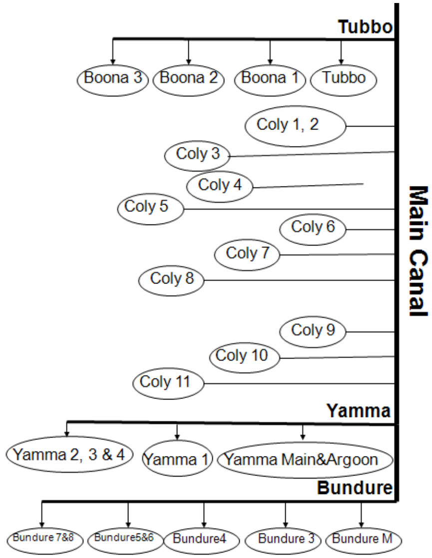
Integration Framework for Irrigation Demand and Supply Management



Hafeez et al., (2011)

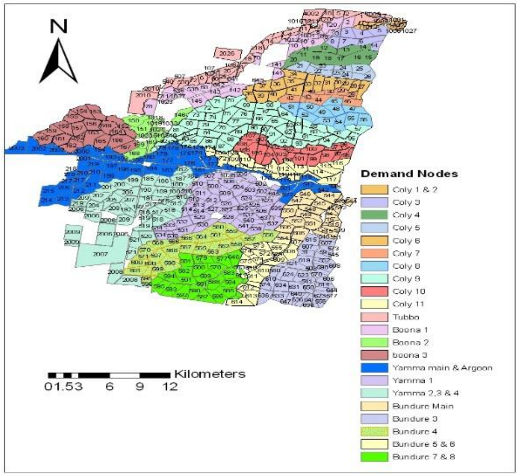
Nodal Irrigation Water Supply – Demand Model

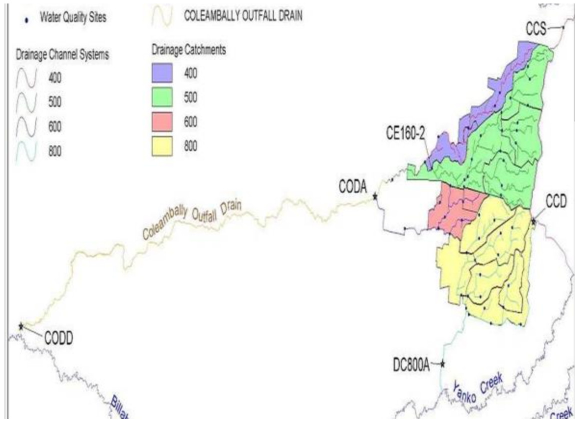


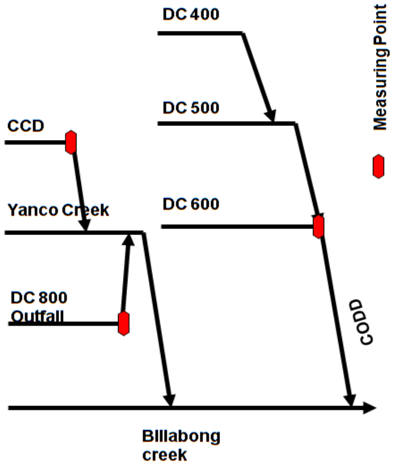


Irrigation System

Drainage System

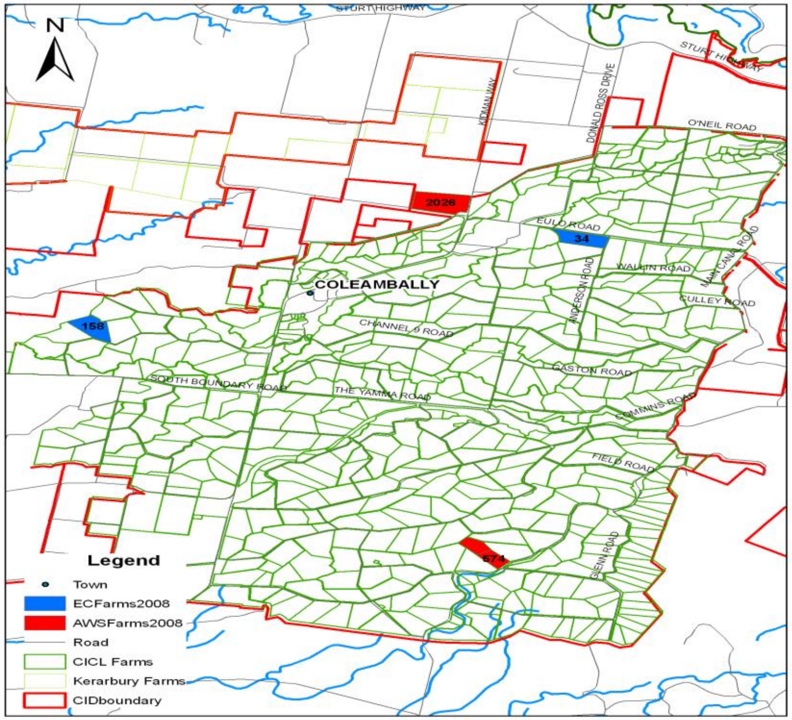






Ullah and Hafeez (2011)

Benchmarking Sites in Coleambally Irrigation



AWS in CIA farm

AWS in CIA farm

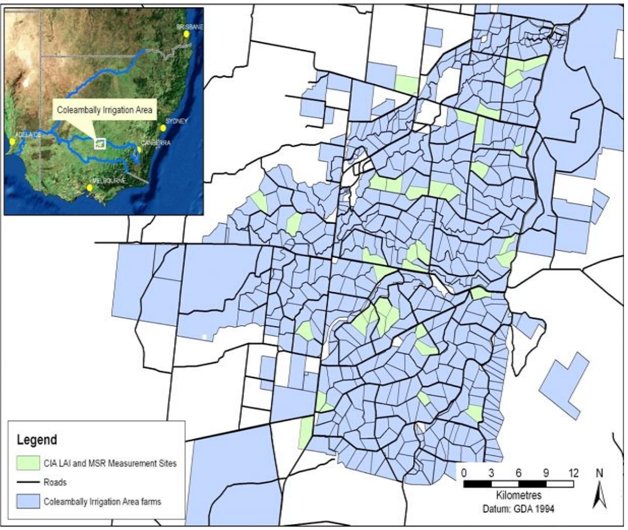
Leeton AWS 2010

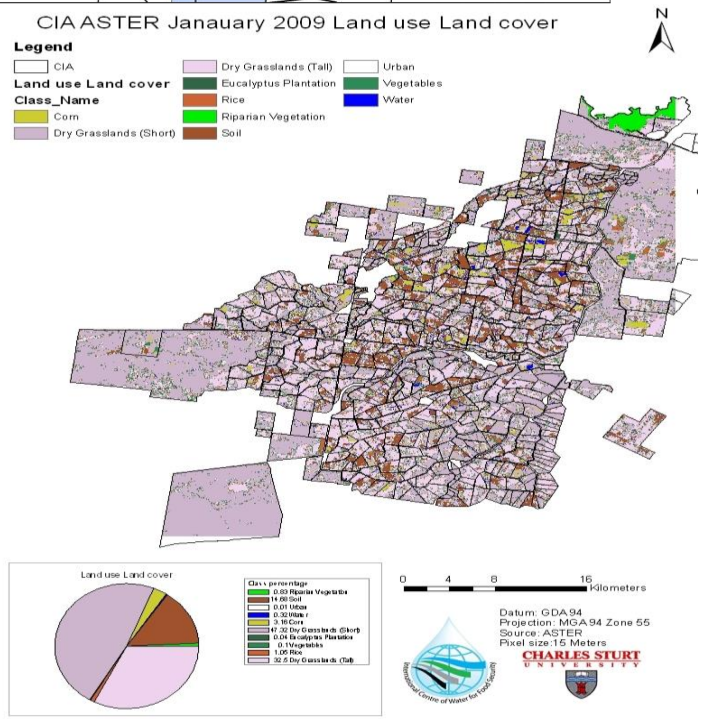
Flux Tower at Canola farm

LAS at Wheat farm

Hafeez et al., (2011)

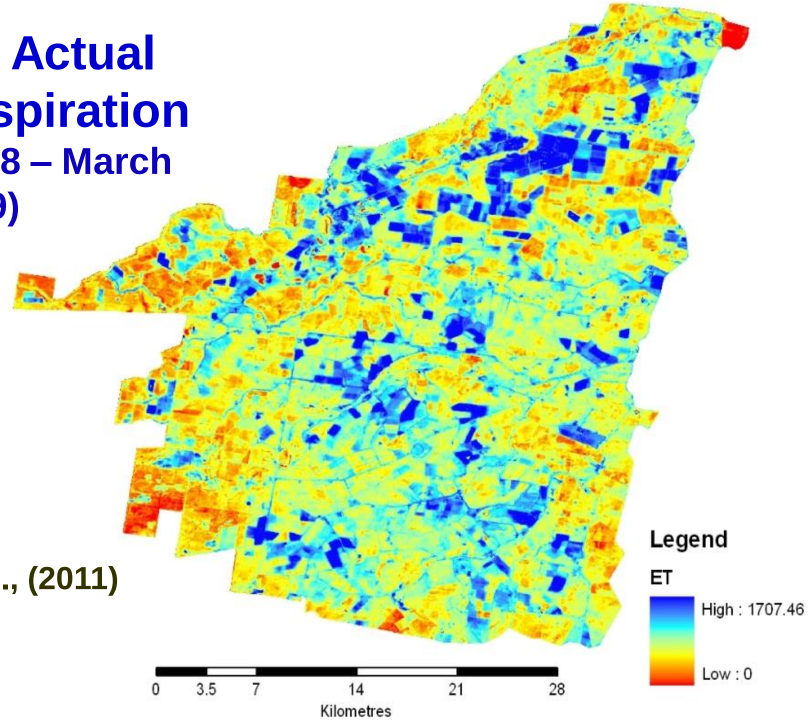
Field Activities





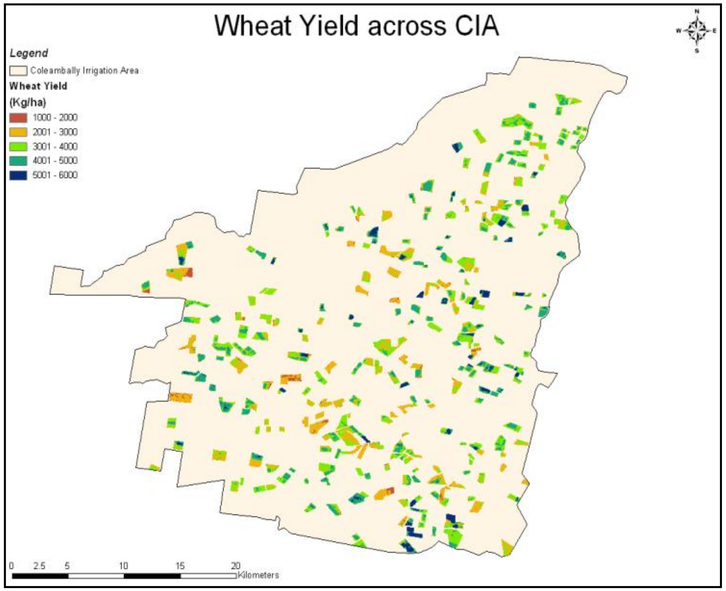
Ullah and Hafeez (2011), Indira (2014)

Seasonal Actual Evapotranspiration (October 2008 – March 2009)



Hafeez et al., (2011)

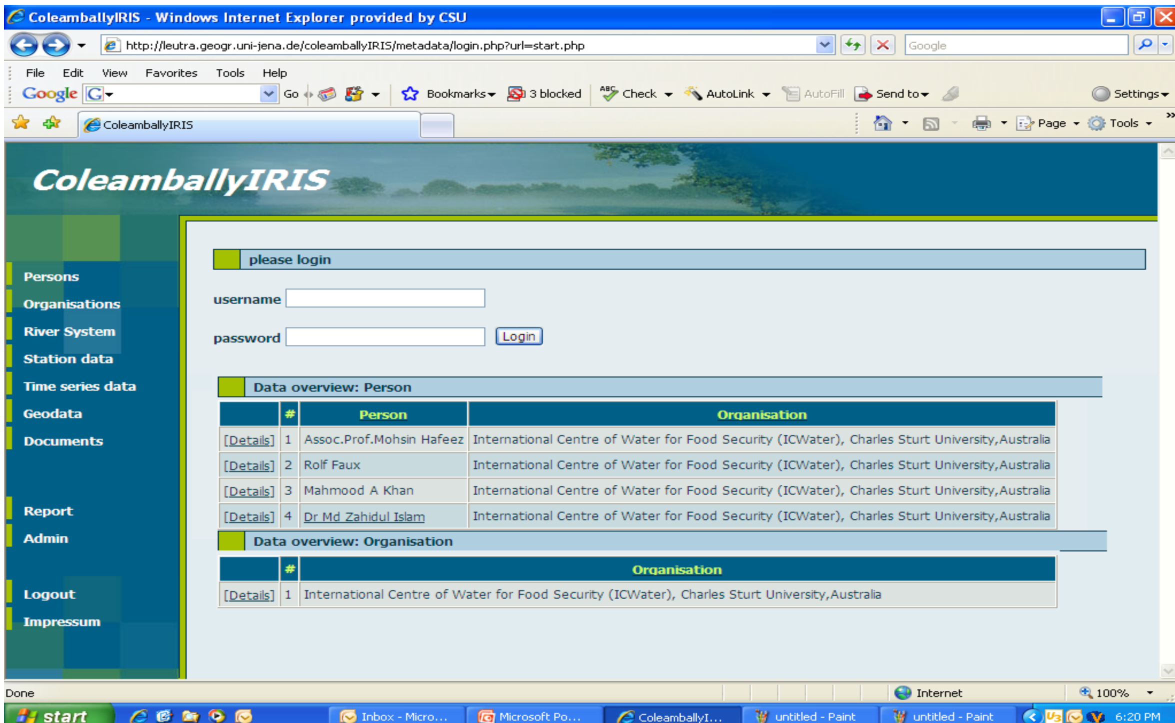
Wheat Crop Yield for 2009

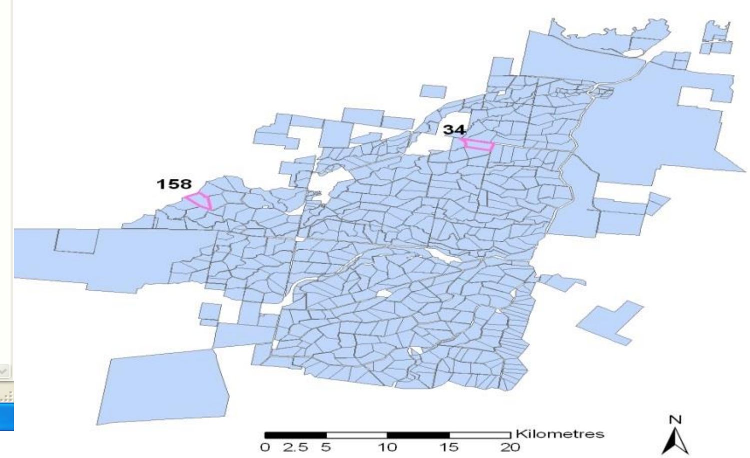


Landsat 5 TM (Spatial Resolution 25 m)

Internet Based Decision Support Tools for Irrigators

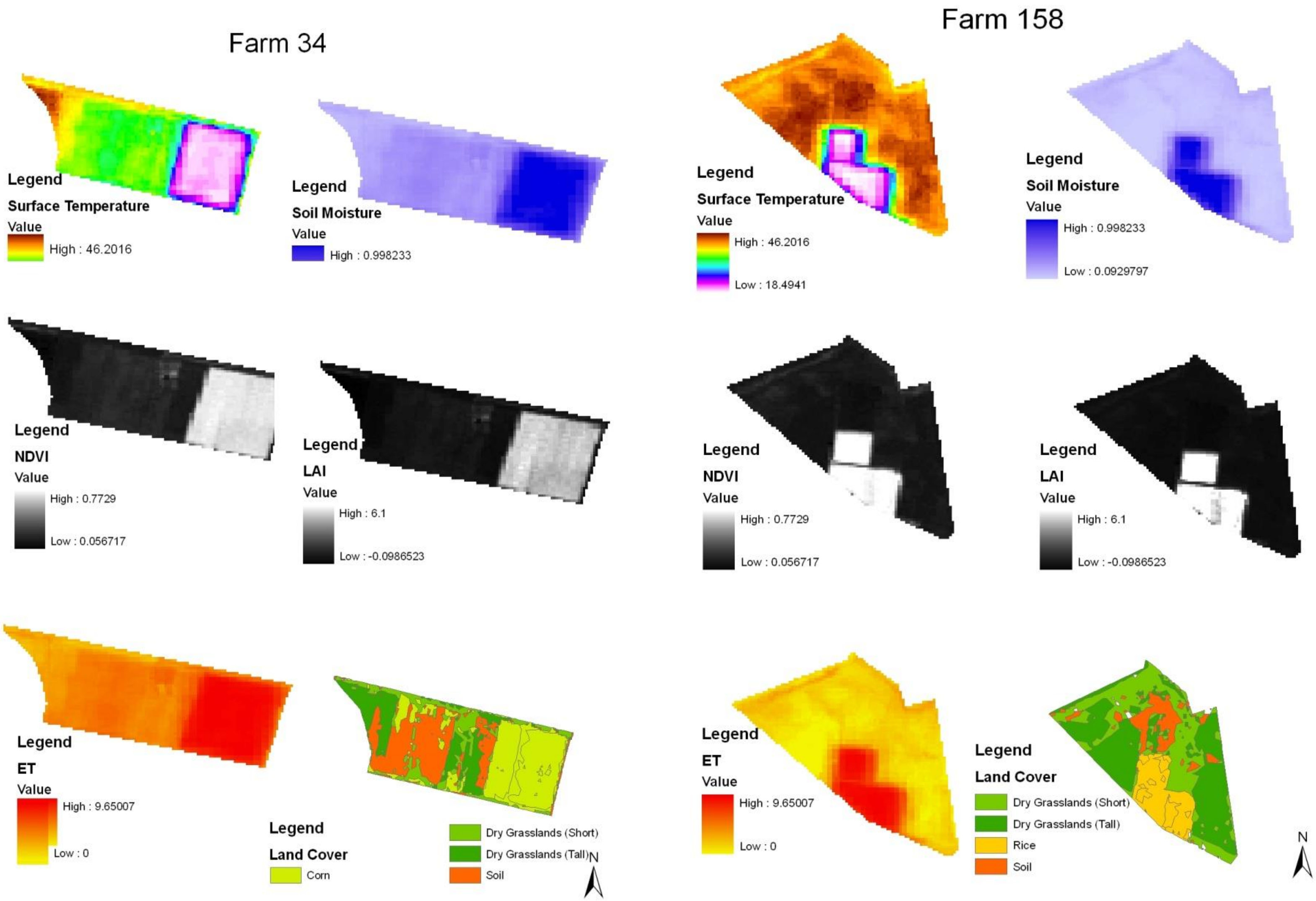
- **DSS mainly into three categories of the users;**
  - **Irrigation managers**
  - **Researchers**
  - **Farmers**
- **The parametric images extracted from the processed satellite images are masked to the farms, nodes and whole irrigation district boundaries and are displayed on the web pages.**





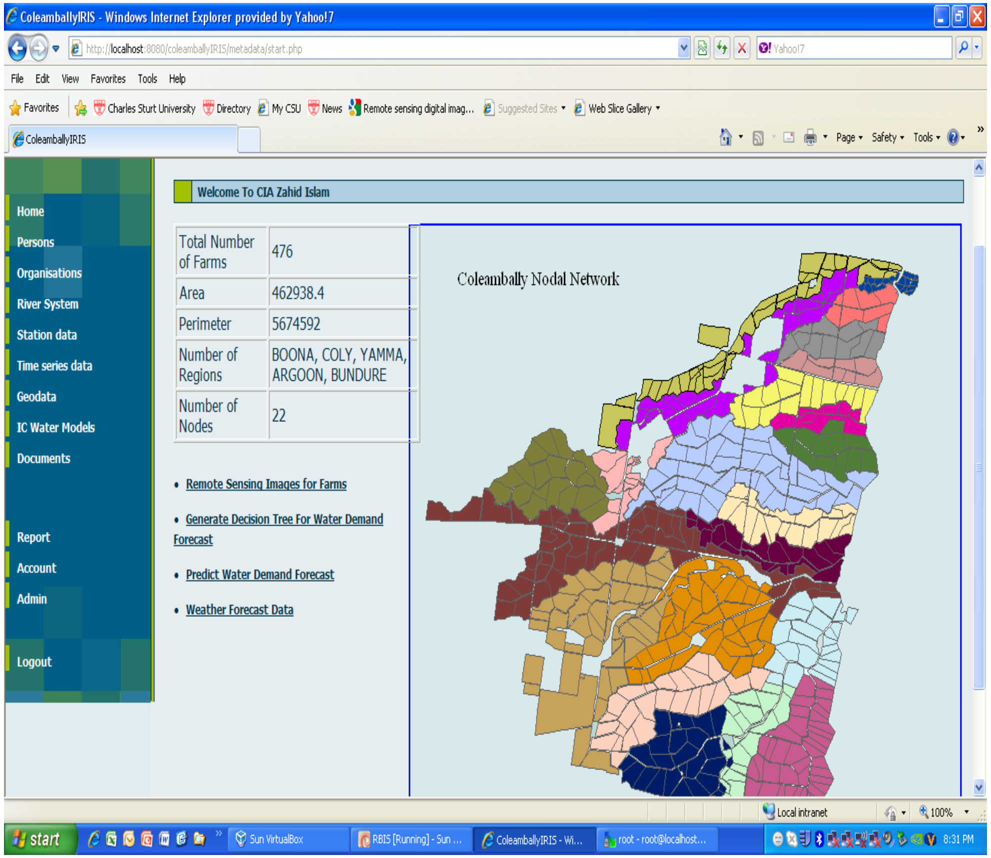
Khan et al., (2011)

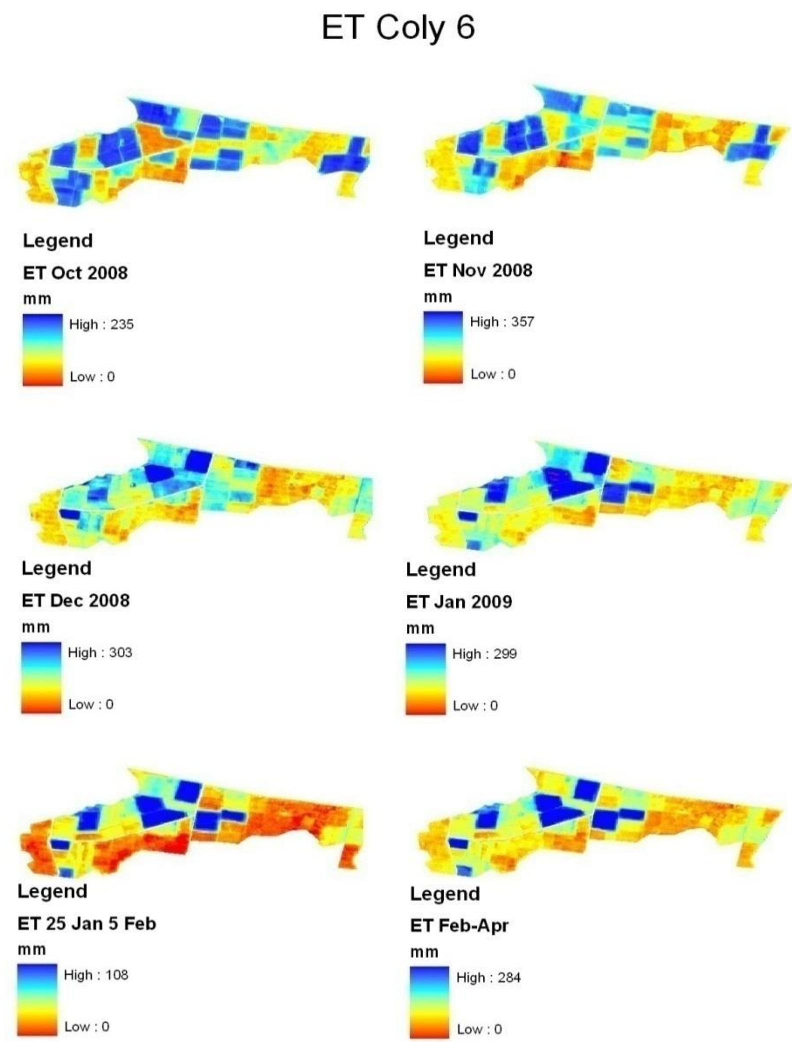
Internet Based Decision Support Tools for Irrigators



Khan et al., (2011)

IRIS DSS for Managers





ET Based Nodal Model – For Irrigation Managers

Khan et al., (2011)

Spatial Water Demand Model – 7 Days Forecast

Impact Pathways

Scale: Field, Farm, Sub-irrigation and Irrigation System

- The net irrigation demand forecasting at the system level has reasonable agreement with actual water diverted to the system and can help in improving irrigation water management.
- Demand forecasting tool, is useful for improved irrigation water management ranging from node to system level in CIA as well as in other irrigation systems located in arid and semi-arid regions around the globe.
- Developed tool can practically help irrigation managers to overcome the risks associated with over and under irrigation application by matching the demand and supply in near real time environment
- Made a valuable contribution in explaining the spatial variation of yield over the area and to identifying the key factors affecting crop yield.

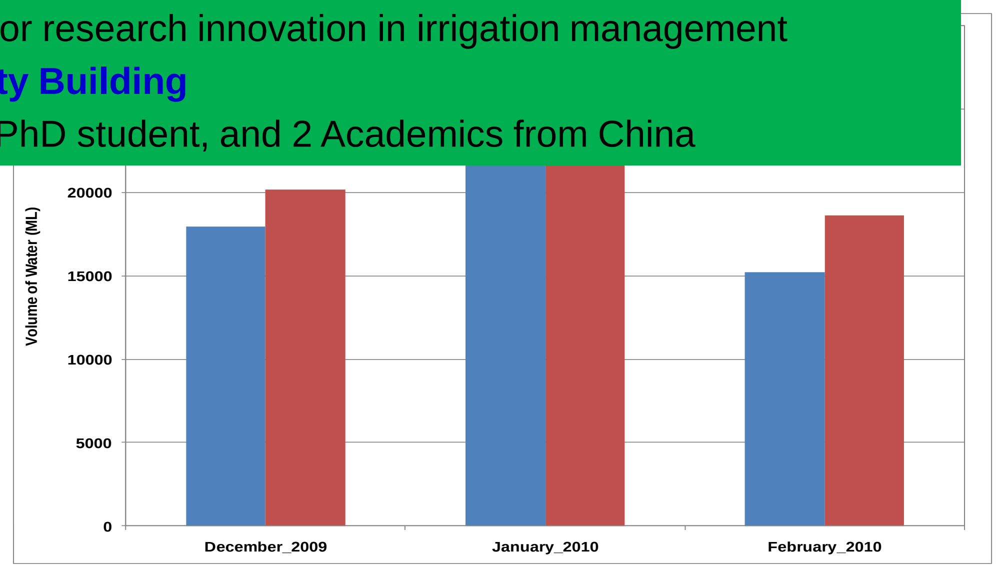
Scientific Recognition

- 2010 CRC for Irrigation Future Leadership award for research innovation in irrigation management

Capacity Building

- 4 PhD & 2 M.Sc. Students, 1 Chinese & 1 Iranian PhD student, and 2 Academics from China

Forecasted Irrigation Demand and Actual Diverted Water in Summer 2009-10



Ullah and Hafeez (2011)

Drone – Monitoring of Water Productivity

Flight weight: ca. 8-12 kg

Time of flight: > 90 min

Range: ca. 5 km

Max speed: 30 km

Max flight hight: ca. 4500 m

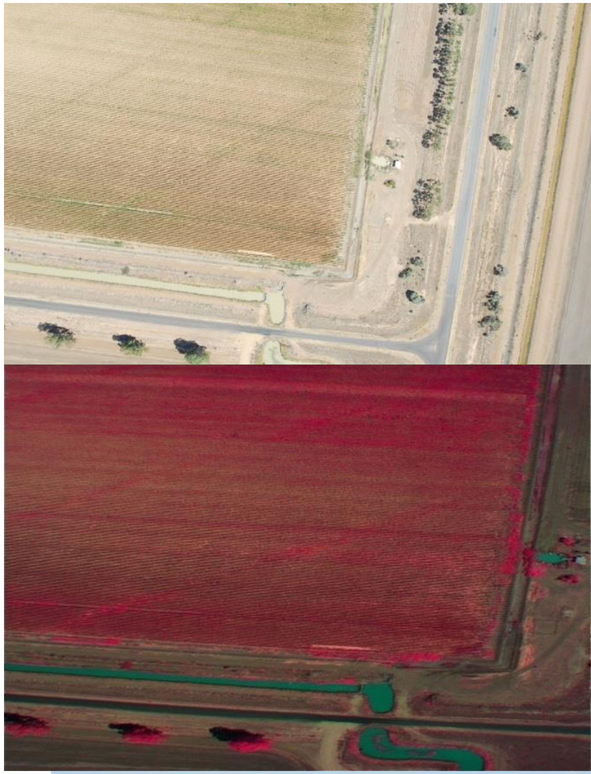
Carrying capacity: ca. 5-6 kg

Sensor: **Digital camera,**

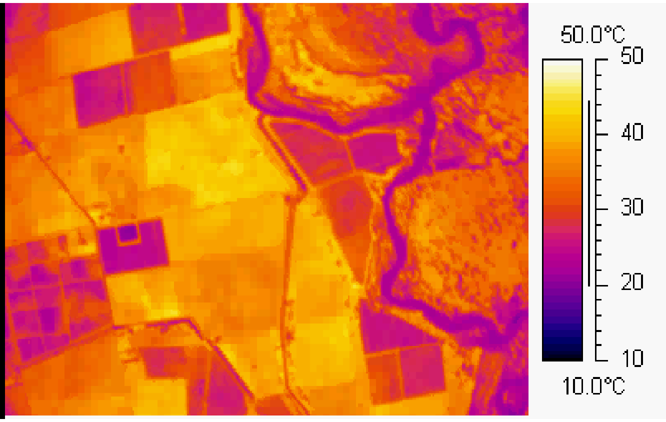
Multispectral camera,

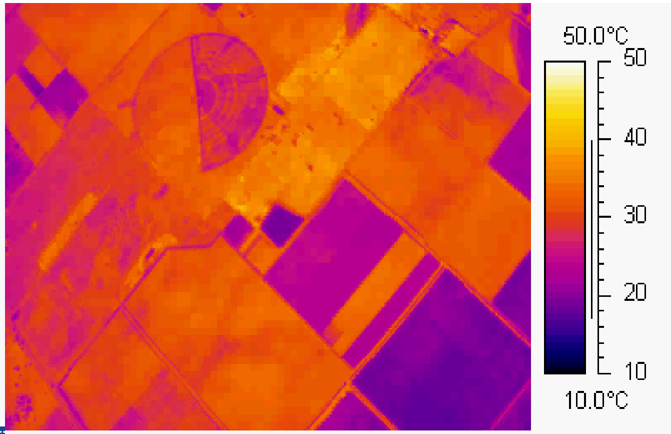
Thermal imager

Observation of Maize Farm from Drone



Understanding Water Availability Using Thermal Imaging





Hafeez et al., (2011)

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Learning and Opportunities from Australia

- Recognise water as a scarce economic good, to be allocated and used wisely for economic, social and environmental benefit- protecting fragile aquatic ecosystem
- Need to focus on both demand and supply management, balanced engineering, policy, planning, regulatory and legal tools for reforms
- Need of drastic water reforms and implementation of water policies
- Preserve and modernize the existing irrigation systems
- Reshape irrigation system for demand-driven water requirements
- Increase investment in irrigation and drainage infrastructure
- Manage groundwater sustainably
- Improve water and land productivity
- Expand irrigation wherever opportunities exist through new smart irrigation system
- Realignment and strengthening of national institutions and regulatory environments
- Improving data capture to assist inform water policy formulation
- Monitoring and reporting of policy implementation: ensuring plans and agencies held accountable

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- **Case Studies from Selective Countries (Philippines, China & Uzbekistan)**
- Issues and Opportunities for Water Management in Asia
- Personal Insights
- Way Forward

Scale Effects on Water Productivity in UPRIIS, Philippines

Scale: WUA, Sub-irrigation and Irrigation System

Philippines Partners:
NARS: NIA and PhilRice
IRRI

Study Area: 34,000 Ha

Crop Types: Rice and vegetables

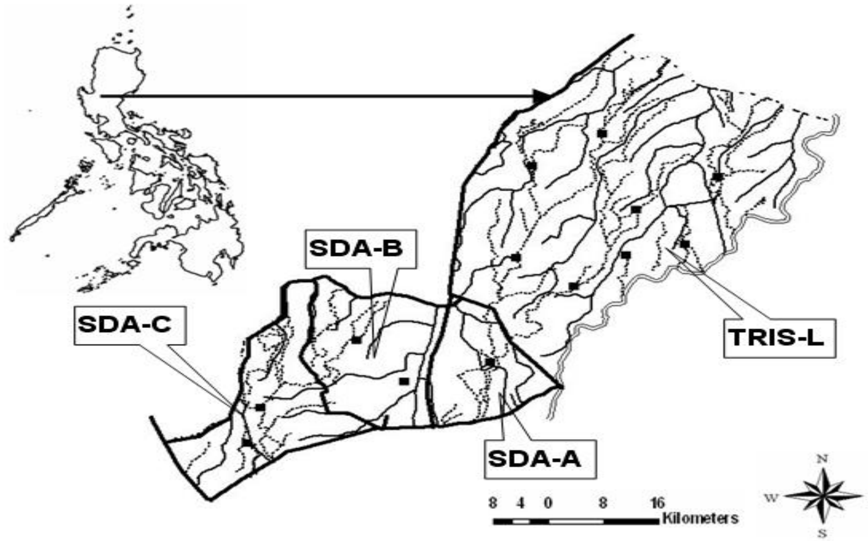
Rainfall: 1800 mm in Wet Season and 320 mm in Dry Season

Strategy: Water accounting at ten (10) different spatial scales (1,513 ha to 18,000 ha)

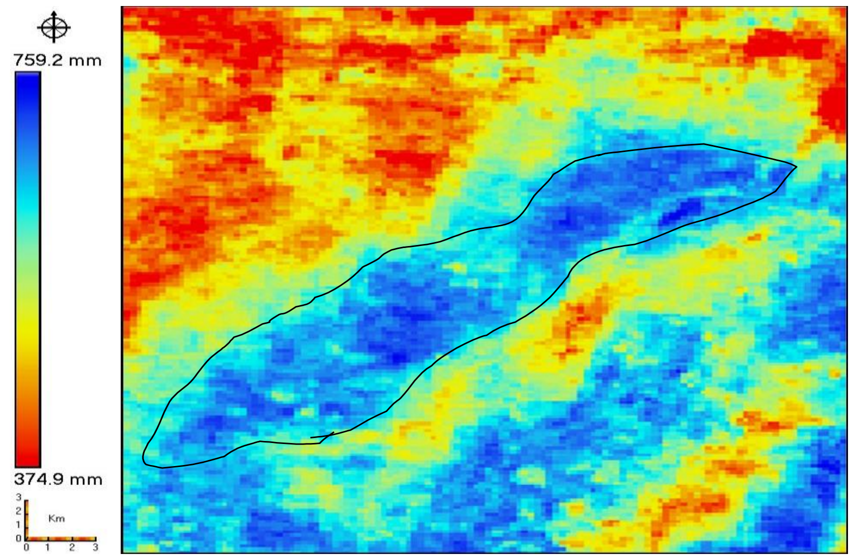
Innovative Feature: Up-scaling effect on water use efficiency and productivity

Outputs: Water use efficiency and productivity increases 3-4 times at higher scales due to water re-use opportunities

Hafeez (2003)



Seasonal Actual ET in 2001



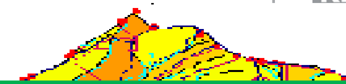
Water Accounting from Farm to Irrigation System

Descriptor	Field[1]	TRISL	TRISL + SDA-A	TRISL + SDA-AB	TRISL + SDA-ABC
Total area (ha)	1.08	11,239	12,752	14,992	18,003
Rice area (ha)	1.00	8,713	9,890	11,599	13,571
Upland crop (ha)	0.00	886	972	1,214	1,629
Rest (ha)	0.08	1,640	1,890	2,179	2,803
Rice yield (t ha^{-1})	7.6	6.09	5.41	5.47	5.31
Farmers (number)	3	7,207	7,958	8,859	9,910
Pumps (number)	0	519	628	735	1154
Water flows	(m^3)	(10^6 m^3)			
Irrigation inflow	5180	355	355	358	358
Rain inflow	910	33	37	41	50
Committed outflow	0	231	245	239	250
Uncommitted outflow	0	49	49	49	49
Available water	6090	157	147	160	159
Rice ET depletion	4350	57	65	77	90
Other ET depletion	100	11	13	16	22
Balance	1640	40	20	18	-3
Internal water flows	(m^3)	(10^6 m^3)			
Rice field percolation	1450	32	36	42	49
Reuse by check dams	0	54	54	61	90
Pumping surface water	0	1	1	1	1
Pumping groundwater	0	14	16	17	26
Groundwater change	0	-3	-3	-5	-7

Scale Effects on Water Productivity in UPRIIS, Philippines

100

Pump Volume



Impact Pathways of Research

Scale: WUA, Sub-irrigation and Irrigation System

- Substantial contribution in generating new scientific knowledge on understanding scale effects on water productivity through reuse of surface water opportunities from check dams and drainage creeks in irrigated rice ecosystem in the Philippines that helps in planning future water management practices.
- Amount of water re-used through pumping is equivalent to 30% of water lost through rice ETs Water can be saved by reducing high losses (32%) through non-process depletion at the SDA-C scale.
- Water productivity of irrigation water increases 3-4 times over scales from small irrigation systems to the large-scale level due to increased water re-use opportunities.
- Groundwater utilization to fully irrigate or supplement canal system deliveries can significantly alleviate the farmer's water scarcity problem in the UPRIIS.

This study findings made a significant contribution in NIA's future plans for rehabilitation of the irrigation system through JICA's funding.

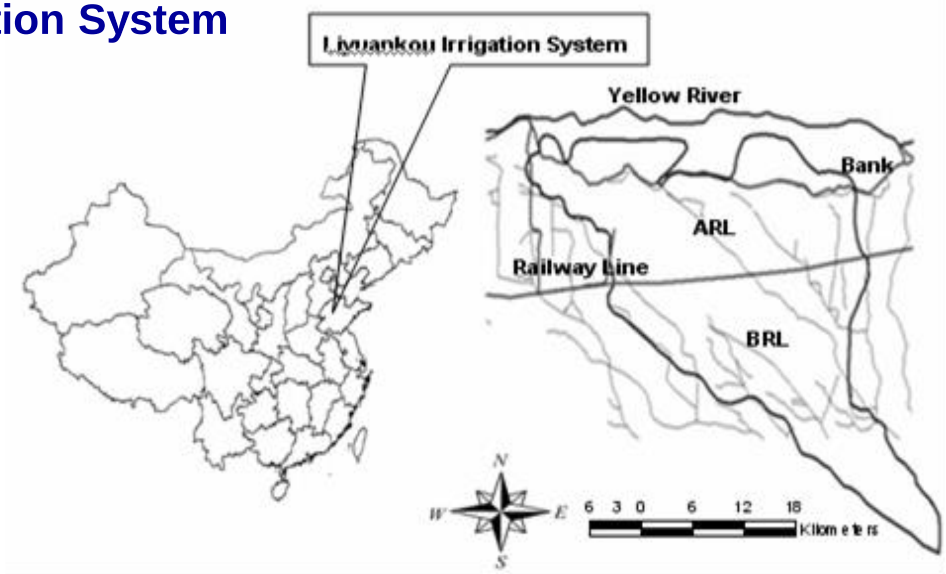
Capacity Building

•Training to NARS and IRRI national staff on hydrological data collection across irrigation system

WPgross (kg/m3) WPirrigation (kg/m3)

System Approaches for Water Productivity in China

Scale: Sub-irrigation and Irrigation System



Chinese Partners:
NARS: LIS and YRC
Wuhan University
IRRI, IWMI

Study Area: 55,512 Ha

Average Rainfall: 626 mm

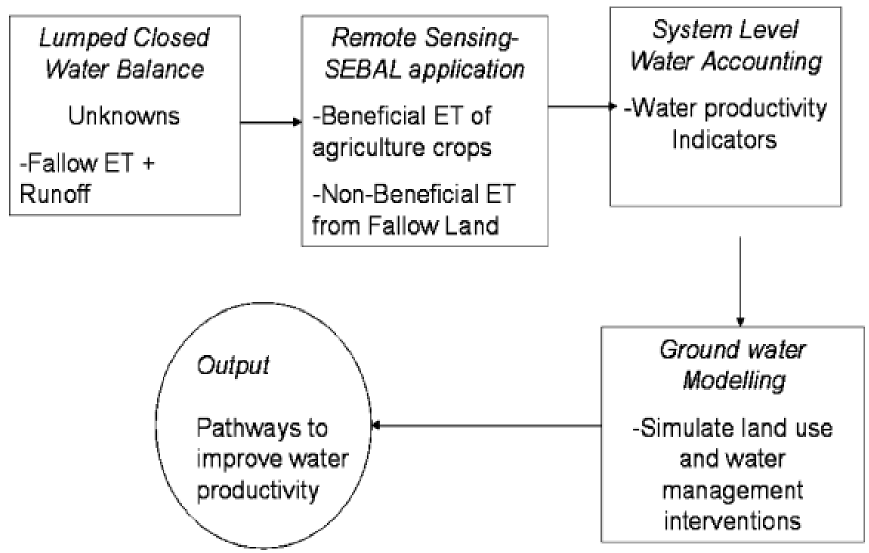
Crop Types: Rice, Maize, Wheat and Cotton

Major Issues: To achieve real water savings

Strategy: Water accounting at system level

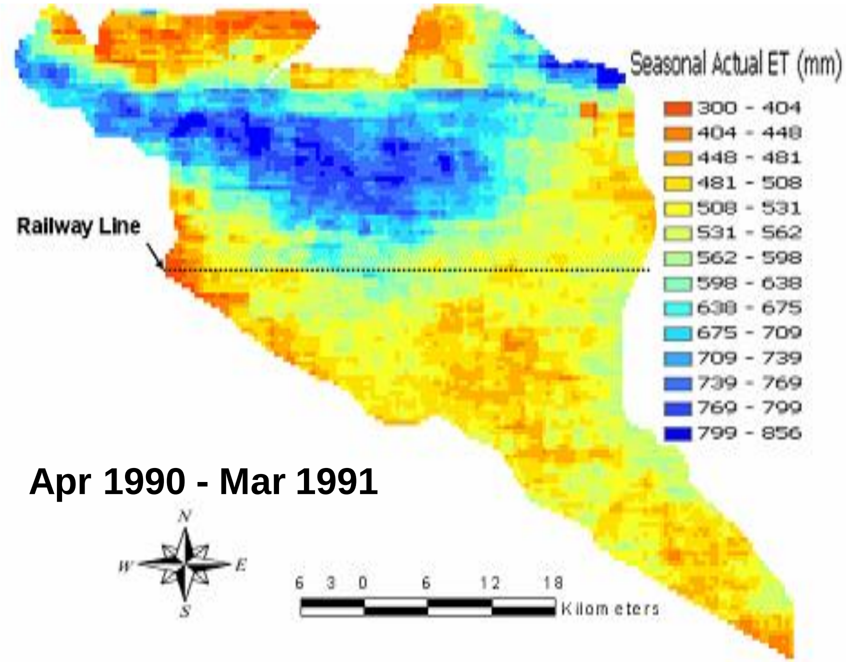
Innovative Feature: Coupling of SEBAL with water accounting framework for irrigated agriculture in China

Outputs: Accurate spatial information of water depletion from fallow lands to develop pathways leading to improve water productivity



Hafeez and Khan (2007), Khan et al., (2008)

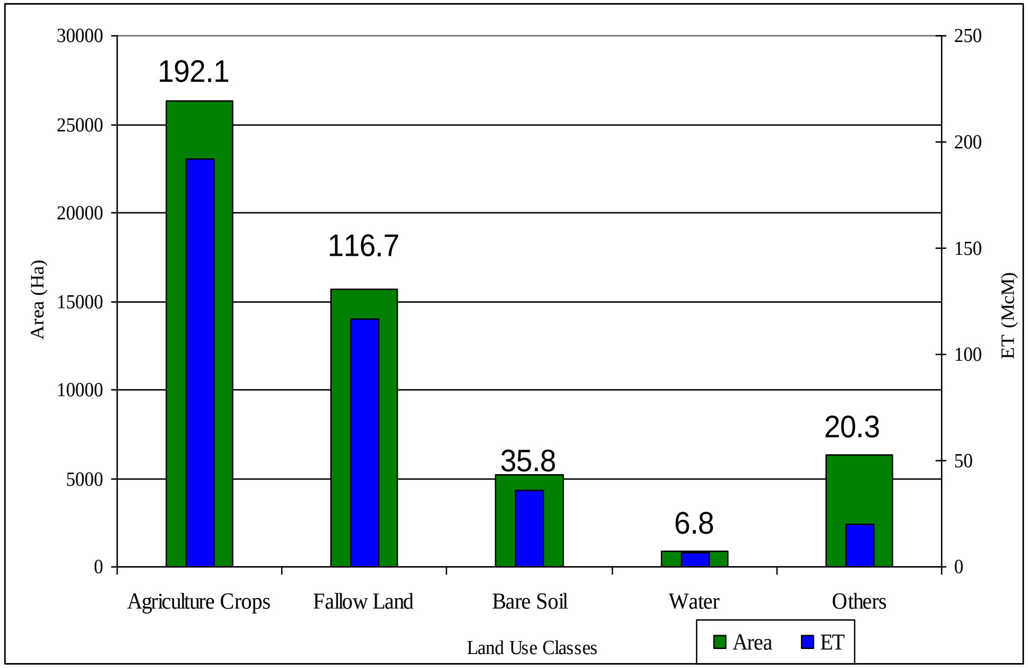
Quantification of Fallow ET in LIS



Apr 1990 - Mar 1991

Fallow ET + Runoff from lumped water balance for 1990 = 166 McM

Annual (Apr. 90- Mar. 91)



Hafeez and Khan (2007)

Hydrology Scenarios

- Present hydrologic conditions (Base run)
- No irrigation supplies from the Yellow River above (ARL) and b
Y
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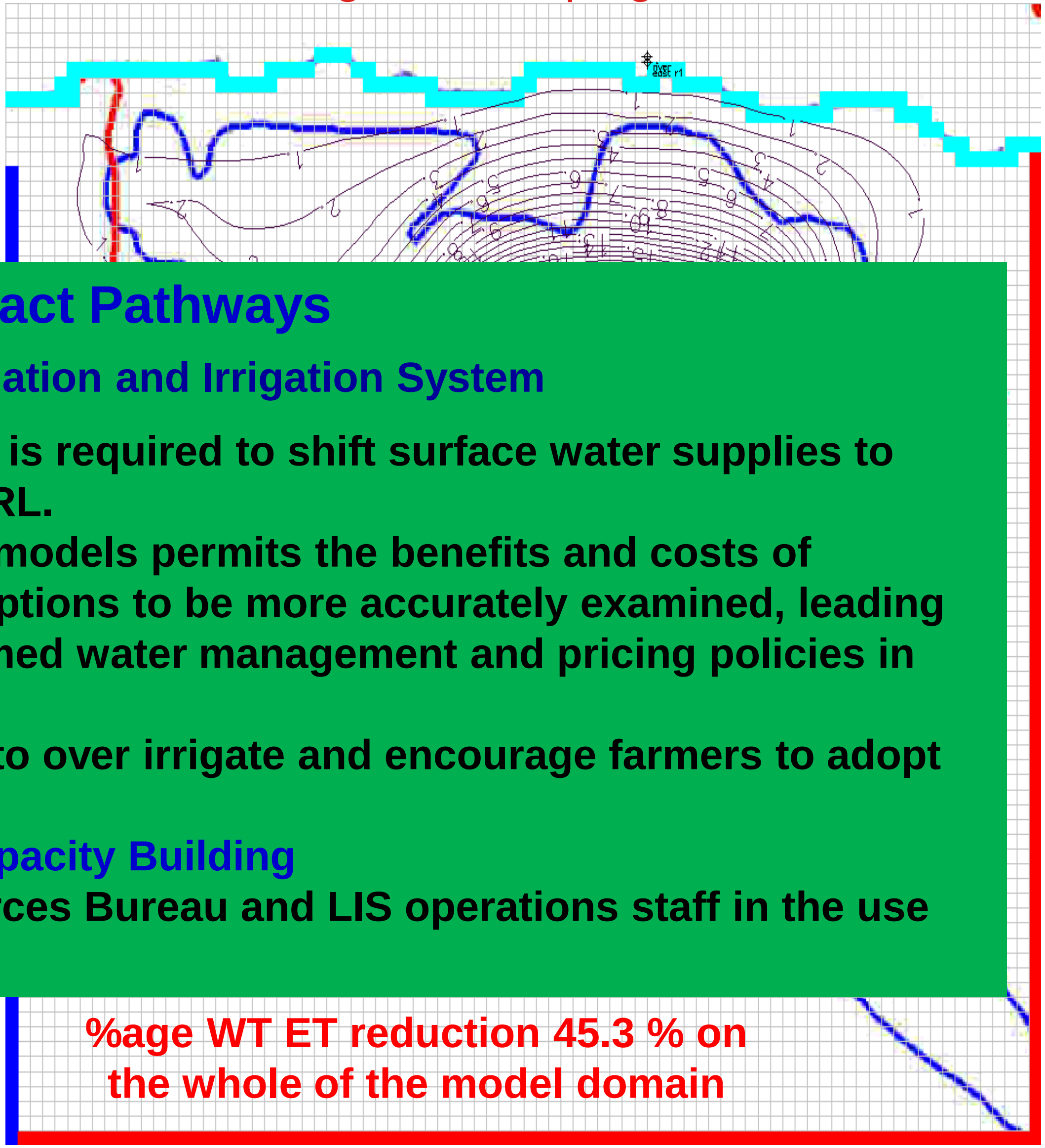
Net Drawdown After 10 Years
Canal Lining and Pumping ARL



Impact Pathways

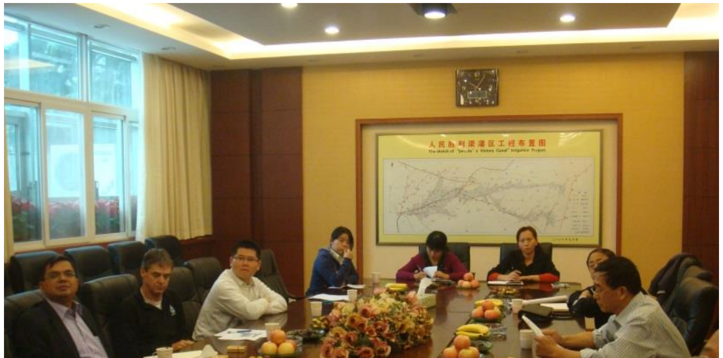
Scale: Sub-irrigation and Irrigation System

- **Major policy dialogue and change is required to shift surface water supplies to BRL and promote GW pumping ARL.**
- **Linking economic and hydrology models permits the benefits and costs of possible irrigation management options to be more accurately examined, leading to the development of more informed water management and pricing policies in LIS.**
- **Water pricing reduces incentives to over irrigate and encourage farmers to adopt modern irrigation technologies.**

Capacity Building

- **Provided training to Water Resources Bureau and LIS operations staff in the use and update of system models**

Khan et al., (2008)



Benchmarking Farm Site in People Victory Channel Irrigation System, China

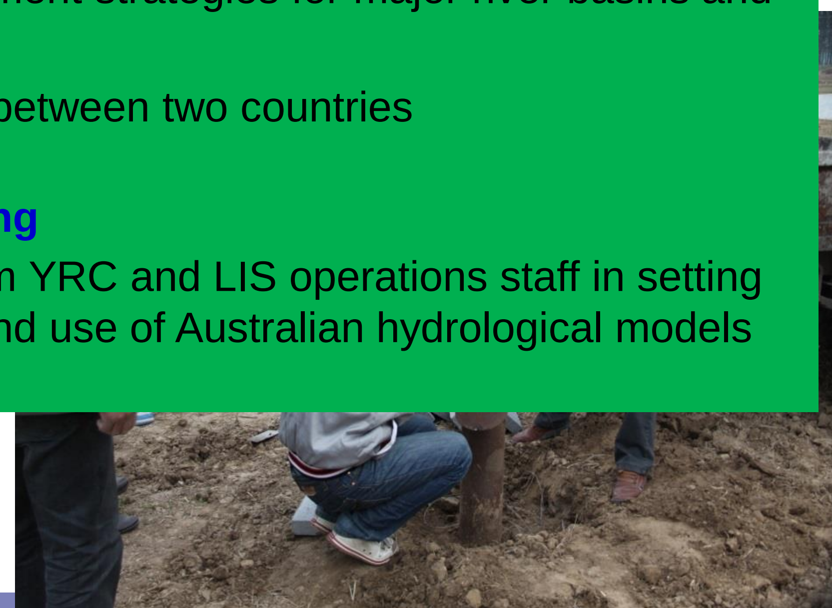
Australia China Environment Development Program 2008-2011

Irrigation Water Management and Water Allocation Activities Under Twin Basin Arrangement

- Sharing of Australian experience in assisting China to progressively revise and strengthen water reform policy and practice for agriculture sector to improve irrigation system efficiency to 50%.
- Australian’s experience provide valuable lessons to help China examine its water management issues, and develop future policies and water management strategies for major river basins and large irrigation areas.
- Scientific exchange of academic and operational staff between two countries

Capacity Building

- Provided training to Water Resources professional from YRC and LIS operations staff in setting up Chinese benchmarking sites in irrigation systems and use of Australian hydrological models for water resources assessment in China



Irrigation Performance Assessment and Water Productivity in the Lower Reaches of the Amu Darya River

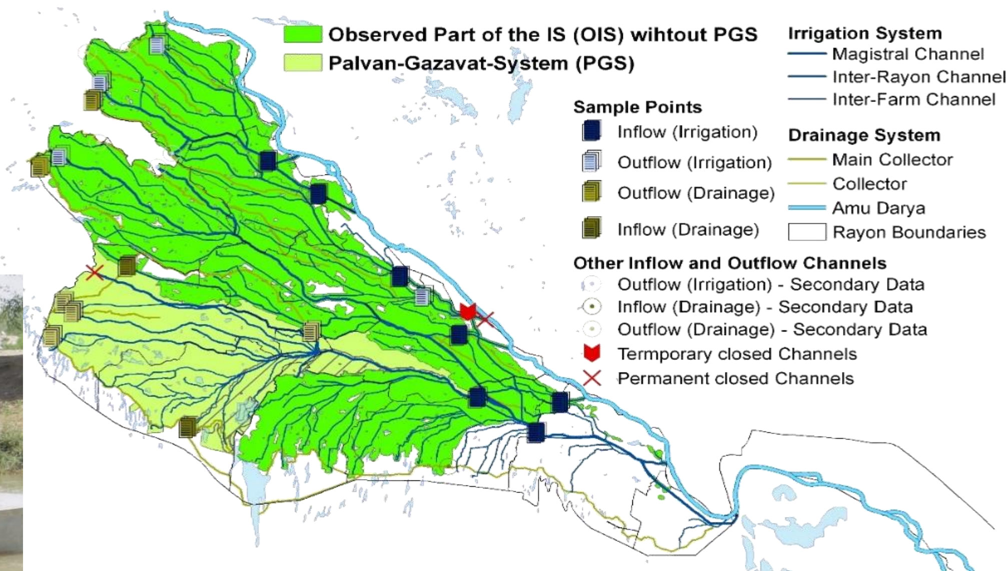
Scale: Field, Farm, WUA, Irrigation and Basin

Total area:	**680,000 ha**
Irrigated area:	**270,000 ha**
Canal length:	**16, 233 km**
No. of WUAs:	**113**
Climate:	**Extreme Arid**
Precipitation:	**92 mm yr^{-1}**
Evapotranspiration:	**950 mm yr^{-1}**
Main Crops	**Rice, Cotton & Wheat**
Withdrawals	**4.5 to 5 km^{3}**
Topography	**Flat, 135-82 m a.s.l.**

Key Issues

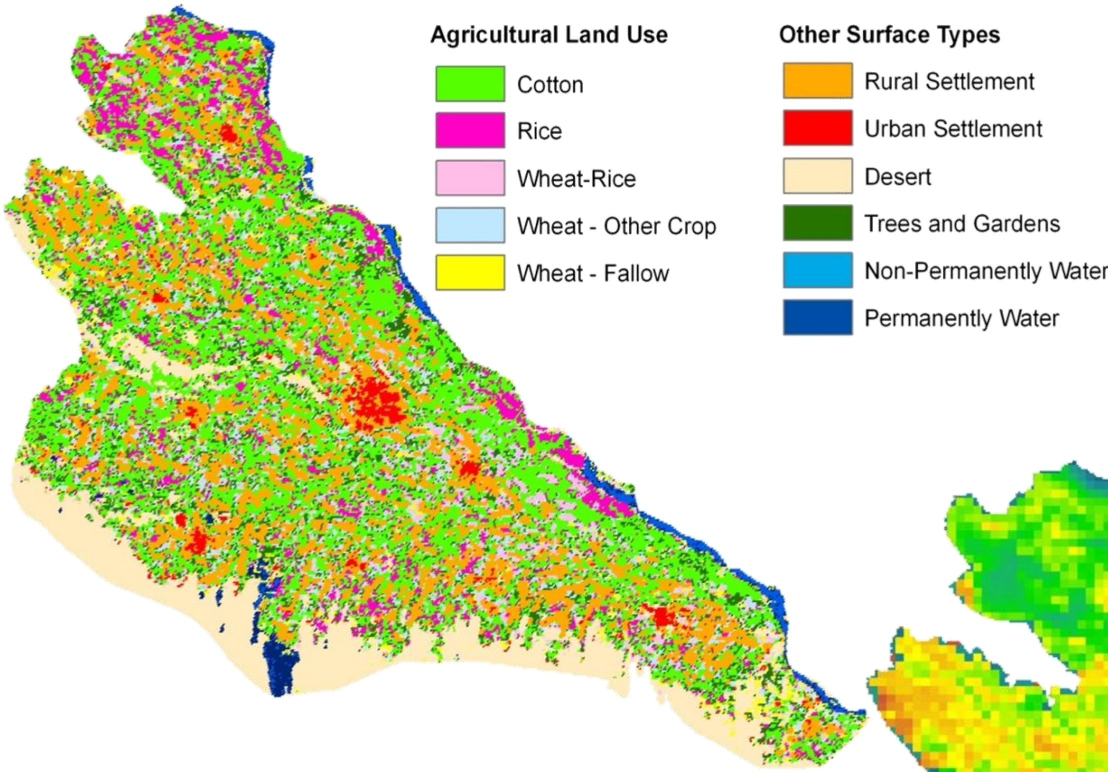
- **Lack of reliable hydrological data**
- **High groundwater levels**
- **Soil and groundwater salinity**
- **Classified information**

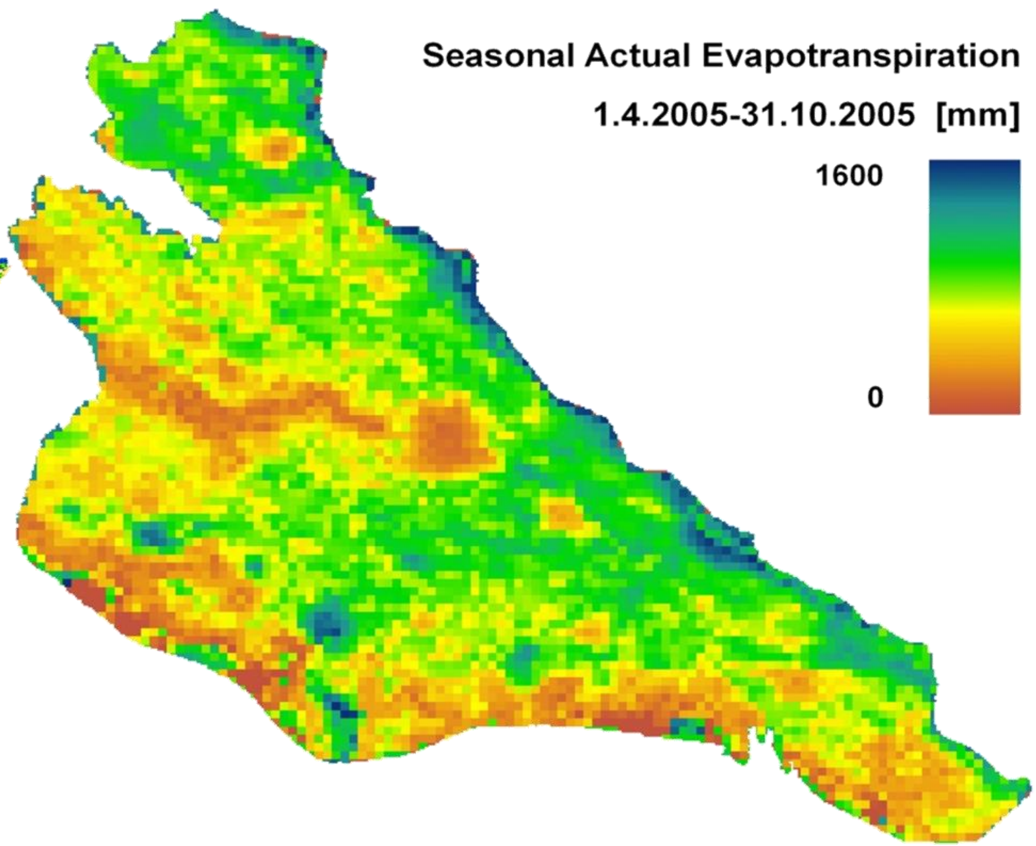
Two Sub-Systems



Hafeez et al., (2003); Conrad et al., (2007)

Water Management at Basin Scale





(Conrad et al., (2007)

Water Use – Depleted Fraction

RICARDO

Vegetation period	Area	Agric. Area	Withdrawal / Agric. Area
2			
C			
P			
C			

Impact Pathways

Scale: Field, Farm, WUA and Basin

- Study provided provides better understanding of water management practices across all scales.
- Study significantly improves water balance estimates across all scales.
- Provided sustainable water management solutions to the Khorezm irrigation region through a holistic approach, combining technology, policy and institutional options developed in cooperation with local and international stakeholders.
- To address the ongoing problems of substantial losses due to both technical and institutional deficiencies, irrigation scenarios were tested using mathematical modeling to explore various options of decreasing the region's overall demand for irrigation water.

Capacity Building

- Provided training to farmers from Khiva Water User Association on flow measurement.
- Train irrigation operational staff from BIVA in installation of flow measuring devices along major canals of Amu Darya River and developing new rating curves for flow measurement.

- **Lower critical values: 0.5 (Bos, 2004); 0.4 Bandara (2006)**
- **=> need of long term observations (monitoring)**

Conrad et al., (2007)

Presentation Outline

- Introduction to Ricardo/ Energy and Environment
- Personal Experience
- Grand Water Management Challenges and Water Reforms Journey in Australia
- Water Management across Multiple Scales (Continental, River and Irrigation System)
- Learnings and Opportunities from Australian Experience
- Case Studies from Selective Countries (Philippines, China & Uzbekistan)
- **Issues and Opportunities for Water Management in Asia**
- Insight
- Way Forward

Issues and Challenges – Asian Irrigation System

- Aging infrastructure, inadequate operation and maintenance, and high risk of failure
- Outdated technology- not fulfil the requirement of a modern agricultural production system
- Inequity, inefficiency and low water productivity
- Poor drainage, water logging and salinity
- Declining water and land quality and health and environmental consequences
- Reducing water availability due to climate change
- Lack of coordination of irrigation, water and agriculture departments
- Weak institutions especially transferring skills and knowledge to farming base
- Shortage of skilled manpower - latest scientific knowledge & state of the art scientific tools available to carryout assessment
- Poor uptake of research by operational agencies especially NARS
- Poor availability of hydrological data – make sound decisions
- Water policies are based on outdated scientific knowledge

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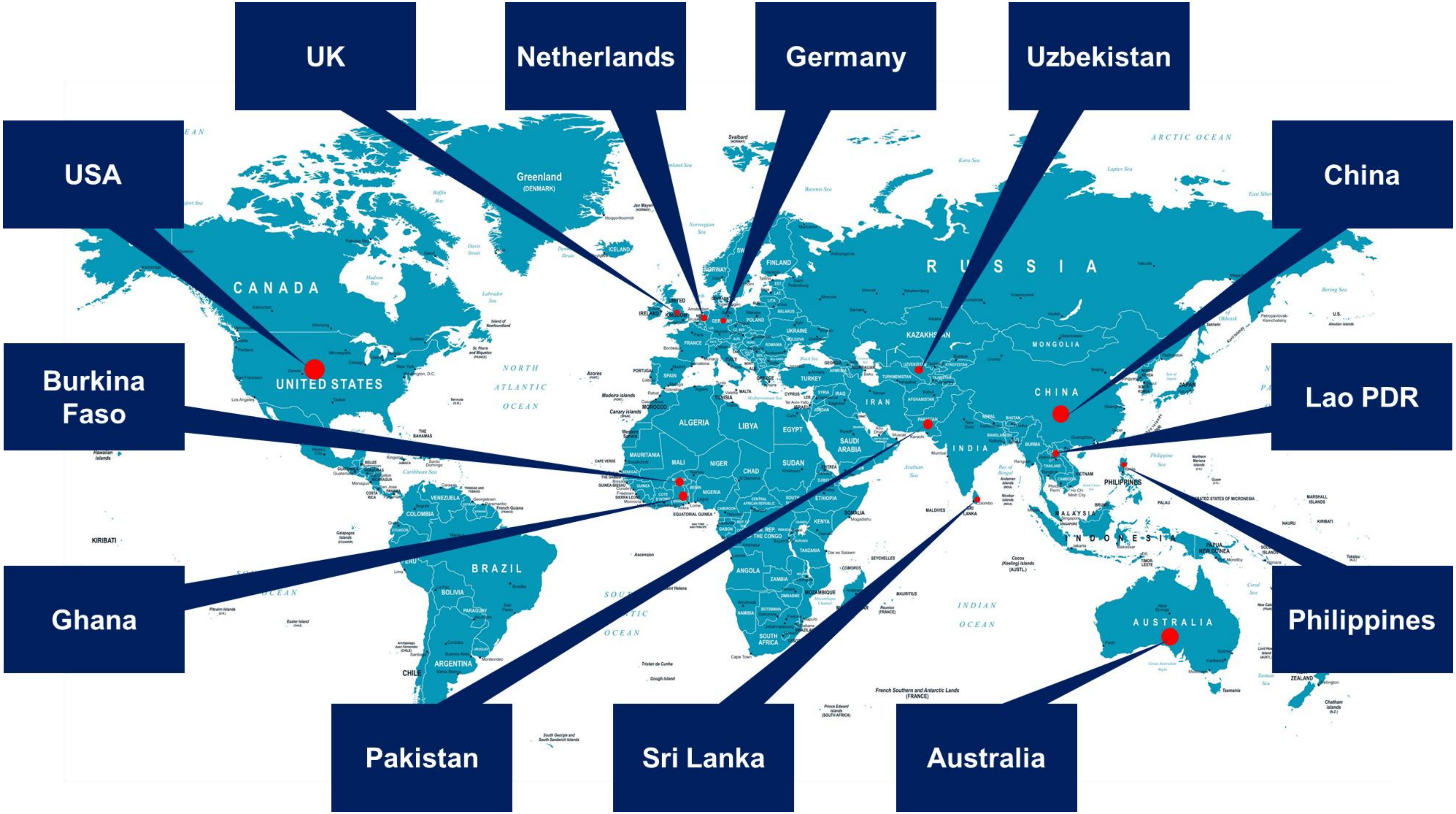
Insight into Water Resources Management



Objective Policy Matrix for Water Resources Management

Key Matrix Indicators/ Country	Scientific Evidence Based Solution for Investment	Holistic Water Resource Management	Opportunities to improve Water Productivity	Availability of Water Accounting System	Water Policy Implementation	Application of Smart Technology	Capacity Building	Knowledge Sharing and Partnership
Australia	H	H	M	H	H	M	H	H
Phillipines	L	L	H	L	L	L	L	L
Uzbekistan	L	L	H	L	L	L	L	L
China	M	M	H	L	M	M	M	M

- **H – High**
- **M - Medium**
- **L - Low**

Way Forward

- **Scientific evidence based solutions – key success to the investment**
- **Holistic water resource management - tackling water and food security**
- **Improving water productivity of agriculture sector - changing climate**
- **Water accounting remains imperative to inform policy development and target investment decisions**
- **Blending of innovative smart technology – new insights to monitor operational performance of water distribution**
- **Capacity building of water resources professional for public sector**
- **Knowledge partnerships are way forward**

Delivering Excellence
Through Innovation &
Technology

Dr Mohsin Hafeez
Head of International Business Development
Ricardo Energy & Environment
The Bright Building
Manchester Science Park
Manchester
M15 6GZ

+44 1235 753344
+44 7968 707236
mohsin.hafeez@ricardo.com
ee.ricardo.com
@Ricardo_AEA
Ricardo Energy & Environment