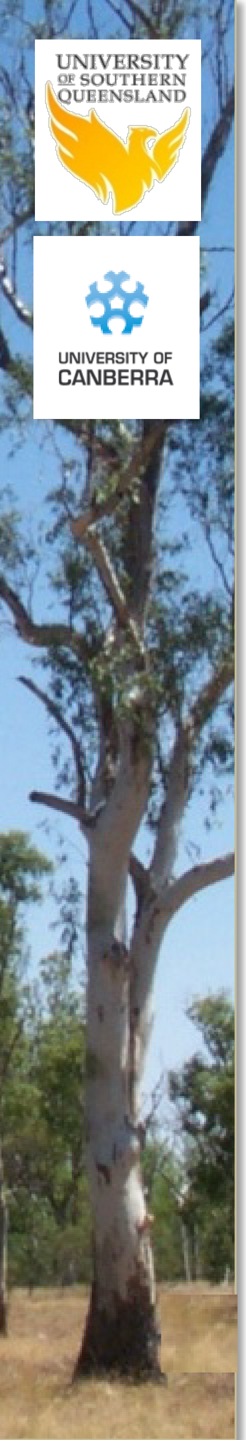

NCCARF Climate Adaptation “Future Challenges” Conference

Gold Coast QLD, 30th September -2nd October 2014,

Groundwater thresholds for drought resilience in floodplain woodlands

A case study from the northern Murray-Darling Basin

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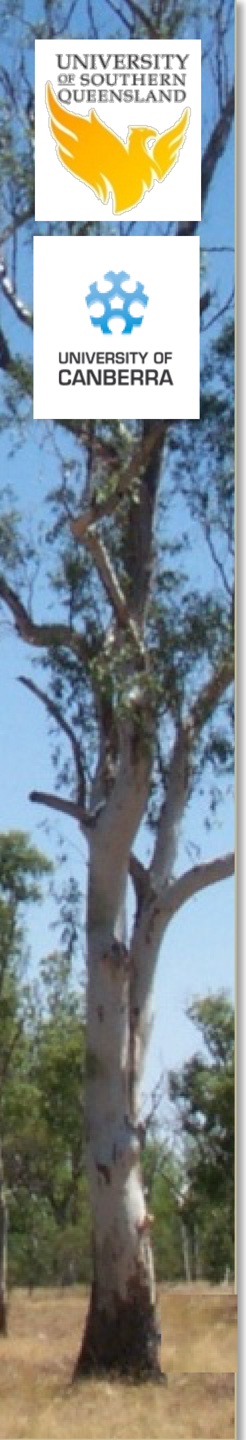
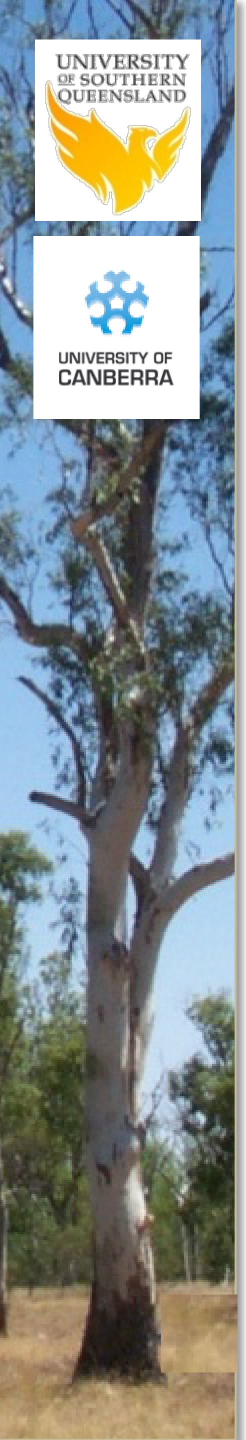
MDB futures Collaborative Research Network



Introduction

- Evidence of poor health of riverine (riparian and floodplain) vegetation in many parts of the world
  - often associated with altered surface flow regimes due to regulation and extraction for human-centred uses
- Management responses:
  - protection of riparian zone from overgrazing
  - provision of environmental flows (overbank flooding)
- BUT lack of understanding of local ecological processes & evidence-based management



Murray-Darling floodplain woodlands

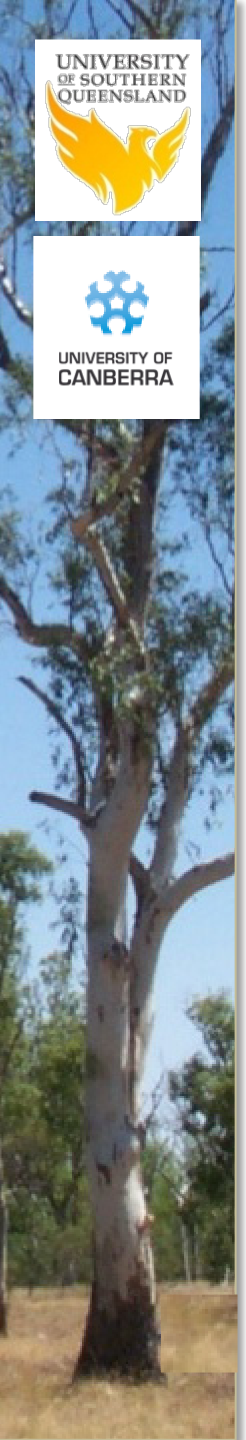
- Dominant floodplain tree species – e.g. river red gum (*Eucalyptus camaldulensis*), poplar box (*E. populnea*)

- Important ecological functions (Reid & Brooks, 2000)
  - habitat, nutrient cycling, hydraulic redistribution within soils
  - keystone species (e.g. ground cover composition, Reardon-Smith 2011)

- Can tolerate long periods of drought; also periodically inundated

  ⇨ adapted to significant phase changes (Colloff & Baldwin 2010)

- Periodic utilisation of (dependence on?) shallow groundwater (e.g. RRG, Mensforth et al. 1994)

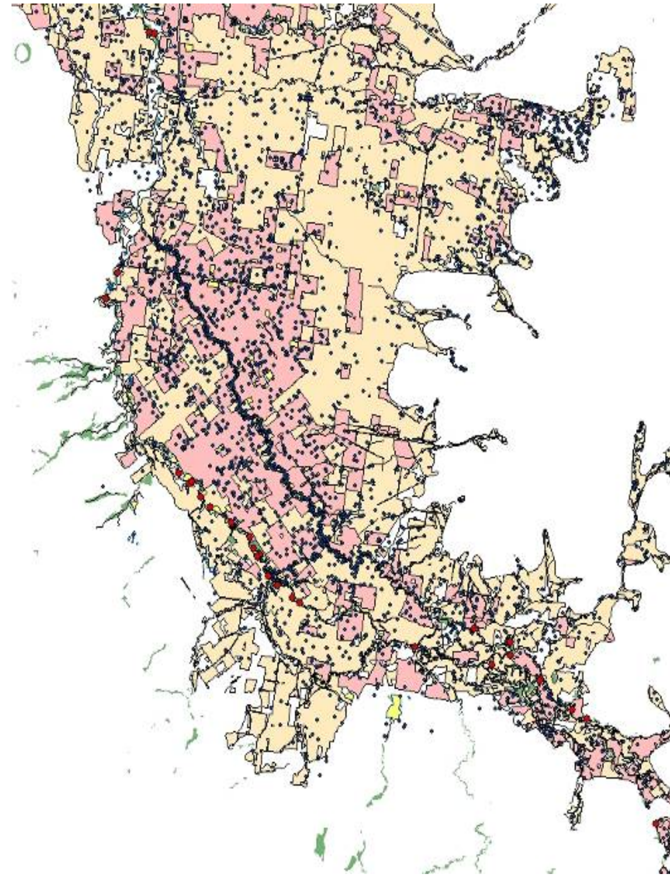


MDB floodplain tree condition

- Declining floodplain tree condition throughout MDB, particularly in agricultural areas (e.g. Banks 2006; Cunningham *et al.* 2011)
- Research focus on altered flow/flooding regimes and salinity as drivers of decline in Sthn MDB (e.g. Cunningham et al. 2011)
- Nthn MBD systems less studied
    - streams ephemeral with significant periods of no-flow
    - recent studies indicate importance of shallow groundwater for floodplain tree condition (Reardon-Smith 2011; Kath 2012; Fritz 2013)
- Shallow groundwater systems may provide an important drought buffer for such ecosystems (e.g. Elmore et al. 2006)

Groundwater use in Condamine

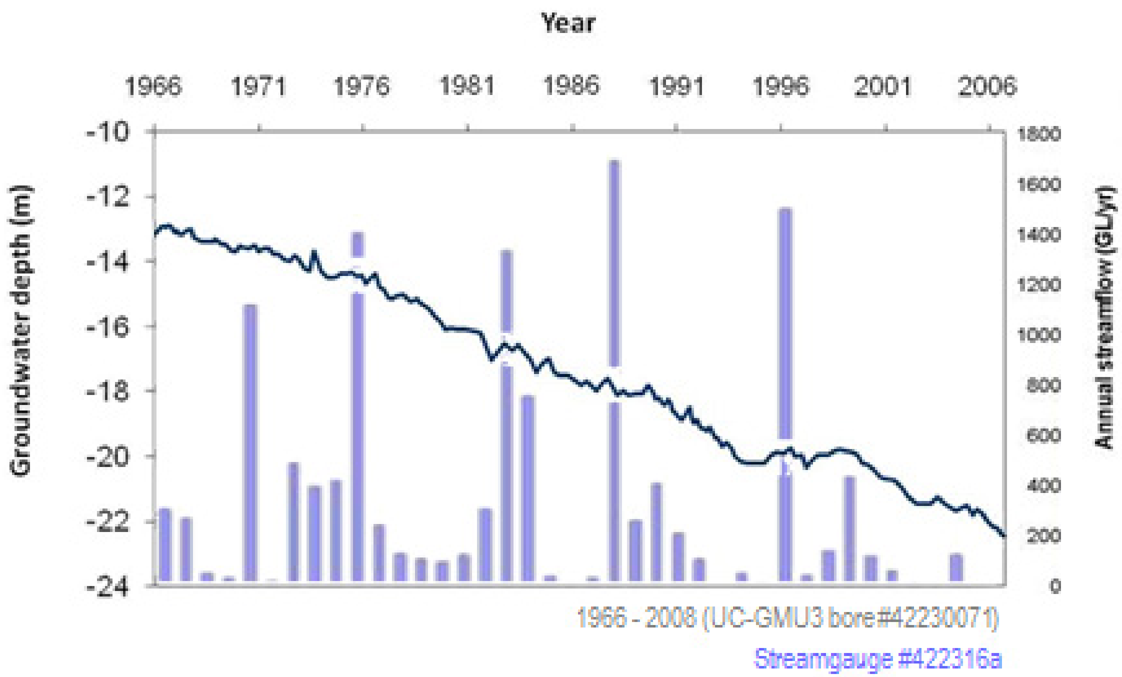
- Irrigation development since 1950s
- Dependent on surface water, groundwater & overland flow
- Managed (GMUs), but significant groundwater decline & lack of recharge evident (CSIRO 2008)



- Groundwater worth ~ $34 billion per year in Australia (Deloitte Access Economics 2013)

Groundwater decline in Condamine

- Decline in groundwater levels in shallow unconfined alluvial aquifers through irrigated cropping areas of the nthn MDB



- Comparable to significant groundwater overdraft reported elsewhere in the world (e.g. Gleeson *et al.* 2012)

Ecological consequences of groundwater decline

- Ecological consequences of groundwater change could be substantial:

➢ long term consequences due to time lags/long response times

➢ potentially difficult to reverse; e.g. aquifer collapse; salinity intrusion; shifts in ecosystem type/function (Busch and Smith 1995; Stromberg et al. 1996; Karam et al. 2012; Mora et al. 2013)

➢ could greatly increase ecological vulnerability to other threats, such as future droughts (e.g. Elmore et al 2006)

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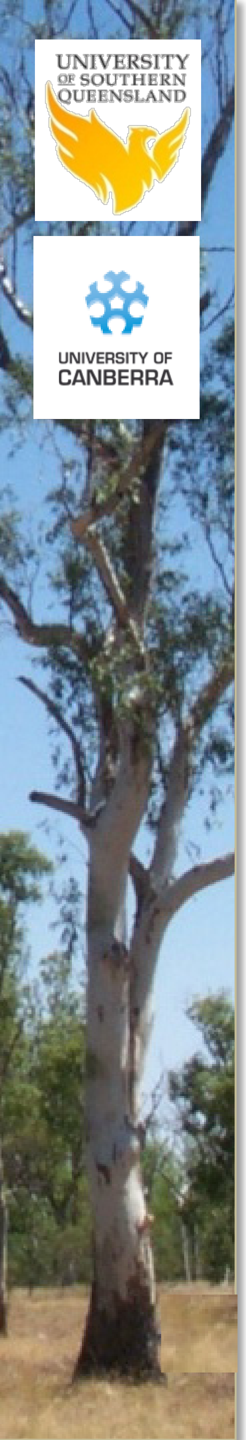
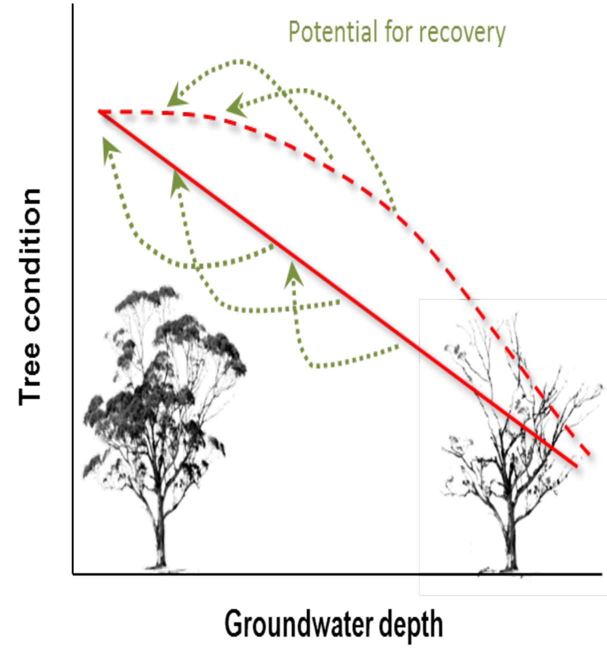
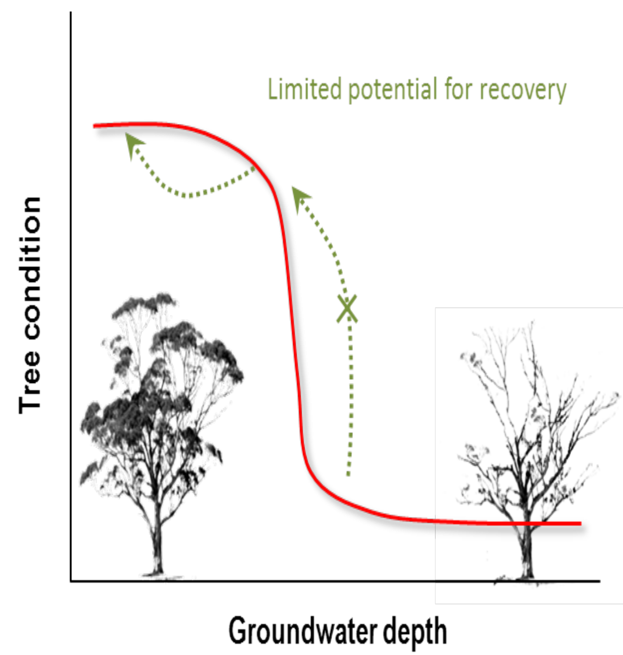
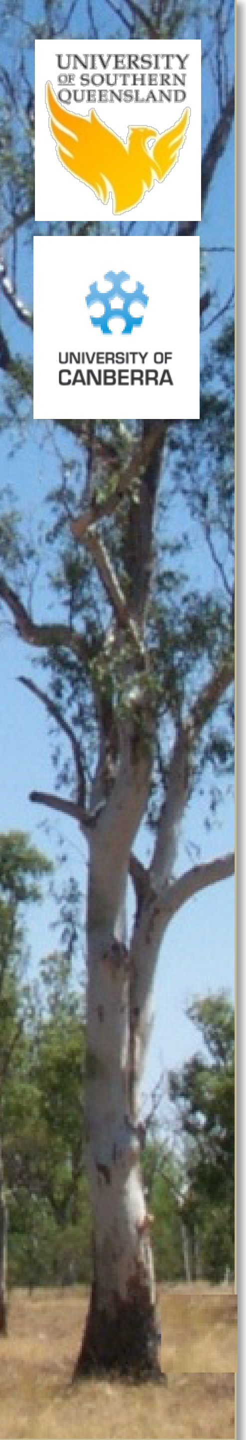


Problem

- Resilience theory suggests ‘tipping points’ or thresholds important (Baker & King 2010; Briske et al. 2010)
  - regime shifts to alternative states (altered composition and function)
  - increased degradation risk
  - altered ecosystem goods and services
  - increased management effort and costs (and potential for poor success)
- But identification of thresholds tricky

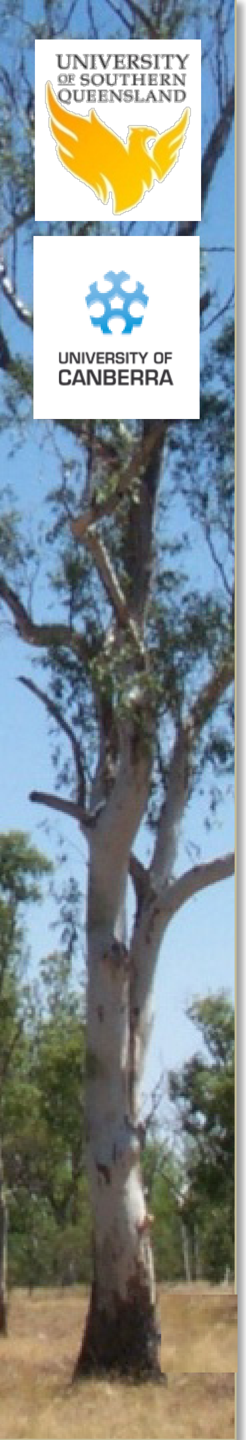






Questions

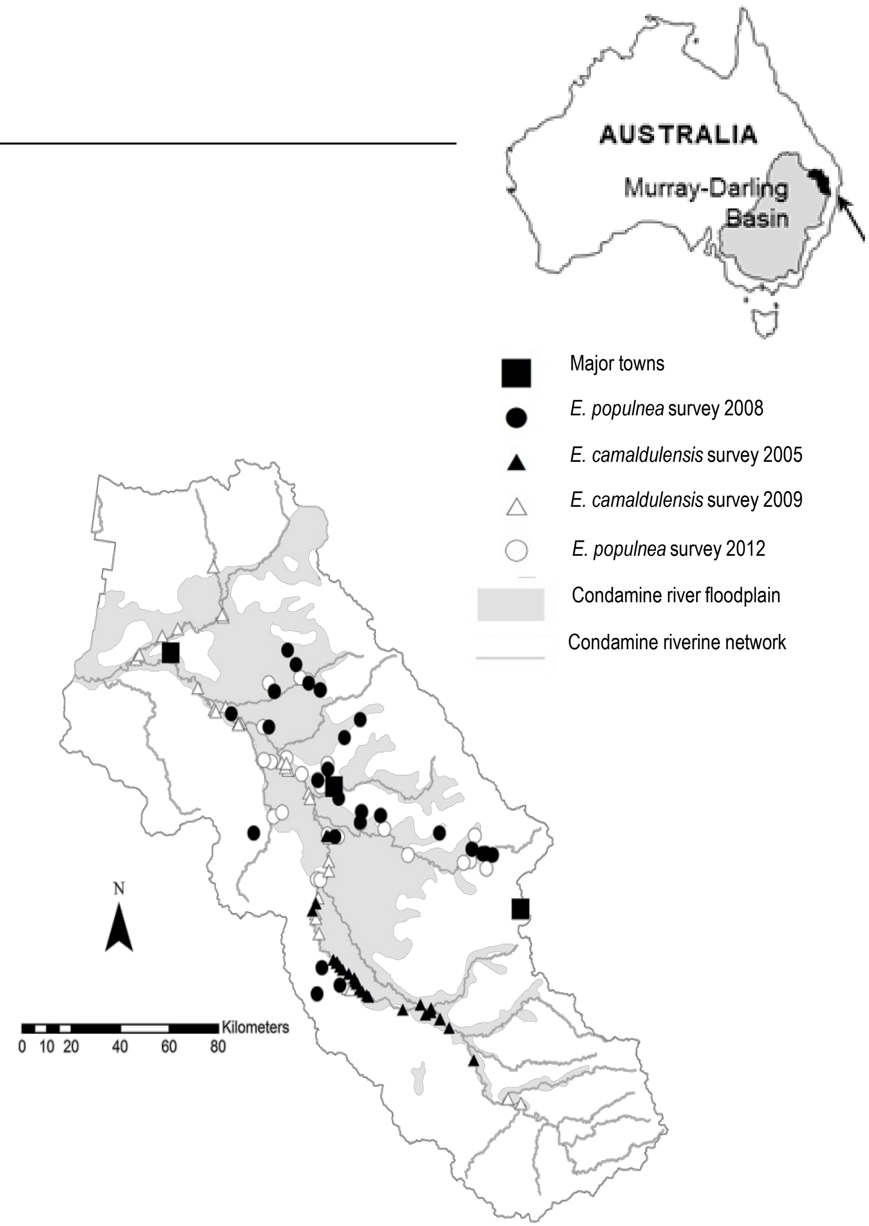
- Given the range of tree condition and groundwater depths in the Condamine catchment:
  - are tree condition responses for *Eucalyptus camaldulensis* and *E. populnea* to groundwater change *gradual* (linear/ curvilinear) or *threshold-like* (non-linear)?
  - if non-linear, can groundwater depth thresholds for tree condition be identified?

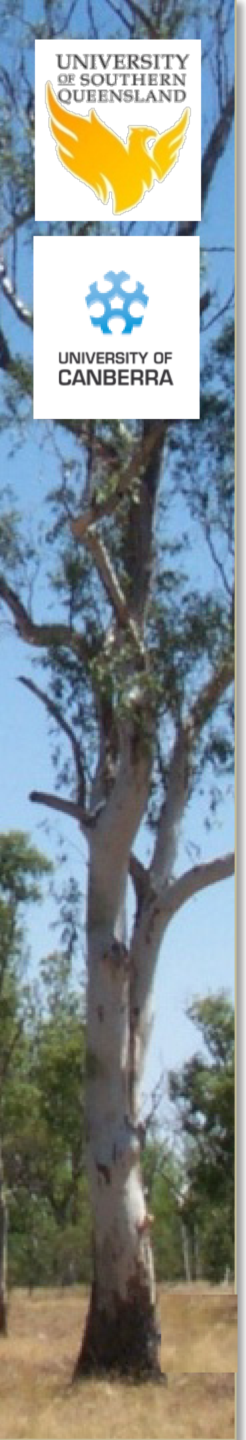


Methods - field

- 118 sites surveyed in different years (2005, 2008, 2009 and 2012)
  - River red gum (Reardon-Smith 2011; Kath 2012)
  - Poplar box (Batterham 2008; Fritz 2013)

- Common tree canopy condition assessment methodology
  - site level Average Foliage Index (Banks 2006) /'crown vigour' (Cunningham *et al.* 2007)

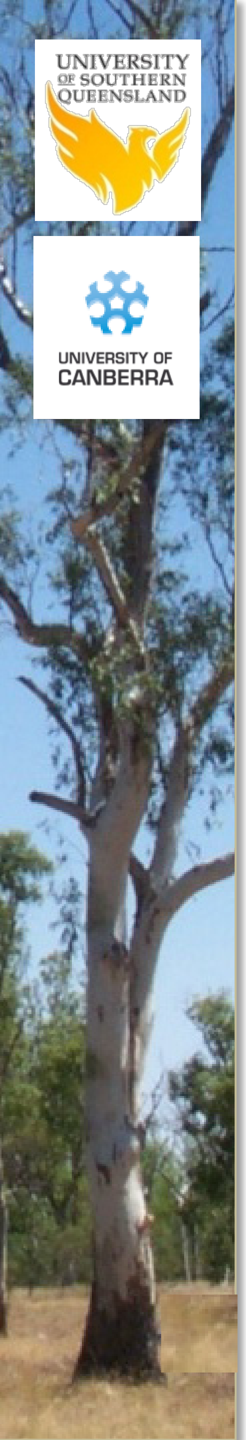




Methods – modelling

- Boosted regression tree (BRT) (Elith 2008; Ridgeway 2012) and threshold identification approaches (quantile regression with GUIDE and TITAN) (Baker & King 2010, Kail et al. 2008)

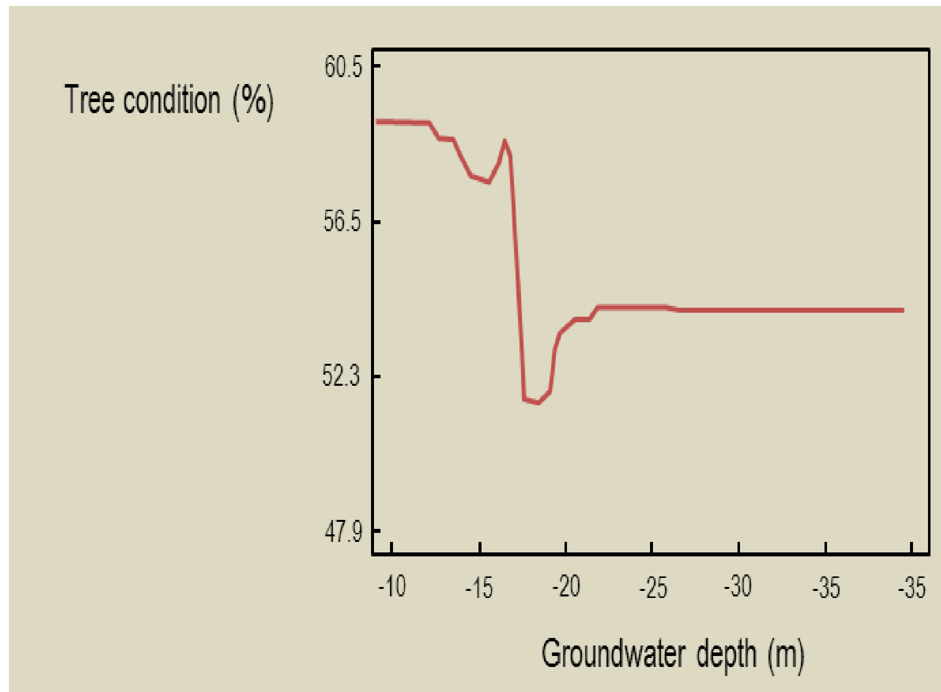
- BRT model included:
  - Survey year
  - Tree species
  - Lateral river connectivity index
  - Upstream area of nearest stream segment (m2)
  - Groundwater depth (m) (1987, 2000, 2005, 2009, 2012)
  - Groundwater flow system
  - Groundwater depth decline (m) (1987–2009)
  - Mean annual rainfall (mm)
  - Tree density at site (tree/ha)

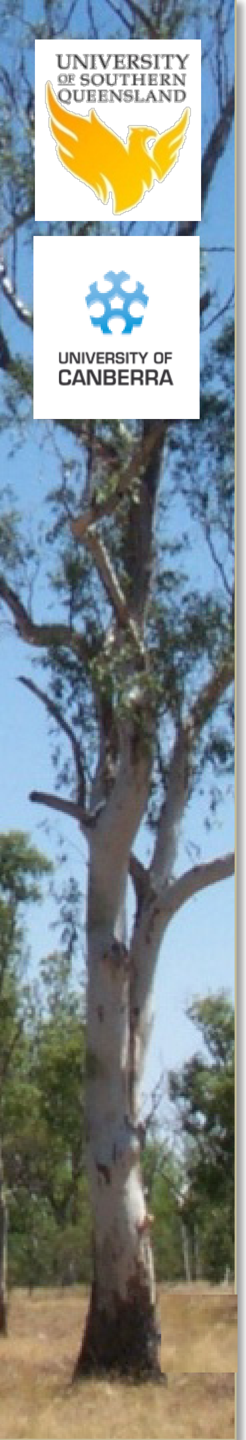


Results

- Tree condition-groundwater depth threshold relationship indicated in BRT model
- Groundwater depth explained 24% of variation in tree condition in BRT model when all predictor variables accounted for

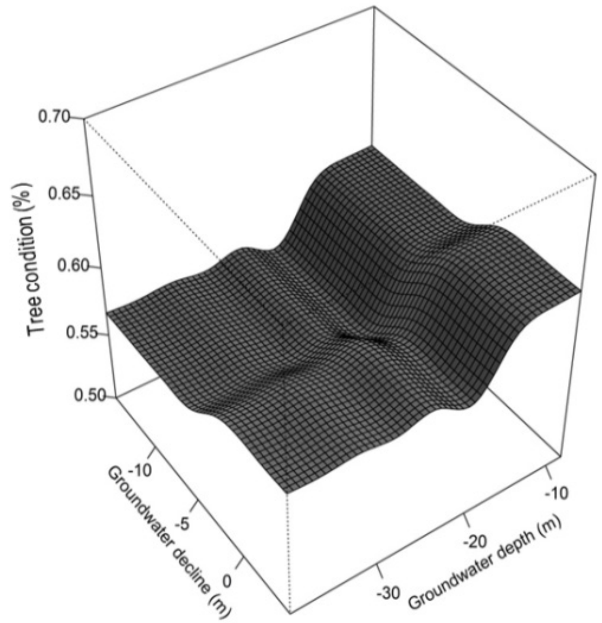
BRT plot showing relationship between floodplain tree condition (*E. camaldulensis* and *E. populnea* combined) and groundwater depth

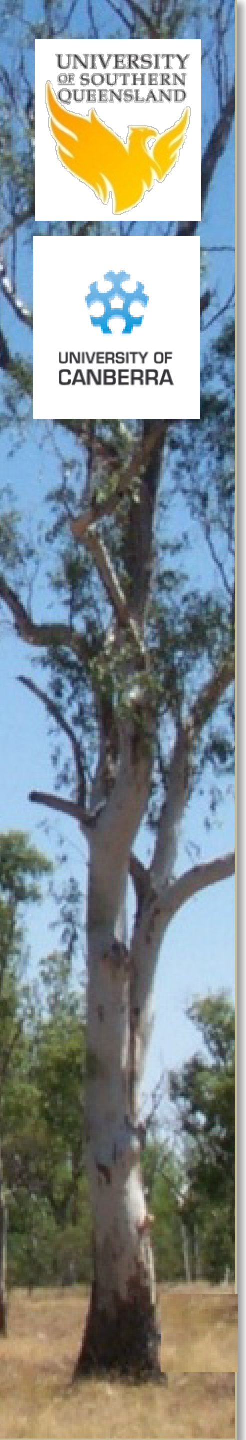




Results

- Thresholds identified for both *E. camaldulensis* and *E. populnea:*
  - *E. camaldulensis* thresholds from 12.1 – 22.6 m (90% c.i.)
  - *E. populnea* thresholds from 12.6 – 26.6 m (90% c.i.)
- Consistent finding regardless of threshold identification method used
- Other thresholds may also be important:
  - rate of groundwater decline
  - groundwater quality (Cunningham et al 2011; Kath et al. (in prep.))





Discussion

- Acknowledge others factors influence tree condition; e.g. grazing, insect herbivory, pesticides, fire regimes

- However, potential for groundwater to become a *critical driver* of ecosystem change; likely where:
  - increasing incidence and severity of drought with climate change
  - ongoing pressure on groundwater resources likely
  - altered susceptibility of riverine eucalypts to drought (current study)
  - increasing potential for population failure?

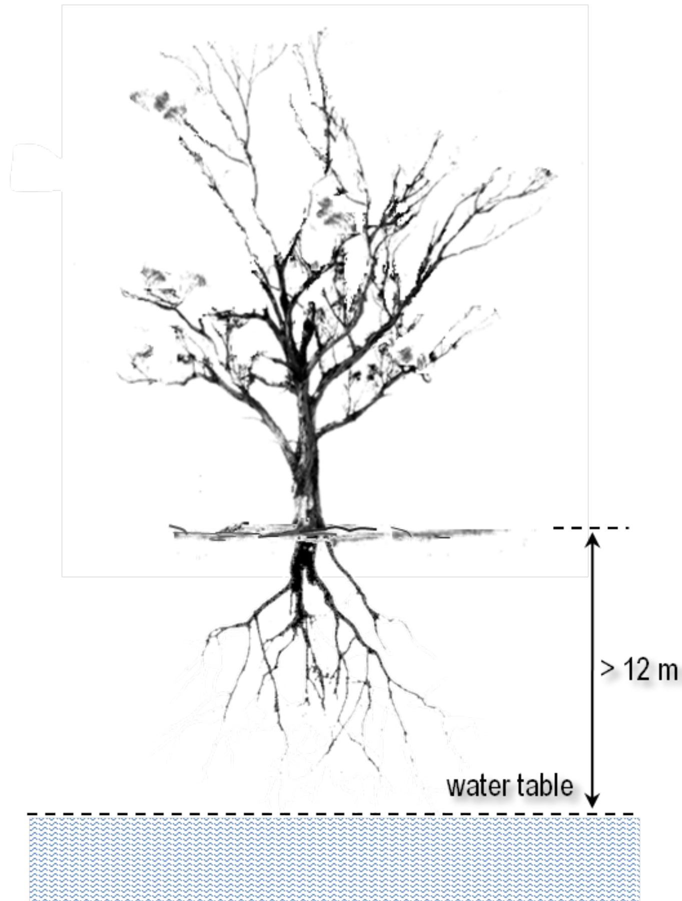
- Recovery less likely if threshold exceeded & increased potential for shift to alternative ecological state
  - e.g. *E. camaldulensis* ⇨ *Acacia stenophylla* dominant woodlands

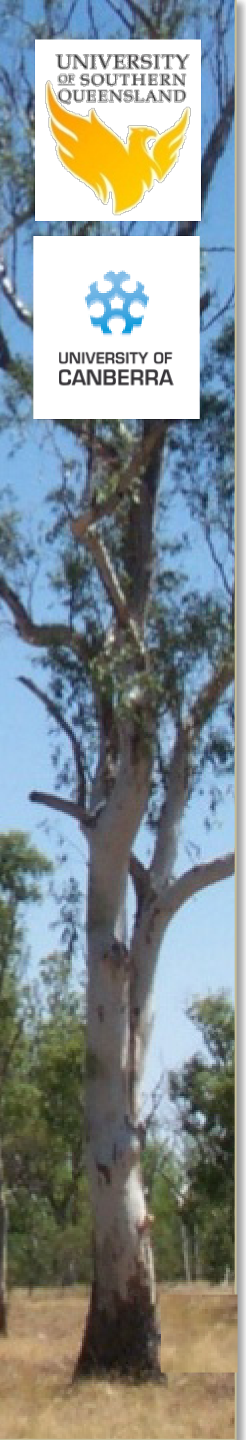
Conclusions

- Non-linear response to groundwater depth identified for *Eucalyptus camaldulensis* and *E. populnea* tree condition in Condamine

- Minimum groundwater depth thresholds predicted:
  - ~12 m for Eucalyptus camaldulensis
  - ~12.5 m for E. populnea

- Future directions:
  - mechanisms behind thresholds
  - confirmation of thresholds (e.g. isotope studies)
  - generality of response (e.g. other landscapes, interactions with salinity; other species)





Significance

- Approach represents a **repeatable method** to:
  - **quantify ecological response thresholds** along environmental gradients
  - **identify safe operating limits** for sustainable resource management
- Potential **evidence for improved decision making** (e.g. water extraction limits) to support resilient ecosystems
  - especially in regions where groundwater decline driven by increasing water demand and drying climates is predicted

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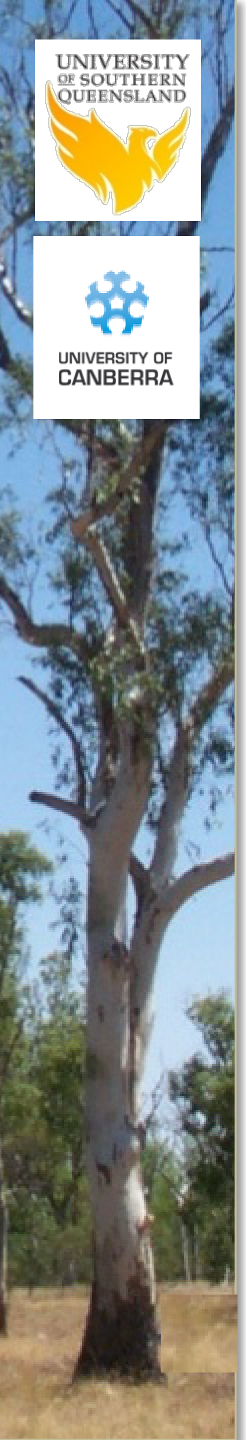

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Original research article

Groundwater decline and tree change in floodplain landscapes: Identifying non-linear threshold responses in canopy condition

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ABSTRACT

Groundwater decline is widespread, yet its implications for natural systems are poorly understood. Previous research has revealed links between groundwater depth and tree condition; however, critical thresholds which might indicate ecological 'tipping points' associated with rapid and potentially irreversible change have been difficult to quantify. This study collated data for two dominant floodplain species, *Eucalyptus camaldulensis* (river red gum) and *E. populnea* (poplar box) from 118 sites in eastern Australia where significant groundwater decline has occurred. Boosted regression trees, quantile regression and Threshold Indicator Taxa Analysis were used to investigate the relationship between tree condition and groundwater depth. Distinct non-linear responses were found, with groundwater depth thresholds identified in the range from 12.1 m to 22.6 m for *E. camaldulensis* and 12.6 m to 26.6 m for *E. populnea* beyond which canopy condition declined abruptly. Non-linear threshold responses in canopy condition in these species may be linked to rooting depth, with chronic groundwater decline decoupling trees from deep soil moisture resources. The quantification of groundwater depth thresholds is likely to be critical for management aimed at conserving groundwater dependent biodiversity. Identifying thresholds will be important in regions where water extraction and drying climates may contribute to further groundwater decline.

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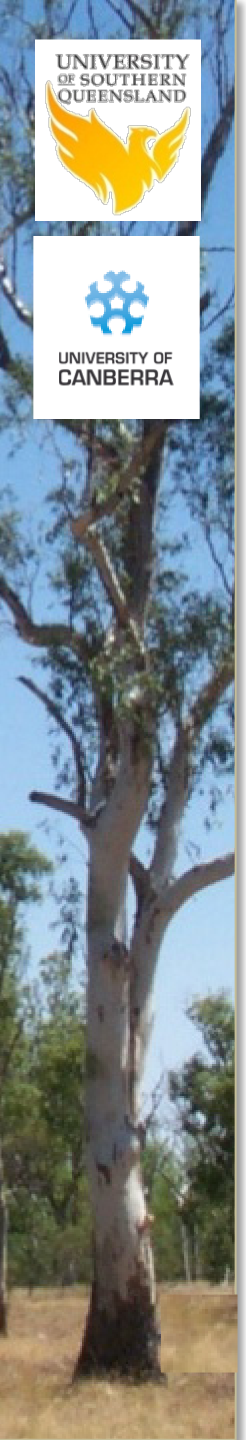
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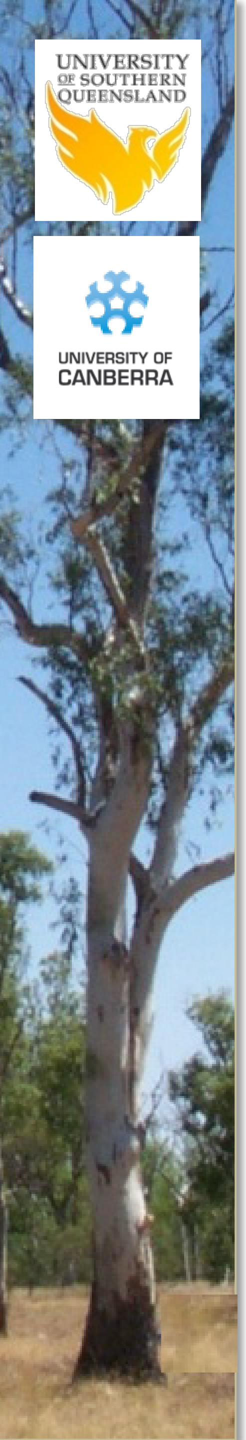

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