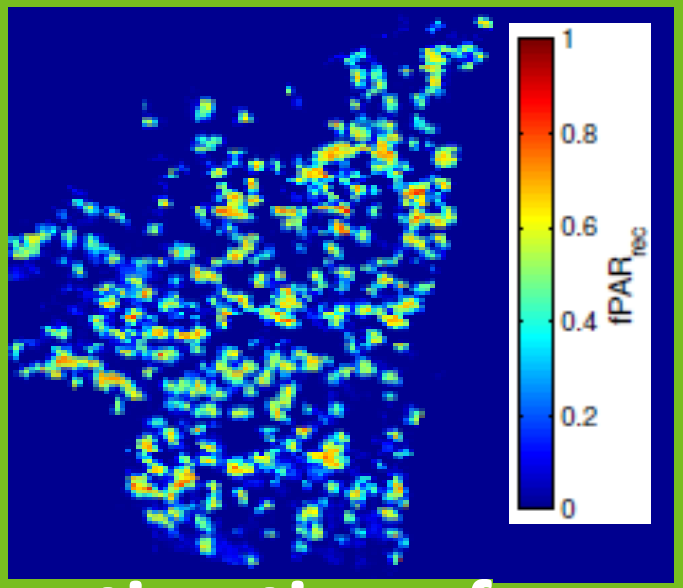


Towards continental dynamic estimation of irrigated areas to assess irrigation agriculture water use

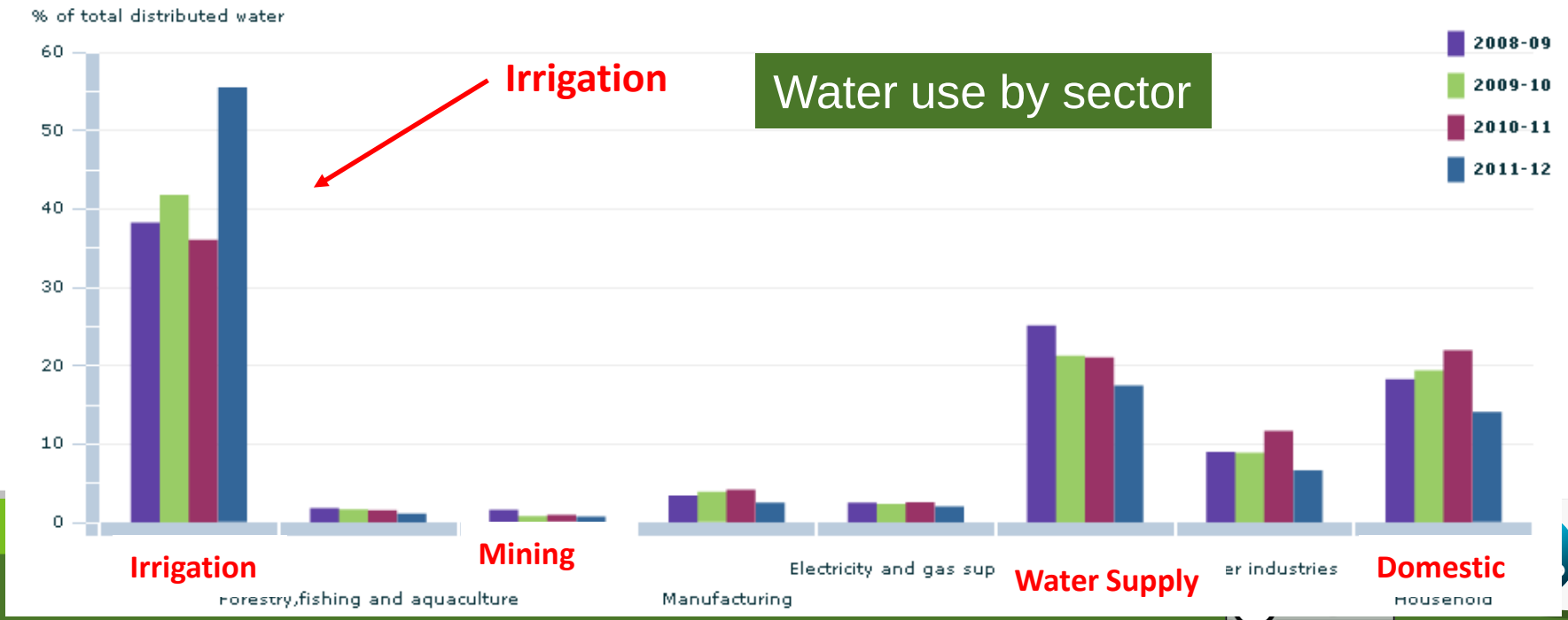
Jorge Peña Arancibia, Juan Pablo Guerschman, Tim McVicar, Albert Van Dijk, Mohammed Mainuddin, Francis Chiew, Justin Hughes, Dushmanta Dutta, Jai Vaze and others

29 October 2014

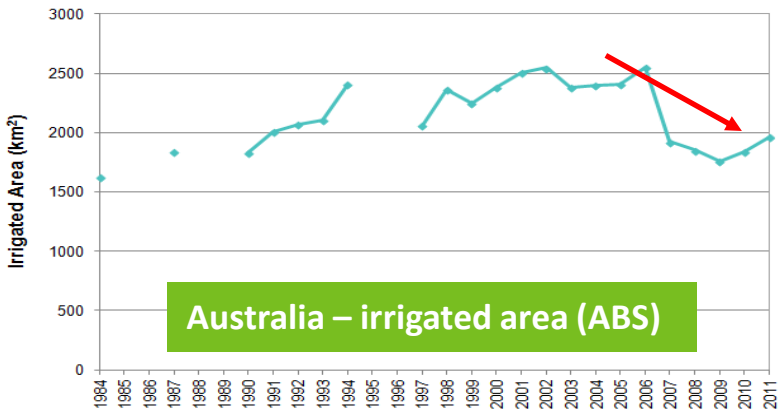
CSIRO LAND AND WATER FLAGSHIP

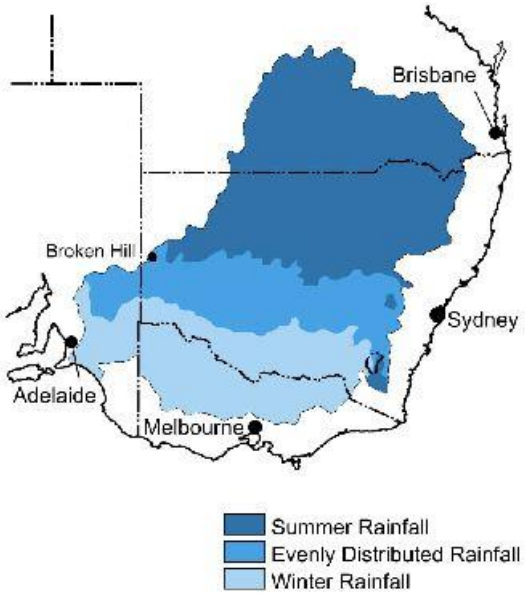
Irrigated Agriculture (2011–2012): facts and figures (ABS)

- Only 0.5% of the total agricultural land (21,000 km^2).
- 28% of the gross value of agricultural production ($ 13.4bn).
- 59% of Australia's water consumption (9,418 GL).

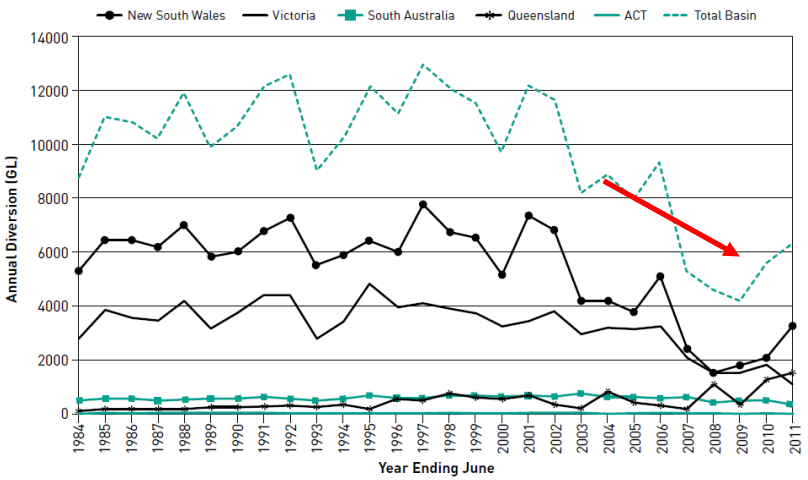


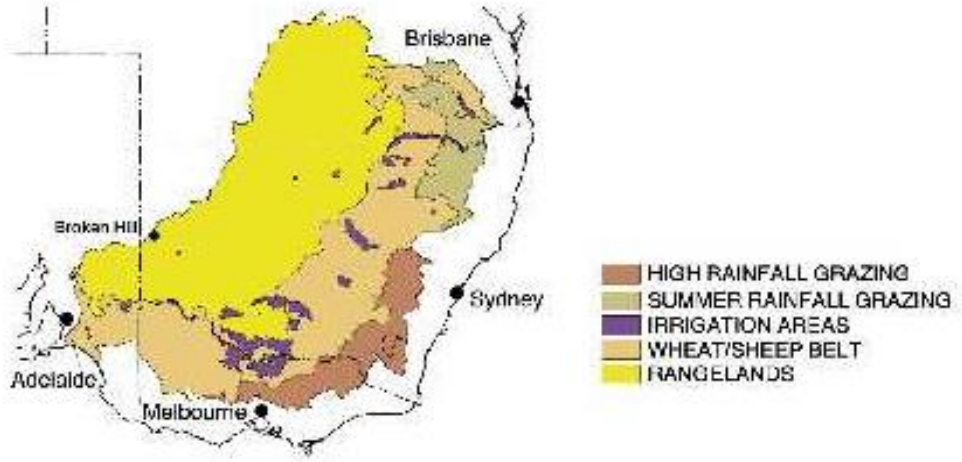
Irrigated agriculture is as variable as climate





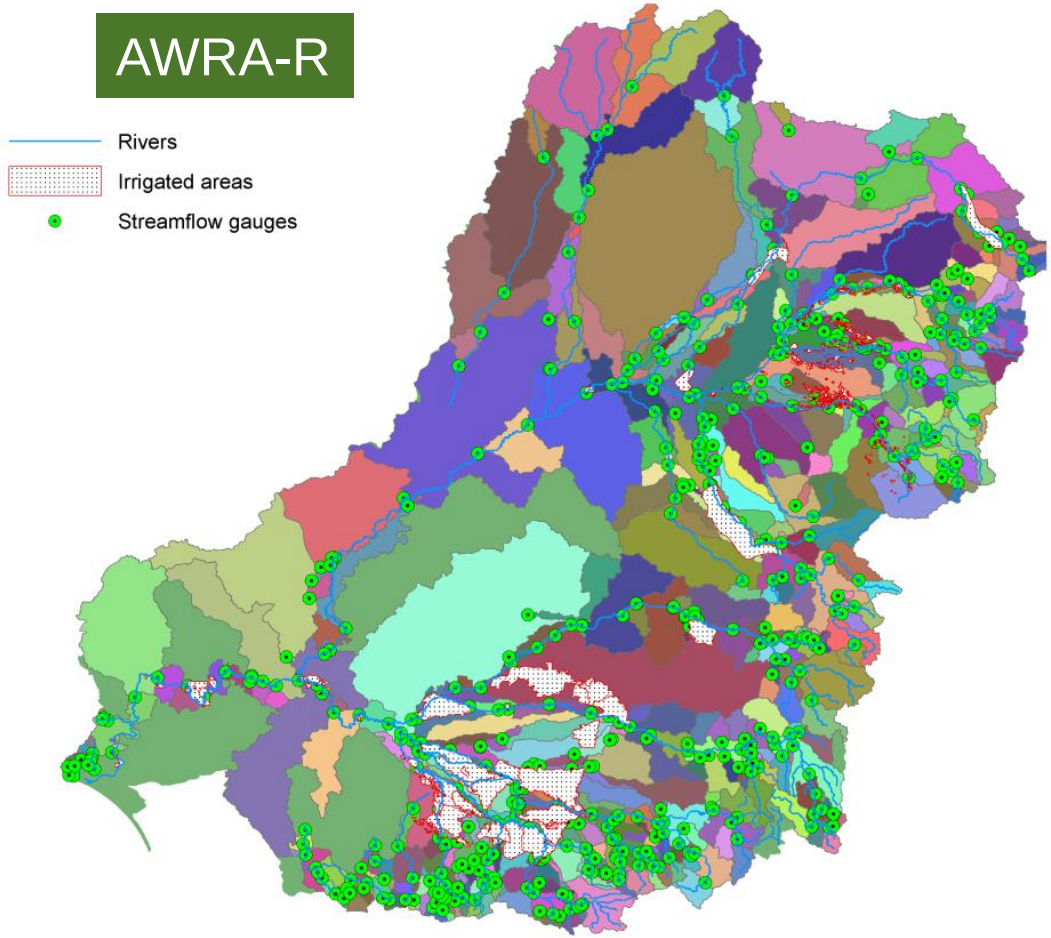
Murray-Darling Basin diversions (MDBA, 2011)

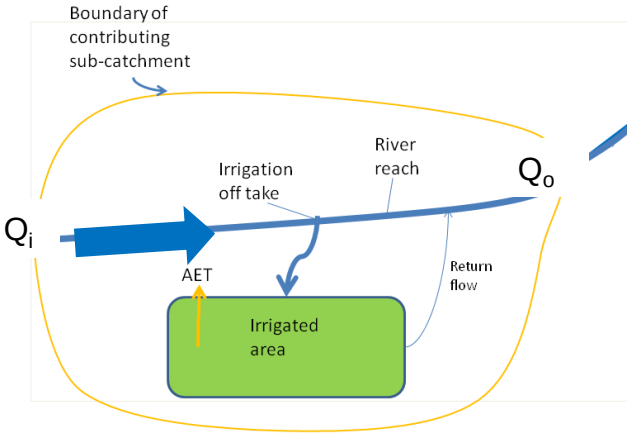




Where and how much water is used?

AWRA-R





$$Q_o = Q_i + Q_t + R_o - D - L + \Delta S_r$$

$$D = Irr_{demand} = \frac{K_c ET_0 - P_{eff}}{I_{eff}}$$

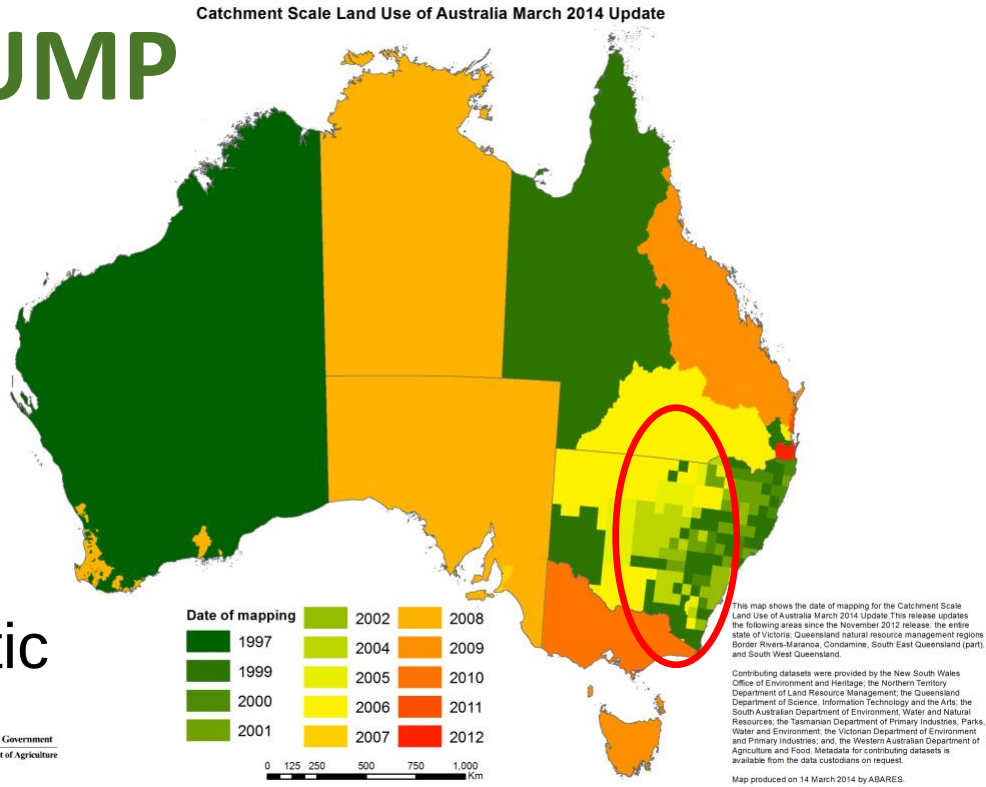
$$Irr_{vol} = Irr_{demand} A_{irr}$$

$$A_{irr} = f(A_{\max}, Irr_{demand}, S_D)$$

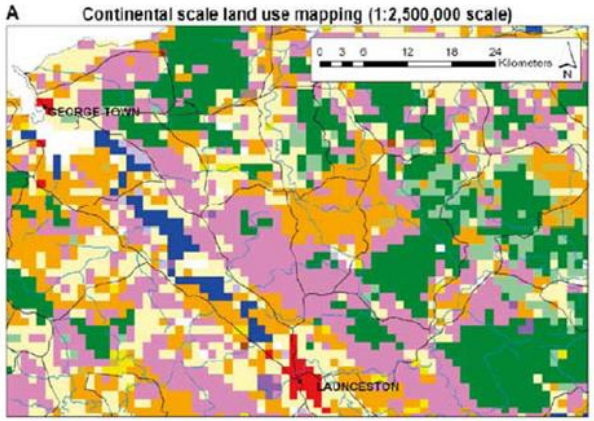
Irrigated areas: ACLUMP

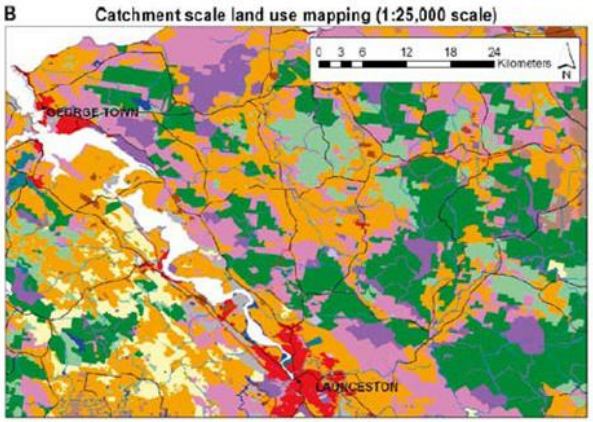
$$A_{irr} = f(A_{max}, Irr_{demand}, S_D)$$

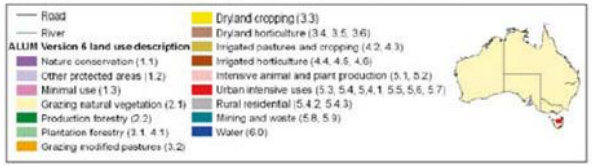
- ❑ Static or infrequent updates
- ❑ National scale: coarse
- ❑ Catchment scale: fine and accurate but outdated and static



Australian Government
Department of Agriculture
ABARES



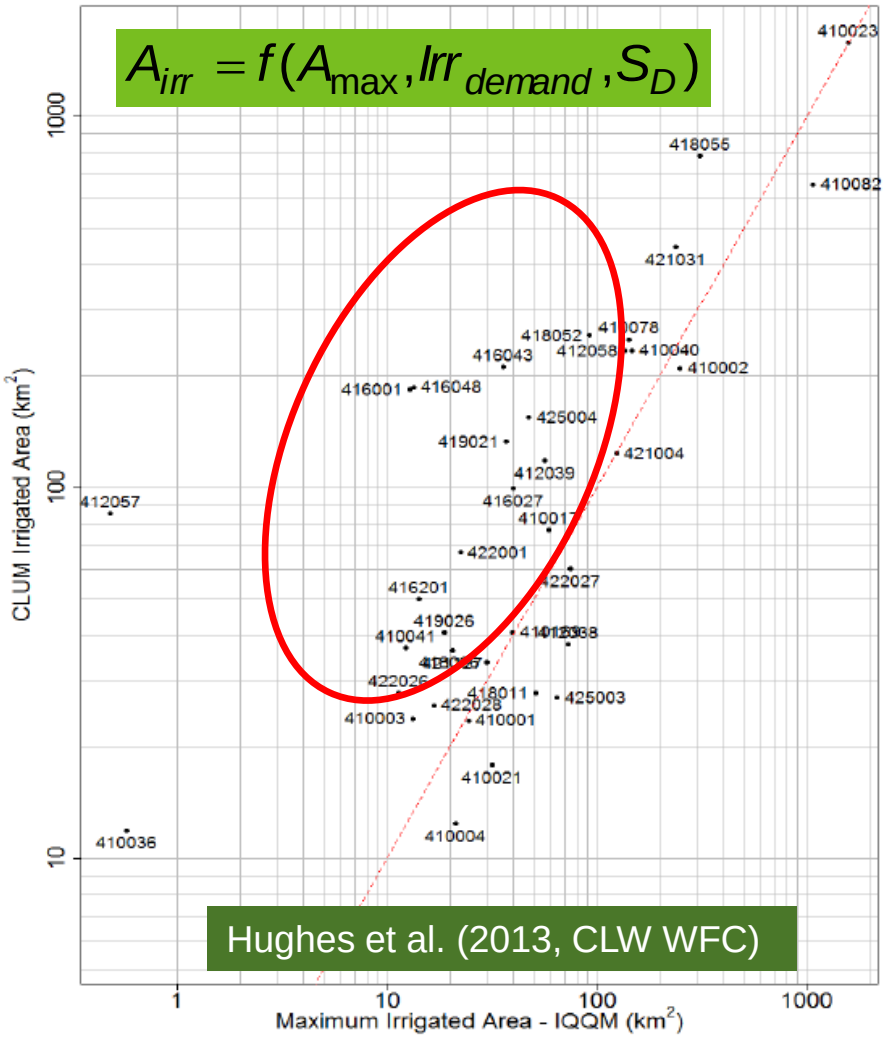




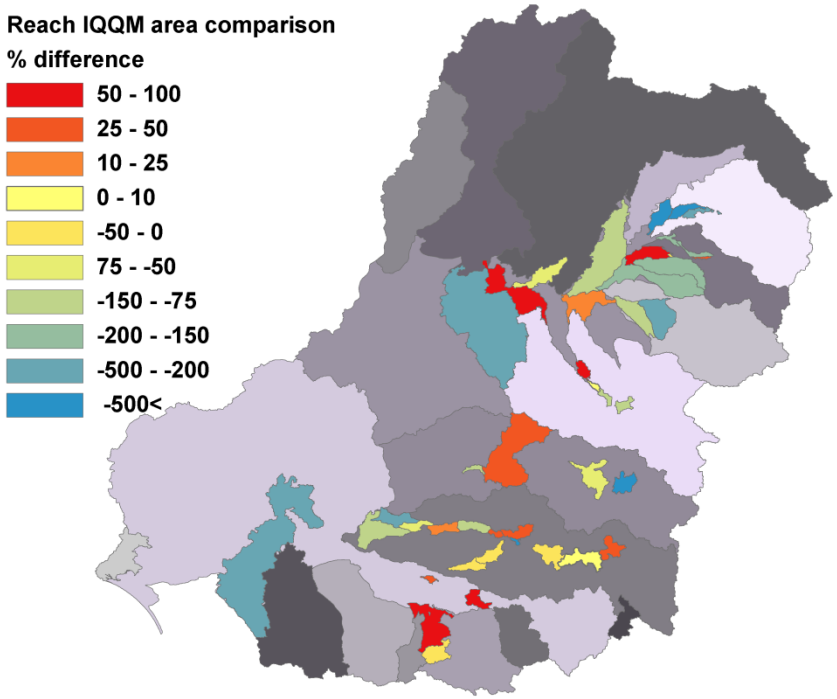
ACLUMP (ABARES)

Irrigated areas and diversions: CLUM *and* IQQM

$$A_{irr} = f(A_{max}, Irr_{demand}, S_D)$$



Hughes et al. (2013, CLW WFC)



- Large under/overestimation
- Questions the accuracy of metered diversions and hence modelled diversions

Evapotranspiration

$$D = Irr_{demand} = \frac{K_c ET_0 - P_{eff}}{I_{eff}}$$

- Locally calibrated for specific crops based on direct measurements
- Direct observations are laborious and costly
- Prescribed crop factors (K_c) on look up tables
- Expert opinion

Diversions (*D*)

$$D = Irr_{demand} = \frac{K_c ET_0 - P_{eff}}{I_{eff}}$$

- Varying degrees of accuracy
- Many areas known to have large inaccuracies
- Records are patchy and short

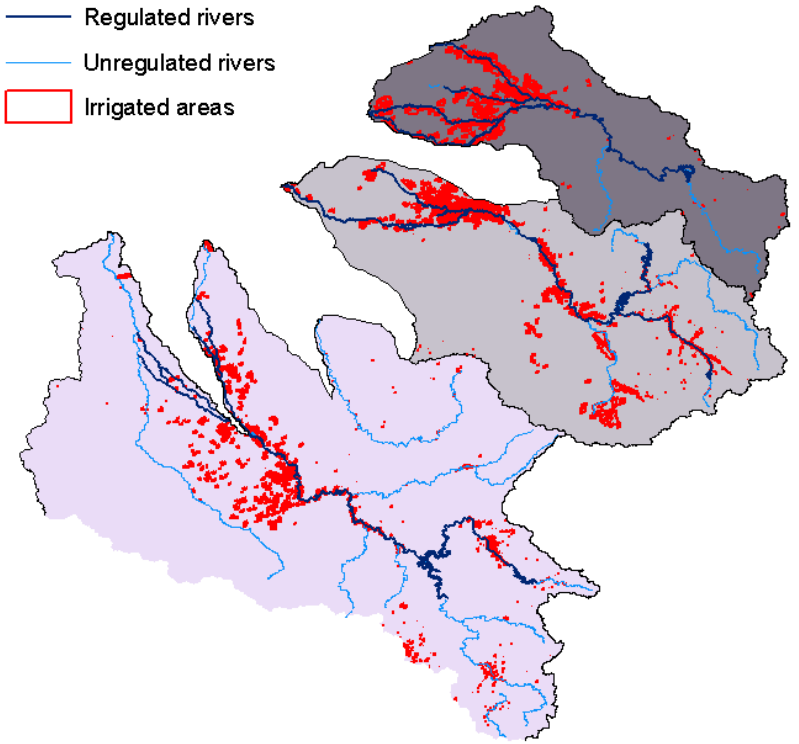
Device	Measurement error (%)
Dethridge wheel	±18
Electromagnetic flow meter	±0.5
Flume or measuring weir	±5

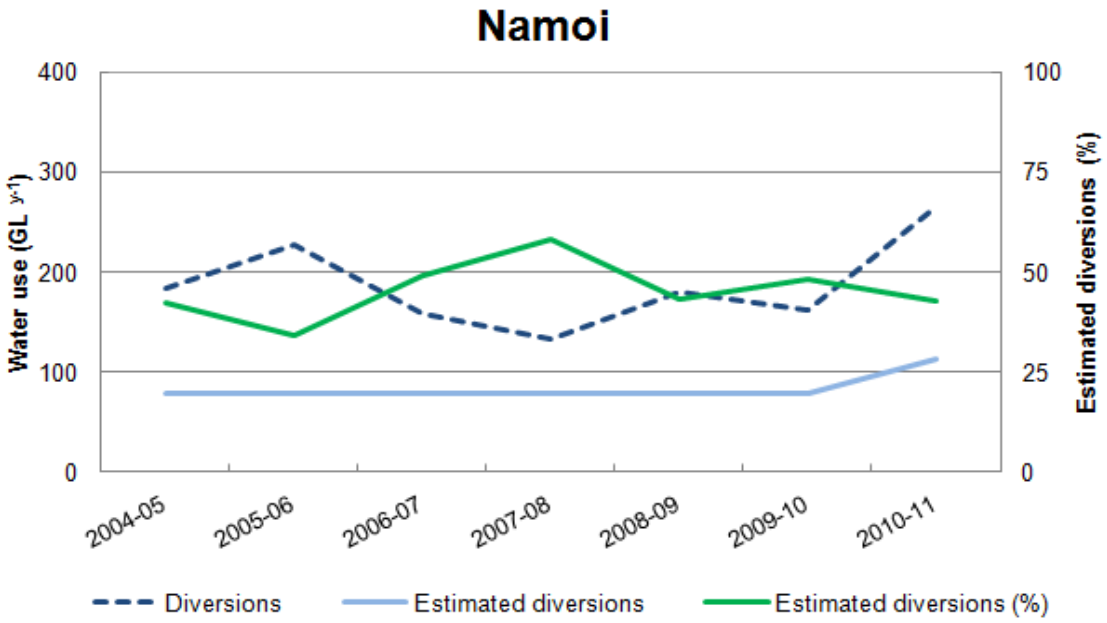
Valleys with dominant large bulk offtake (> 5 GL y^{-1}) inaccuracy
Barwon-Darling/Lower -Darling (NSW)
Lowbidgee (Unregulated) (NSW)
Border Rivers (NSW)
Namoi (NSW)
Macquarie (NSW)
Campaspe (Vic)
Condamine Balonne (Qld)
Lower Murray Swamps (SA)

Source: MDBA (2006)
http://www.mdba.gov.au/sites/default/files/archived/mdbc-media-releases/Bulkofftakes_Registry_Report_18Oct2006v1.pdf

Diversions (*D*)

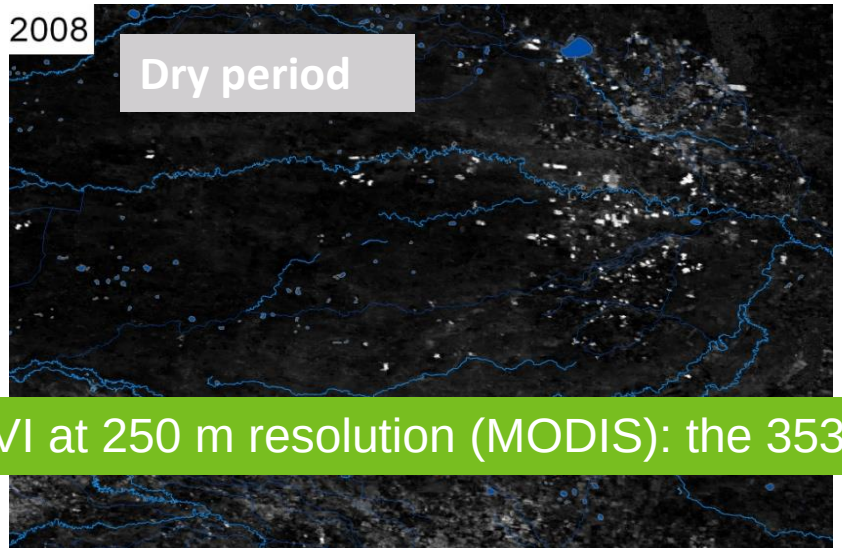
- Large areas not monitored → modelled or estimated
- Undermining management rules
- Suitable measurement devices installed in key areas *and* river models updated
- Slow and expensive

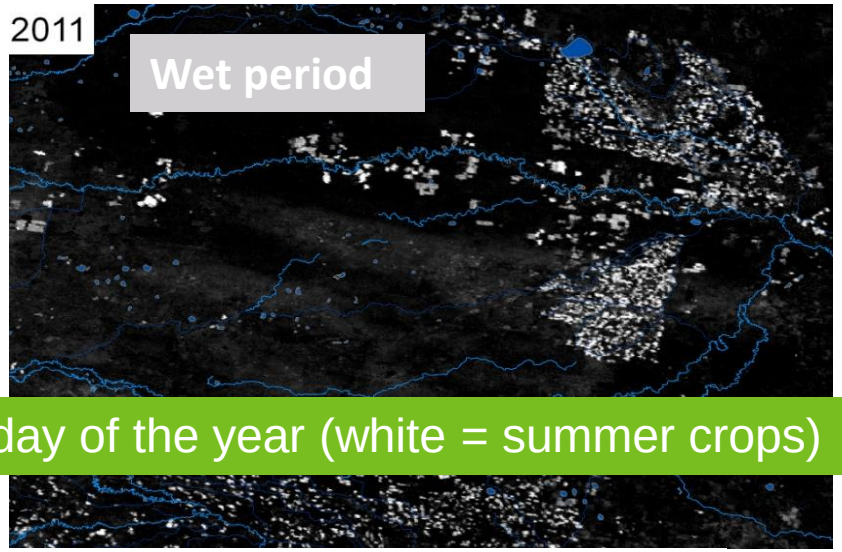




Source: MDBA Cap compliance reports

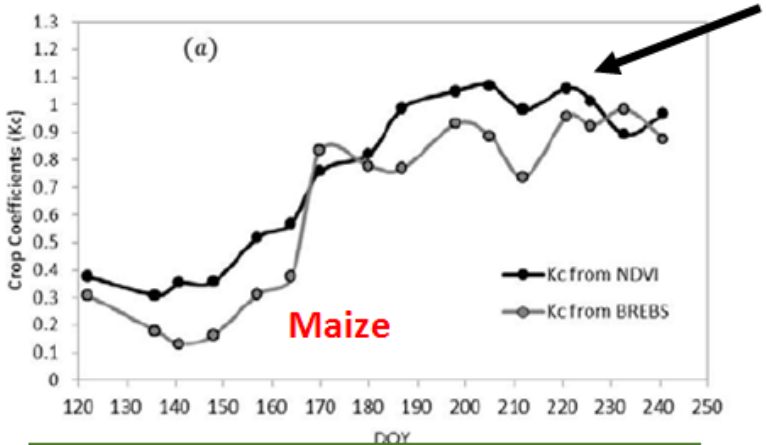
Mapping of irrigation and water use: the role of remote sensing

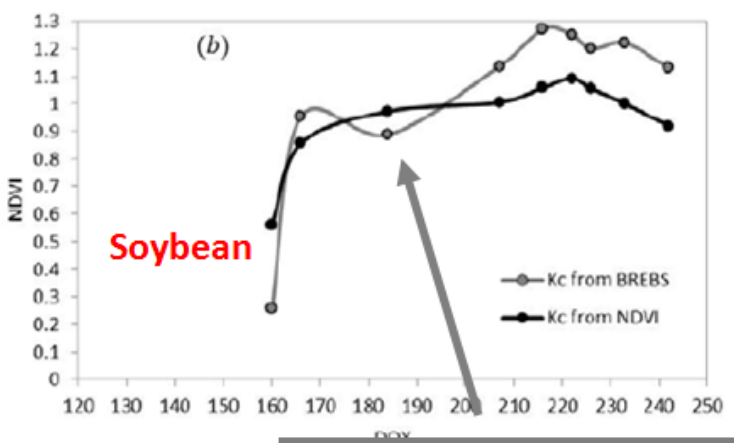




NDVI at 250 m resolution (MODIS): the 353th day of the year (white = summer crops)

Black: Satellite derived K_c *for irrigated maize and soybean*



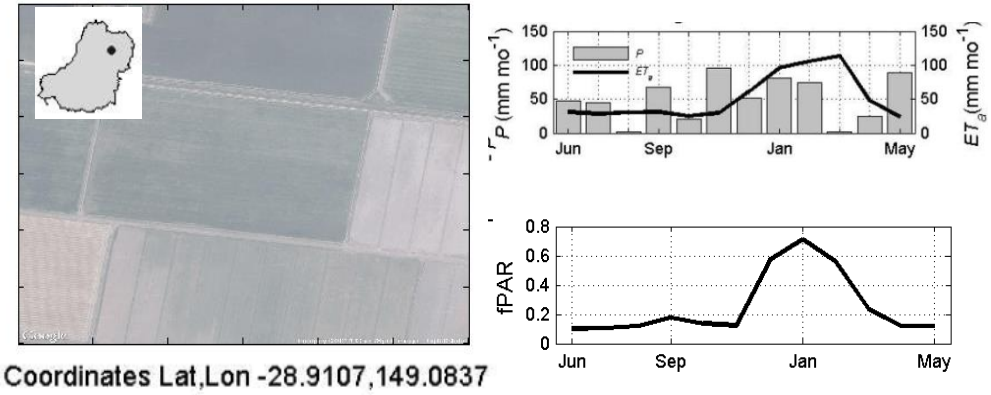


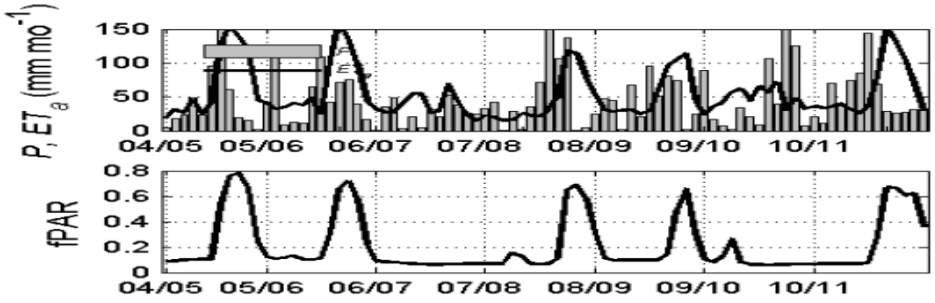
Kamble et al. (2013, RS)

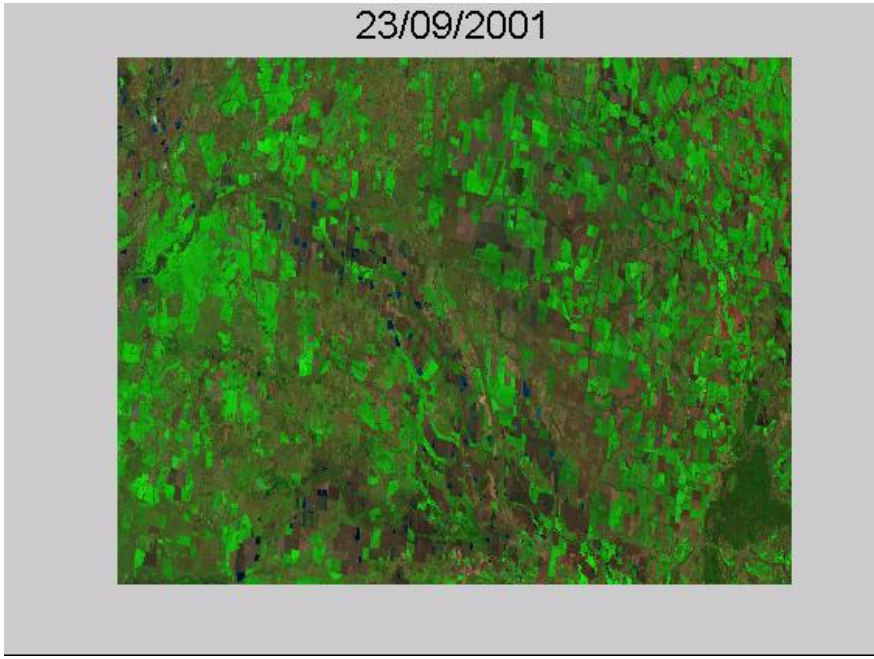
Grey: Flux tower derived K_c

Random forest model: phenology and water use

- **Phenology**: TS remotely sensed inputs of vegetation greenness from MODIS
- **Water use**: TS remotely sensed evapotranspiration estimates





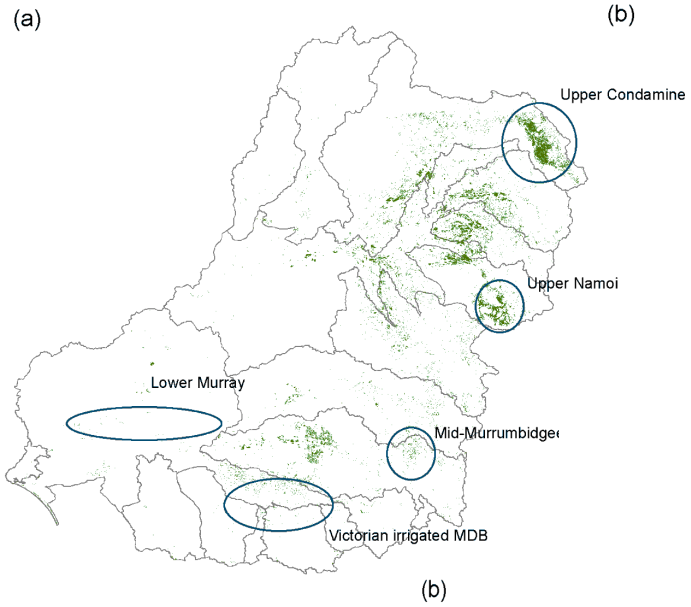


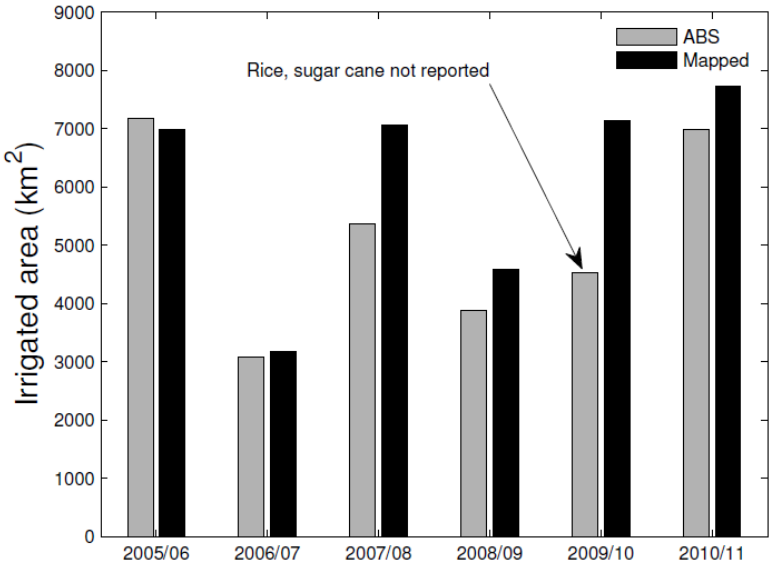
Random Forest model
Monthly values for each water year of:

Total of 120 covariates

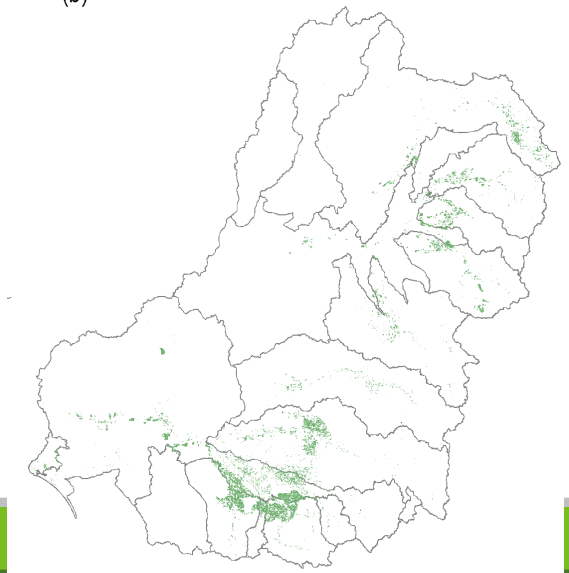
$fPAR_{rec,i}$	$d/dt(fPAR_{rec,i})$
$fPAR_{per,i}$	$d/dt(fPAR_{per,i})$
$ET_{a,i}$	$d/dt(ET_{a,i})$
P_i	$d/dt(P_i)$
$ET_{a,i}$-P_i	$d/dt(ET_{a,I}$ -$P_i)$

Independent evaluation: maps and statistics





Composite map of irrigated areas for 2004–2010 *versus* static map

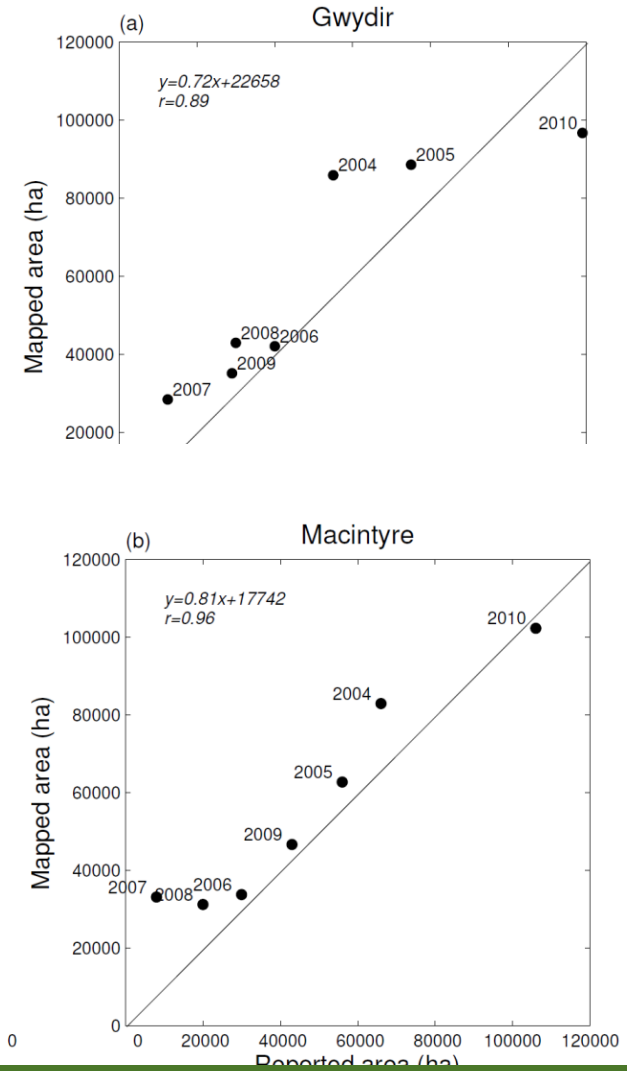


Yearly basin-wide statistics

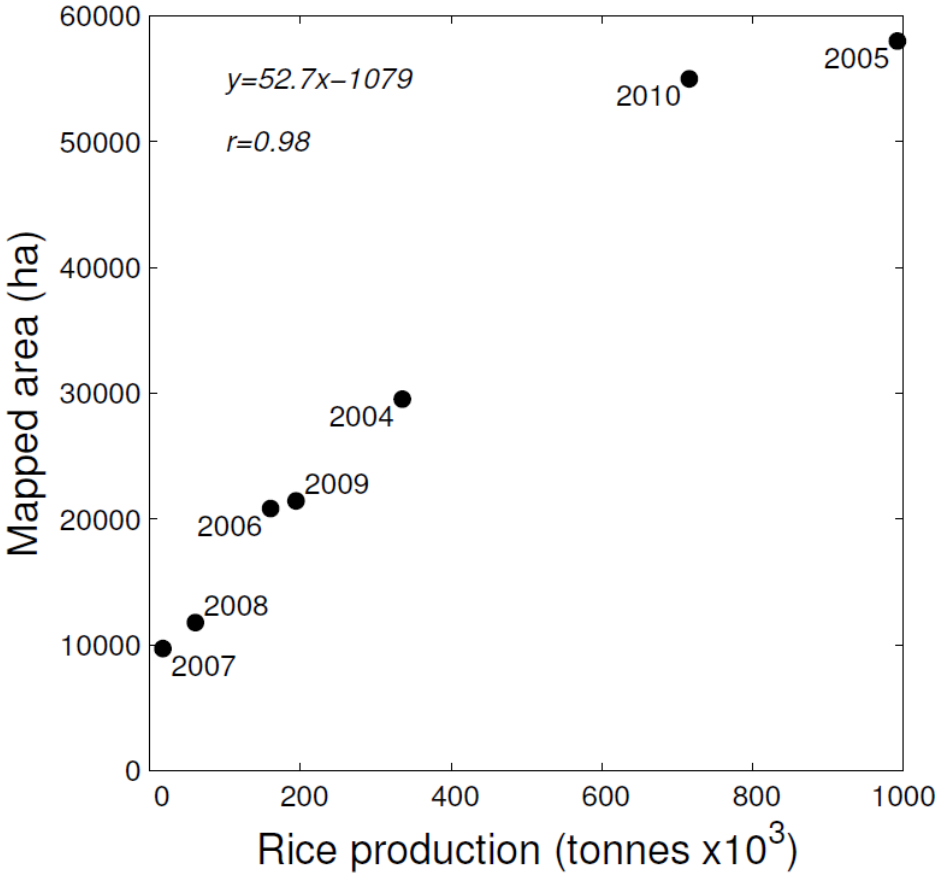
❑ Difference was less than 15% with some exceptions

Peña-Arancibia et al. (2013, RSE)

Independent evaluation: areas and production

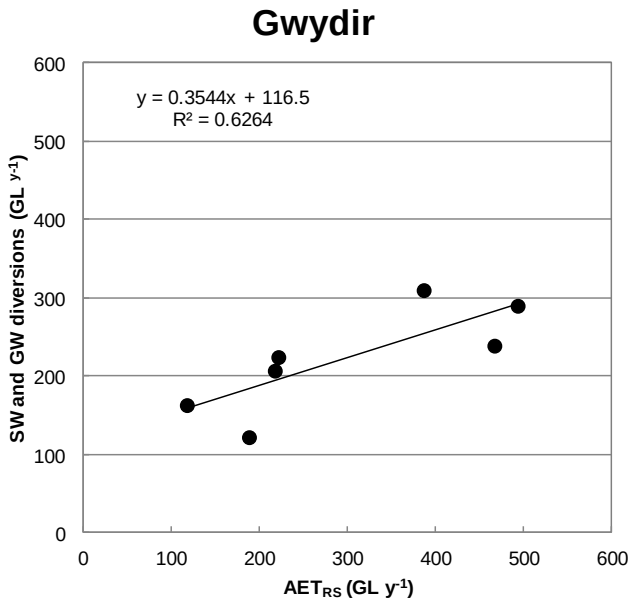


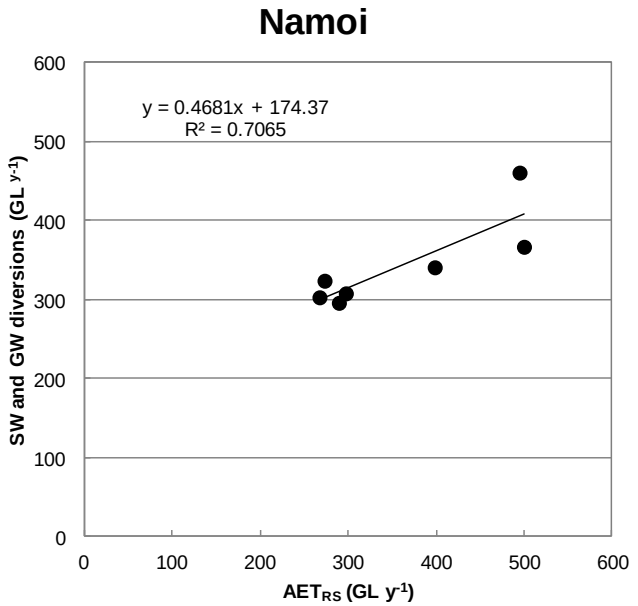
Reported cotton irrigated areas

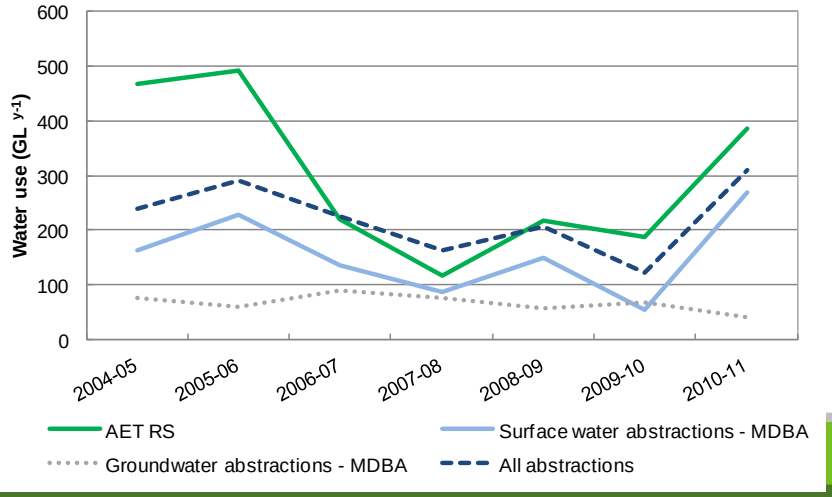


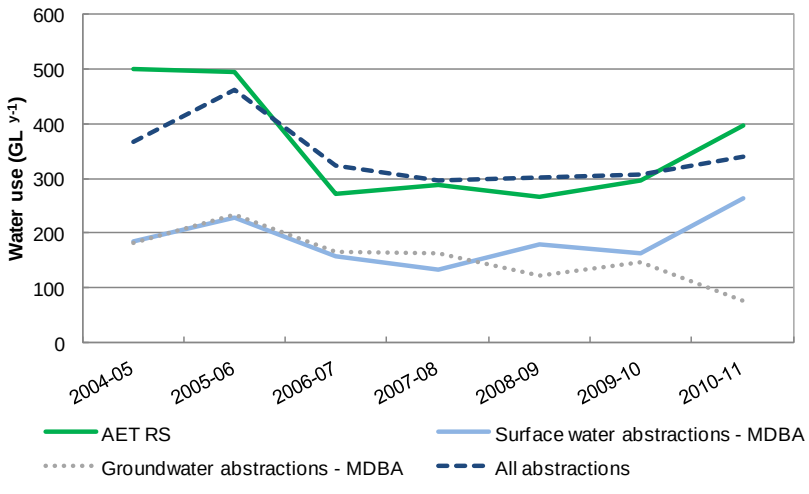
Reported rice production

Independent evaluation: sub-basin Et_a volumes *vs* recorded diversions + groundwater use

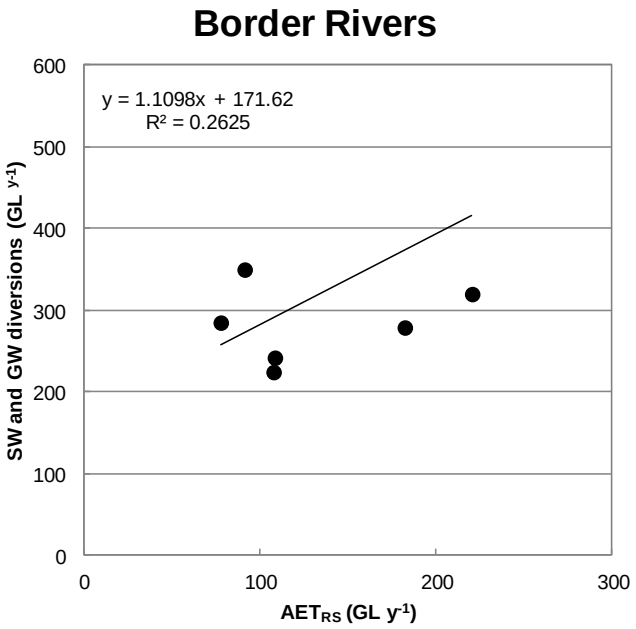


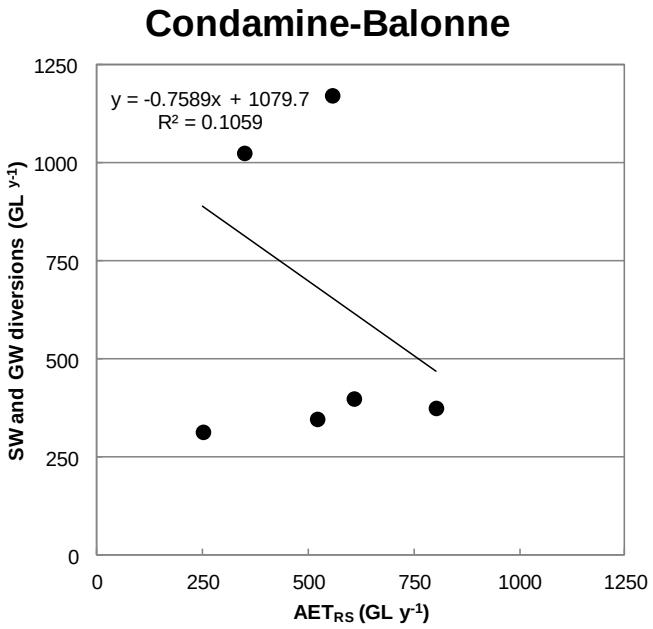


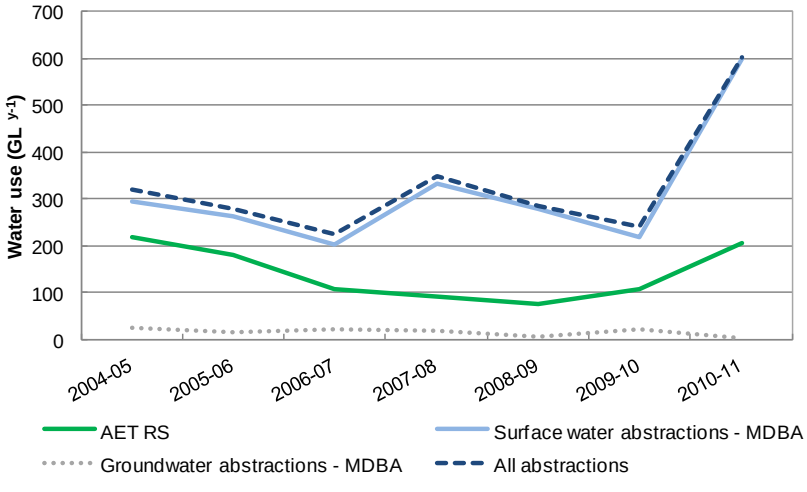


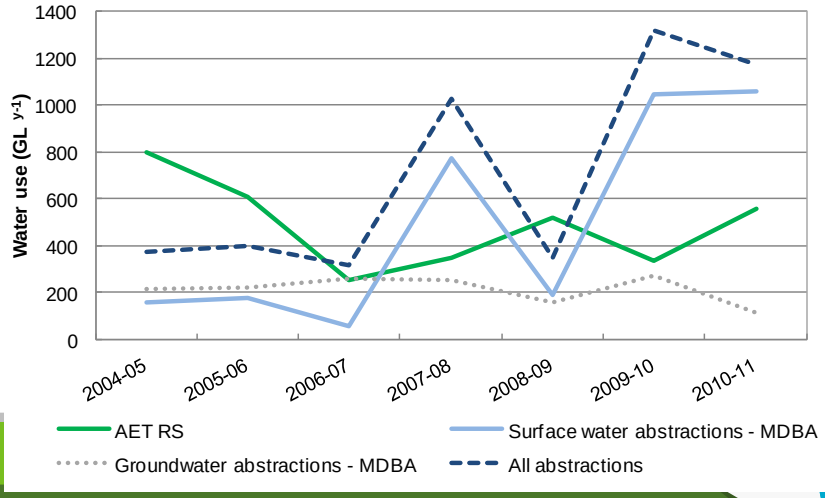


Independent evaluation: sub-basin Et_a volumes *vs* recorded diversions + groundwater use

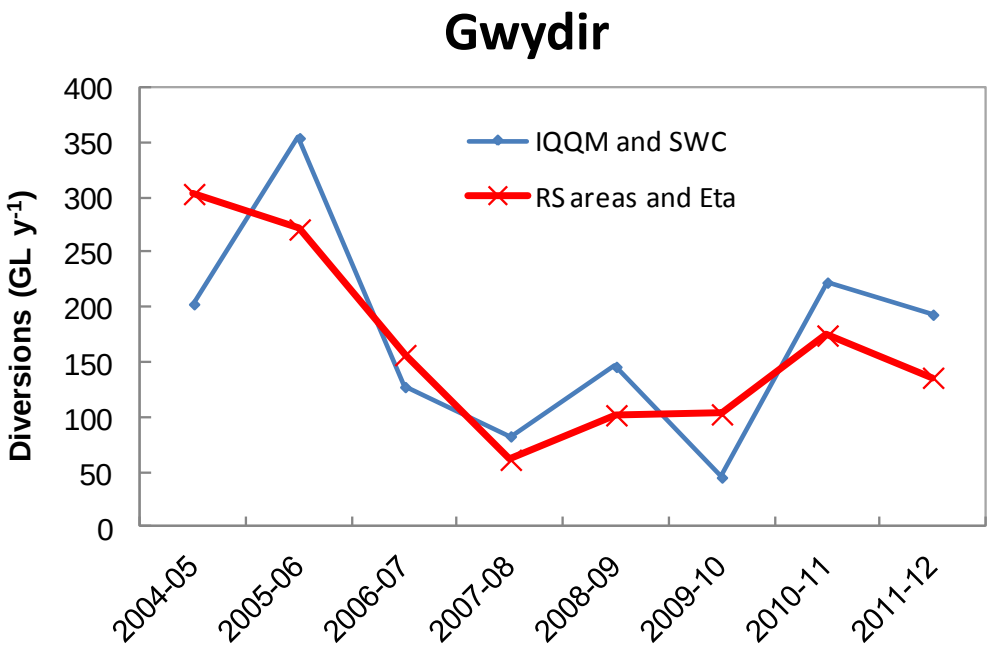








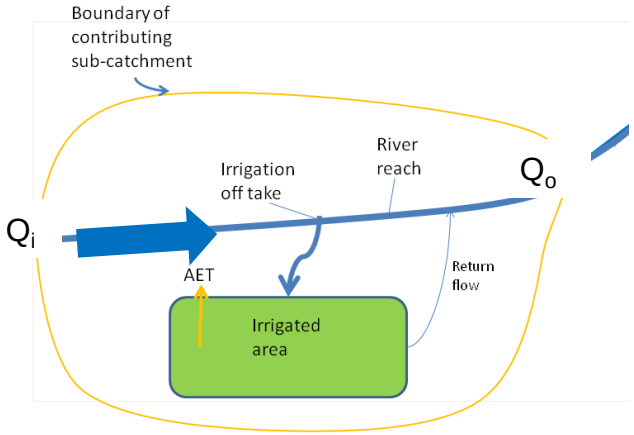
Independent evaluation: simplified hydrology model



$$Q_o = Q_i + Q_t + R_o - D - L + \Delta S_r$$

$$D = Irr_{use} = \frac{K_c ET_0 - P_{eff}}{I_{eff}}$$

$$Irr_{vol} = Irr_{use} A_{RS}$$

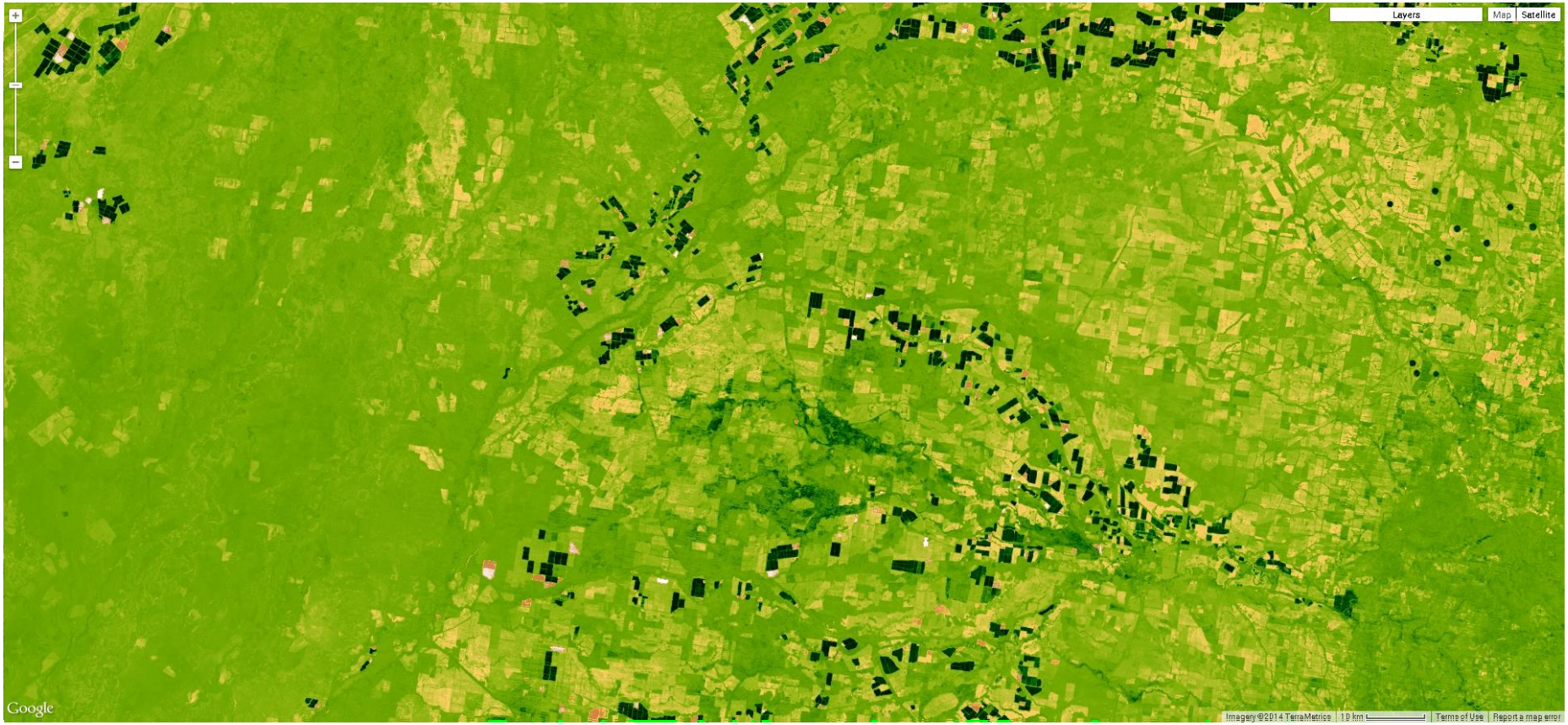


- Simplified river reach model to estimate diversions
- Three reaches in the Gwydir for the years 2004/05 to 2010/11
- Irrigated areas and Et_a with no calibration

Kirby et al. (2013, WATER RESOUR MAN)

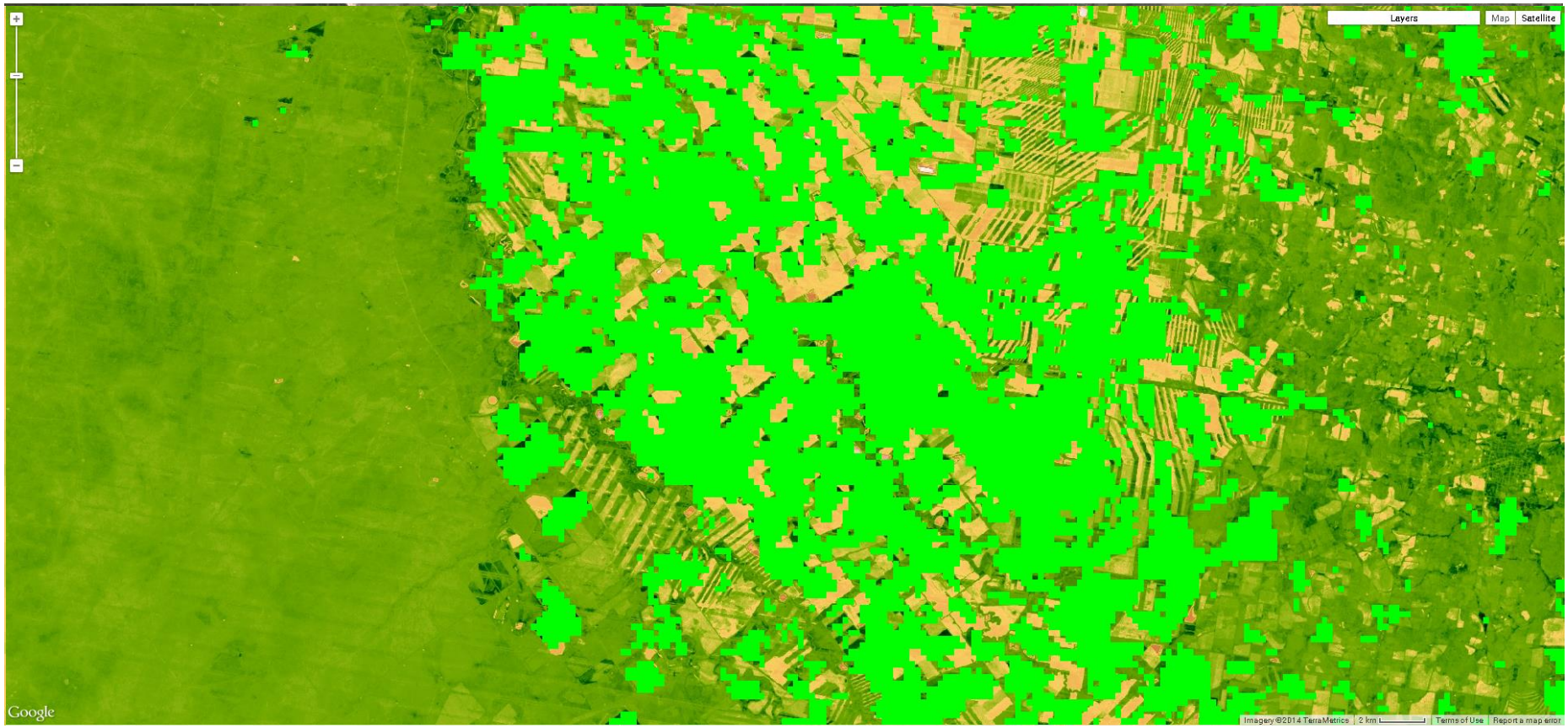
Mapping of irrigation and water use: challenges

Vegetation which mimics irrigation (e.g. floodplains in the north)



Mapping of irrigation and water use: challenges

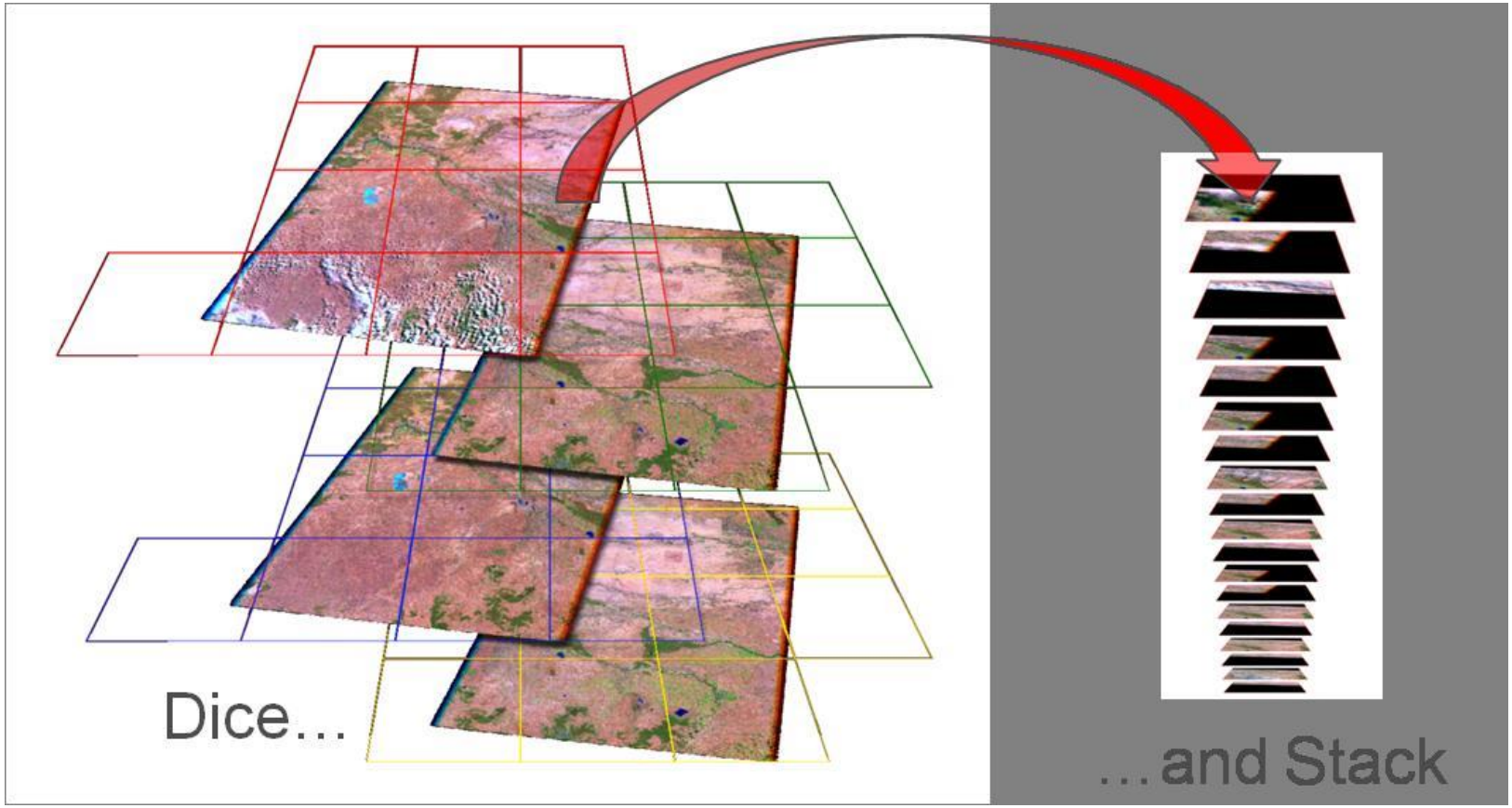
Medium spatial resolution compared to the size of irrigated paddocks (e.g. Condamine plains)



Mapping of irrigation and water use: challenges

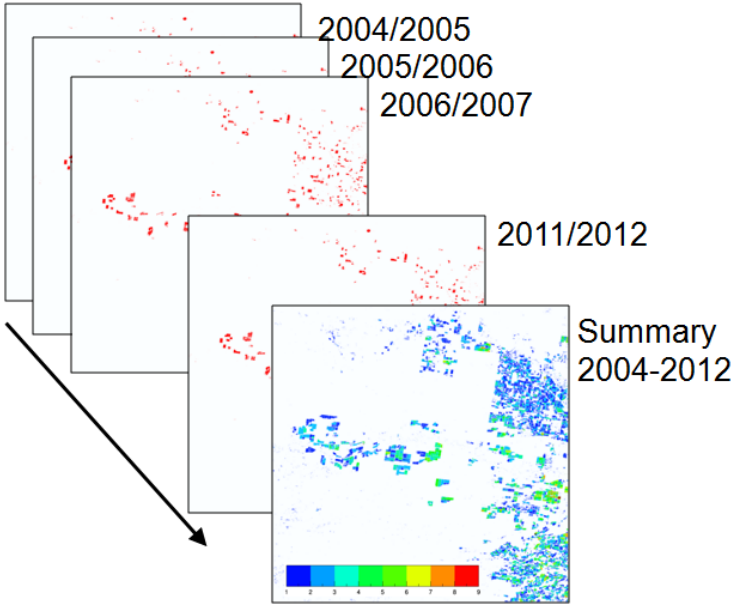
- Temporal resolution for some irrigation practices (e.g. dairy regions in Victoria)
- Including all irrigated types: fruit trees, horticulture, winter irrigation

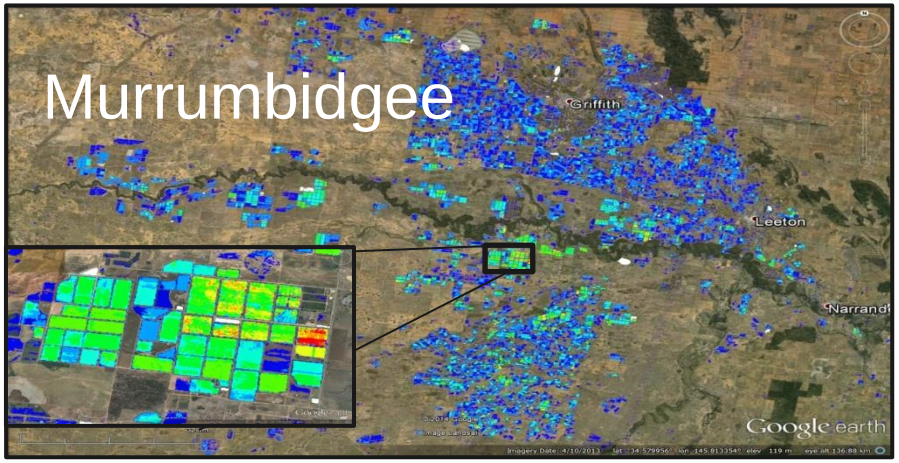
Mapping of irrigation and water use: opportunities

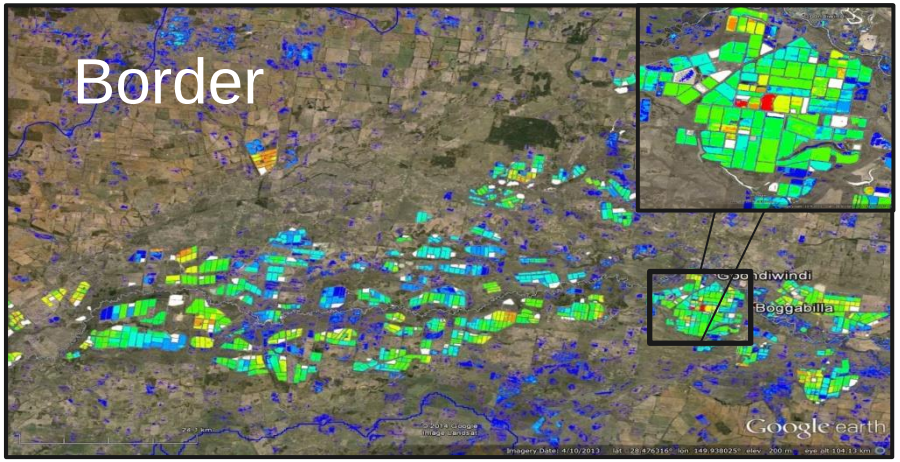


Enter the Australian Geoscience Data Cube

Ongoing work using the datacube



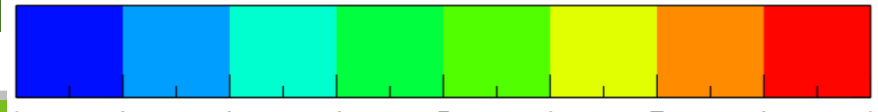




- Monthly Landsat composites
- Original training data
- Random forest with EVI

Guerschman and Peña-Arancibia (2014, OzEWEX)

Number of years with summer irrigation in the paddock



Summary and conclusion

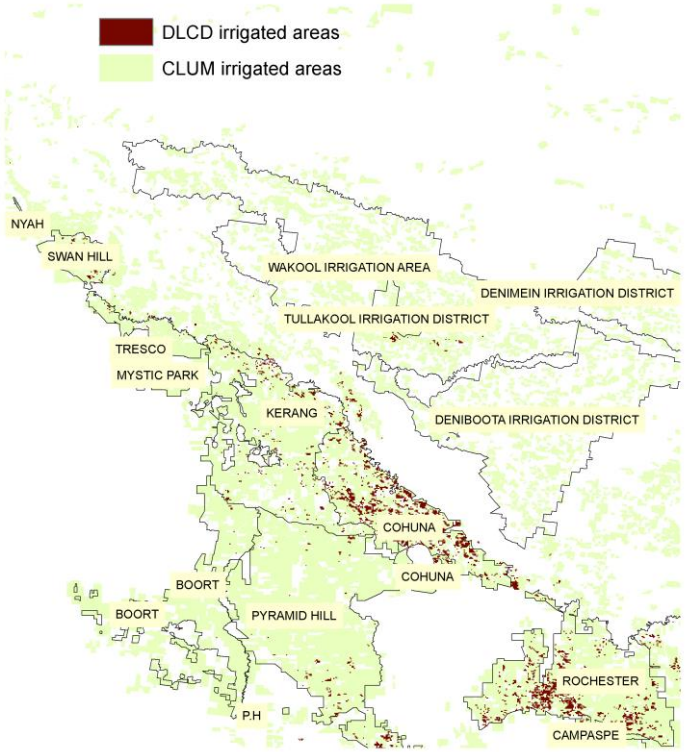
- ❑ High uncertainty in irrigation water use in many areas
- ❑ Uncertainty propagates to resource management
- ❑Remote sensing has the potential to aid in the identification of areas that require better monitoring
- ❑ Remote sensing has the potential to constrain current water use models

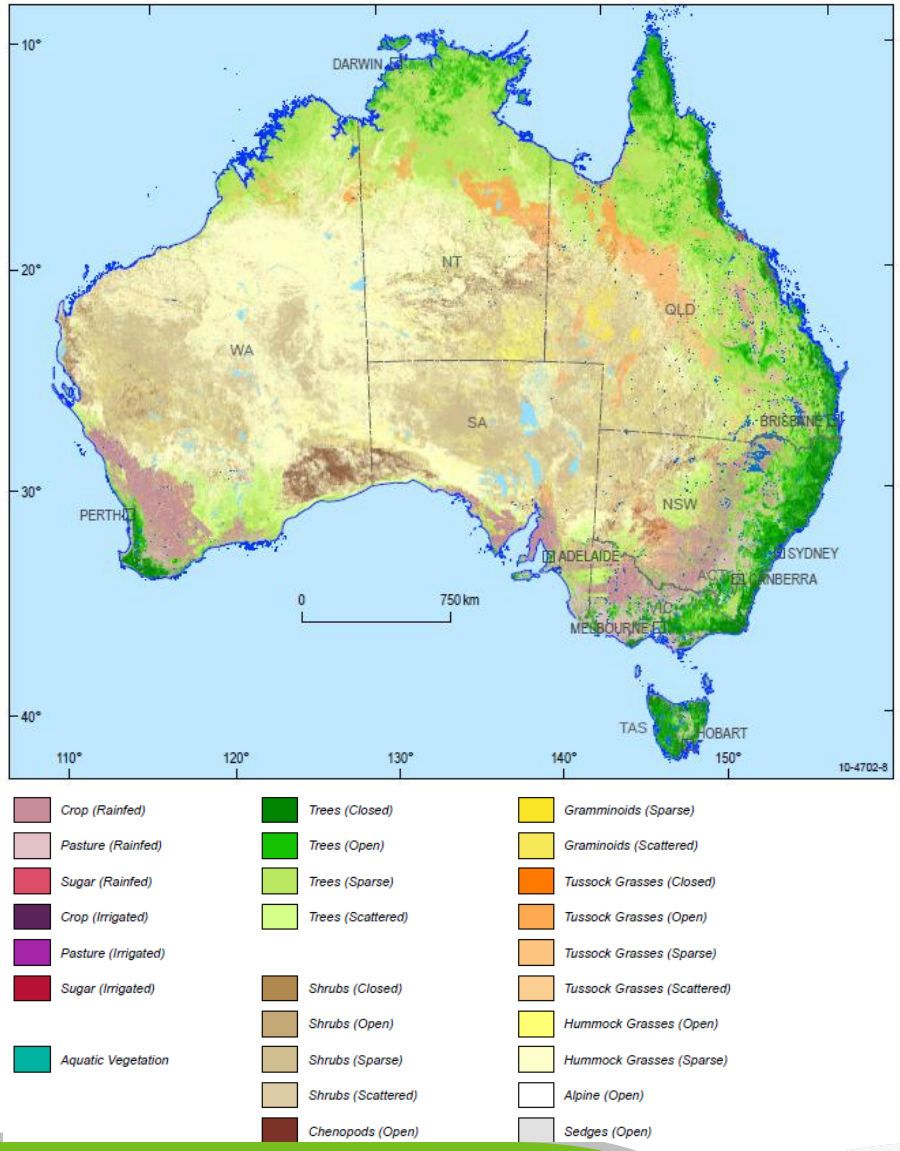
Thank you

Jorge Luis Peña Arancibia
CSIRO Land and Water Flagship
GPO Box 1666, Canberra ACT 2601
Australia
Tel +61 2 6246 5711 | Fax +61 2 6246 5845
Skype: jorge.luis.pena.arancibia

Irrigated areas: Dynamic Land Cover dataset

- Planned biannual updates
- Medium resolution (250 m)
- Inaccurate for irrigated areas



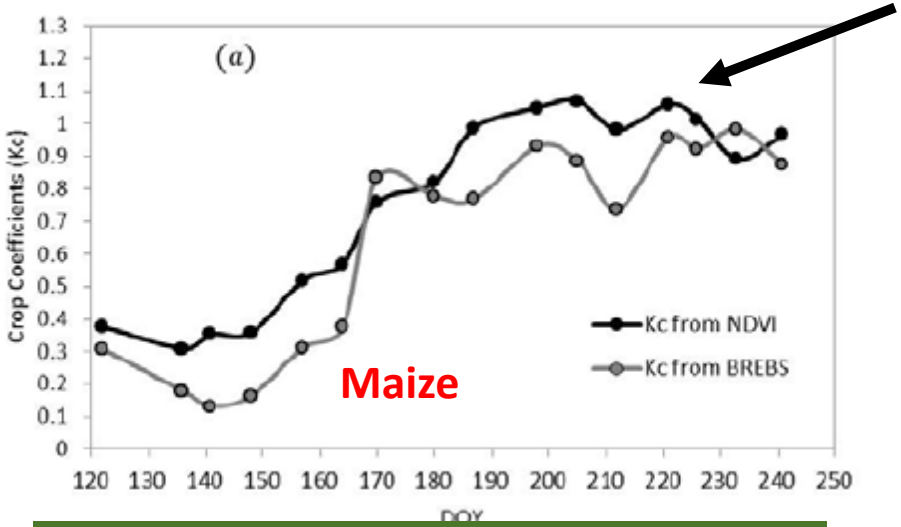


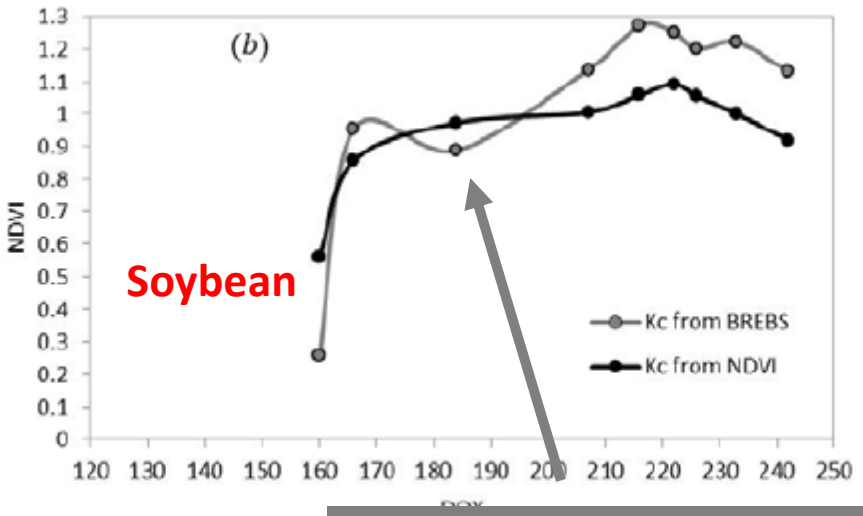
DLCD (GA)

Evapotranspiration

$$D = Irr_{demand} = K_c ET_0 - P_{eff}$$

Black: Satellite derived K_c *for irrigated maize and soybean*



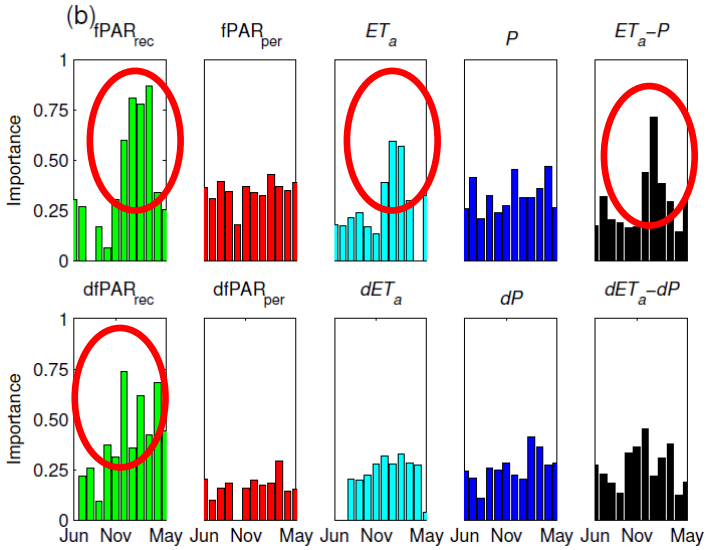


Kamble et al. (2013, RS)

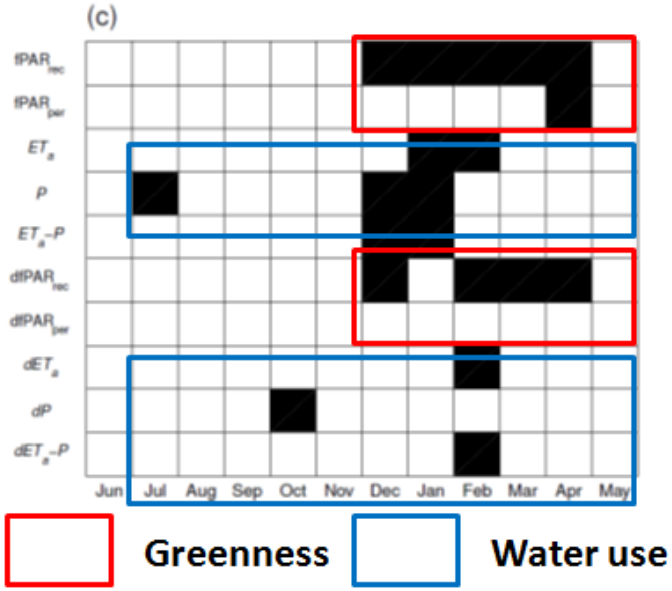
Grey: Flux tower derived K_c

- Locally calibrated for specific crops based on direct measurements
- Direct observations are laborious and costly
- Prescribed crop factors (K_c) on look up tables
- Expert opinion

Random Forest model



'Covariate importance'



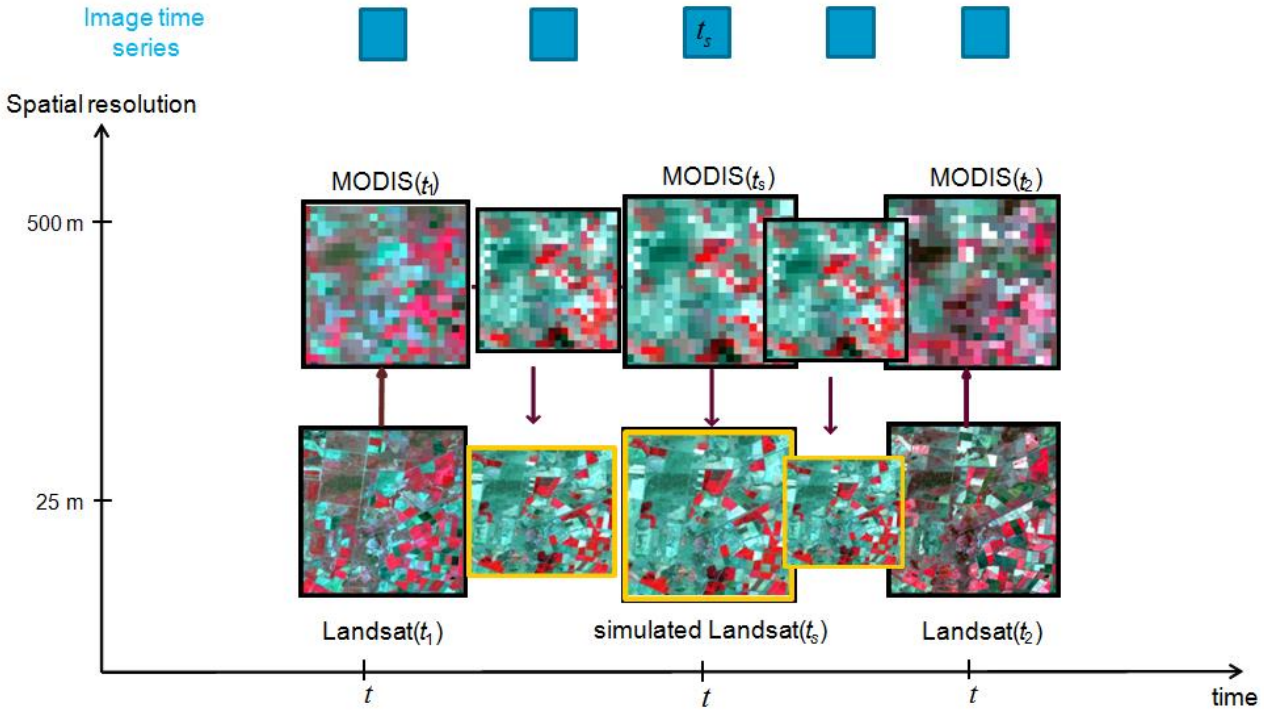
'Optimisation' only 20 covariates

- Training sample for each: average of 332 pixels (roughly 21 km^2)
- Mapping for 2004/05 to 2010/11
- Model with 50% train/predict sample
- 'Pruning' the tree
- Covariance importance and optimisation
- Observed agreement of 99%, kappa of 96%

Mapping of irrigation and water use: challenges

- Difficulties in separating vegetation which mimics irrigation (e.g. floodplains in the north) http://goo.gl/L1mzBI
- Medium spatial resolution compared to the size of irrigated paddocks (e.g. Condamine plains) http://goo.gl/GUHGKi
- Temporal resolution for some irrigation practices (e.g. dairy regions in Victoria)
- Complex irrigation practices

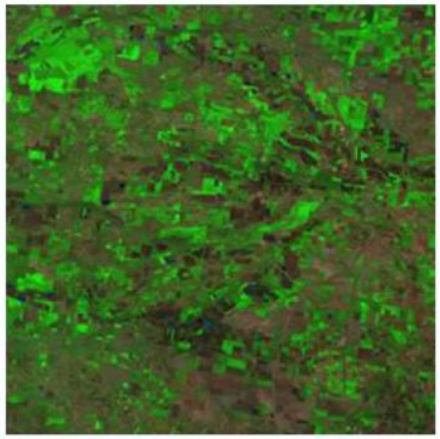
Mapping of irrigation and water use: opportunities



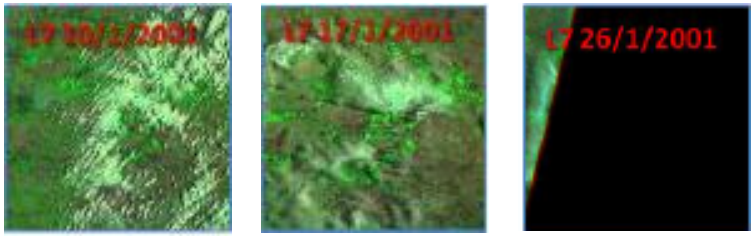
- Temporal resolution for some irrigation practices (e.g. dairy regions in Victoria)

Blending using highly resolved spatial data from one sensor and highly resolved temporal data from another (Emelyanova et al., 2013 RSE)

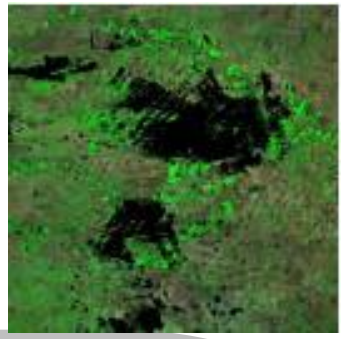
Mapping of irrigation and water use: opportunities



Monthly 'medoid' July 2004

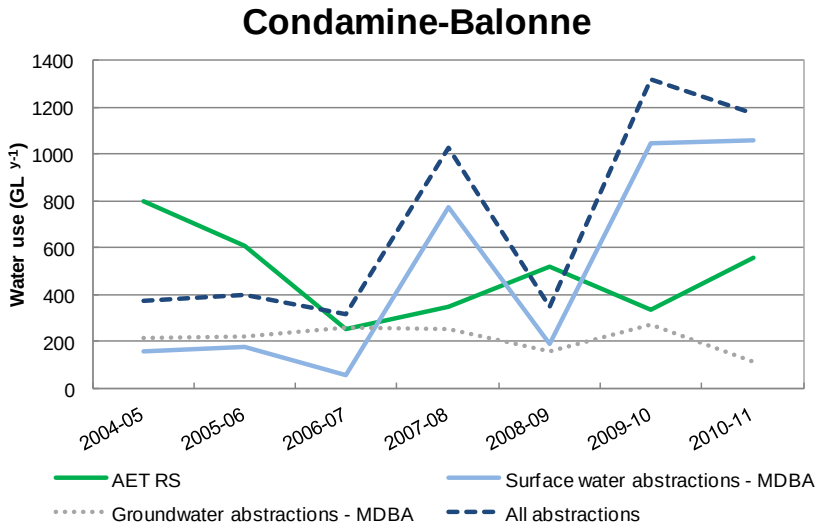


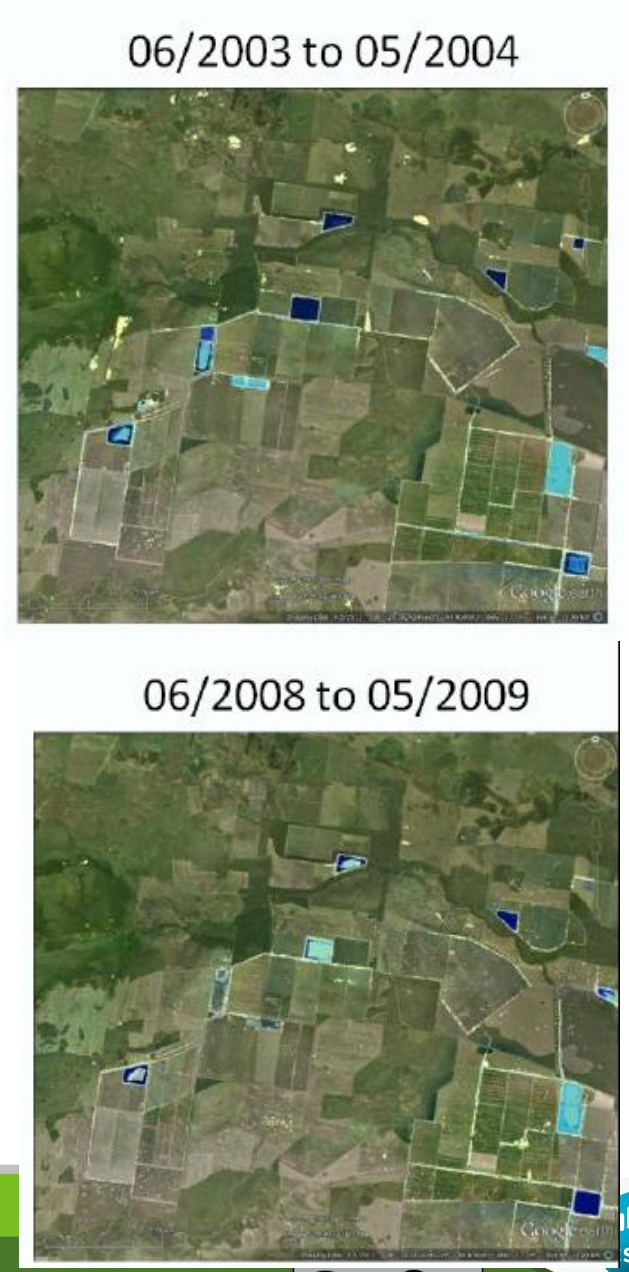
Monthly 'medoid' January 2001. many gaps remain



Aggregating Landsat data into monthly composites: July 2004 and January 2001 (Border Rivers)

Mapping of irrigation and water use: opportunities





- Complex irrigation practices
- Estimation of water diverted to on-farm storages using standing water detection algorithm