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From paddock to catchment: practices, processes and pollutant budgets

Scott Wilkinson, Rebecca Bartley, Peter Thorburn et al.

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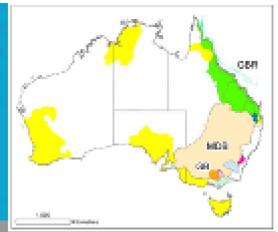
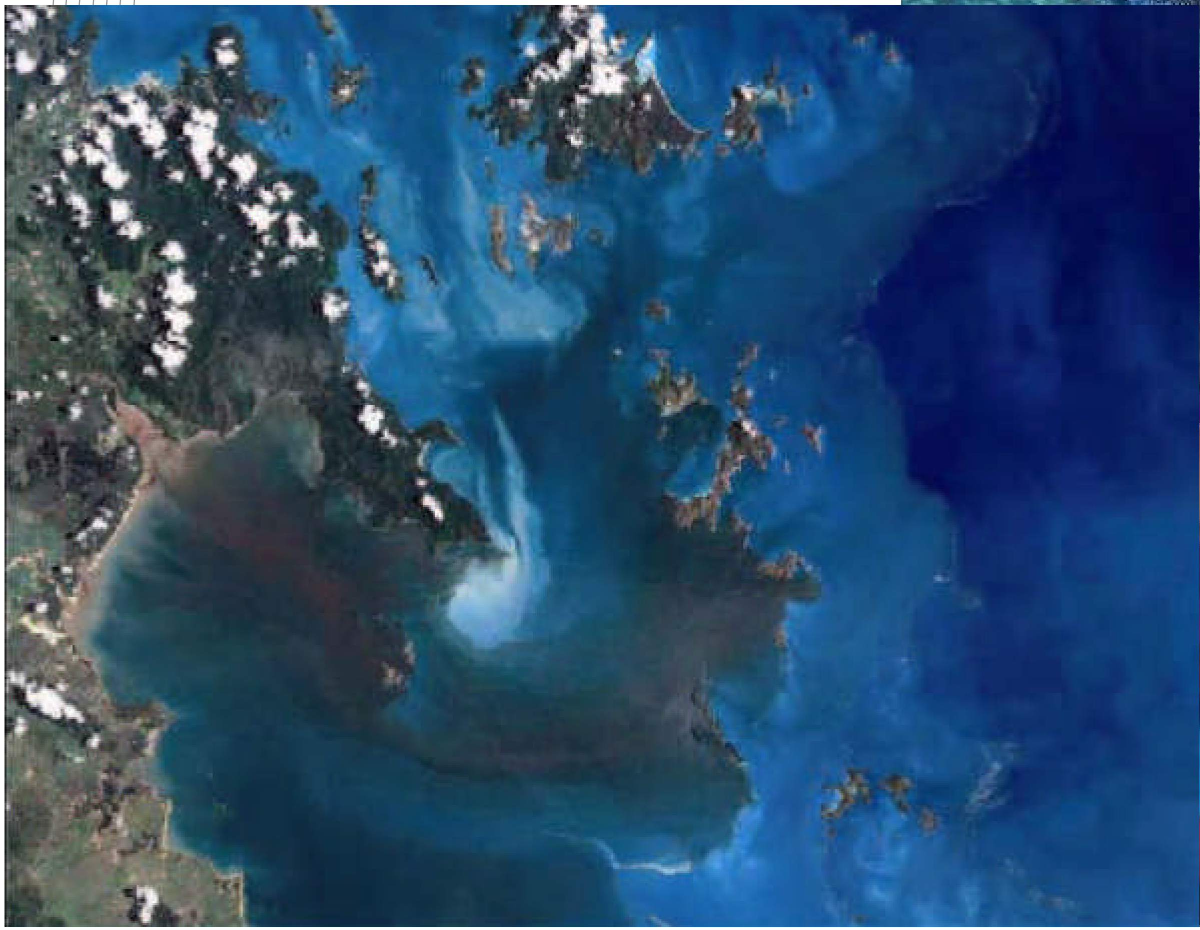
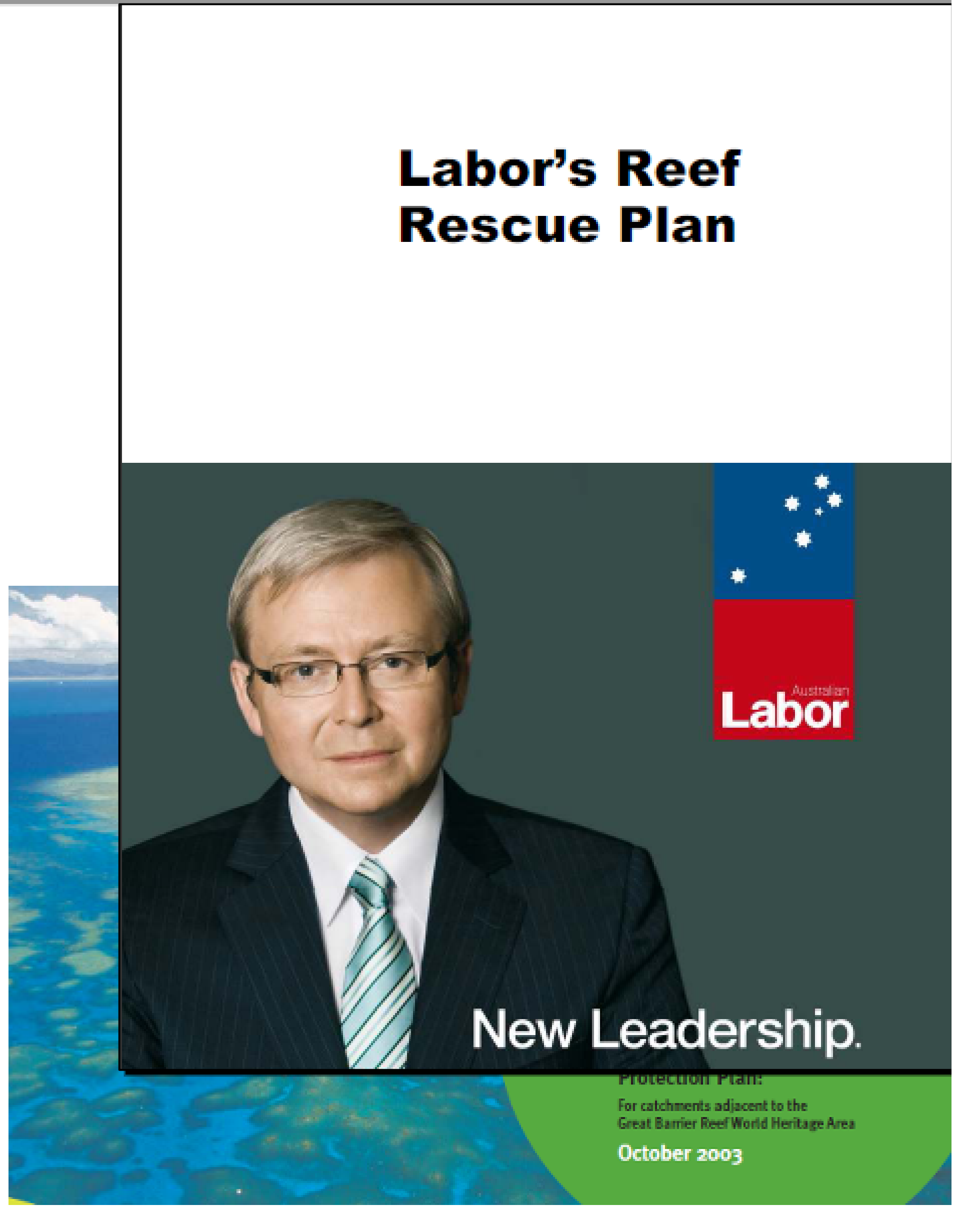
Water quality impacts (catchment scale)





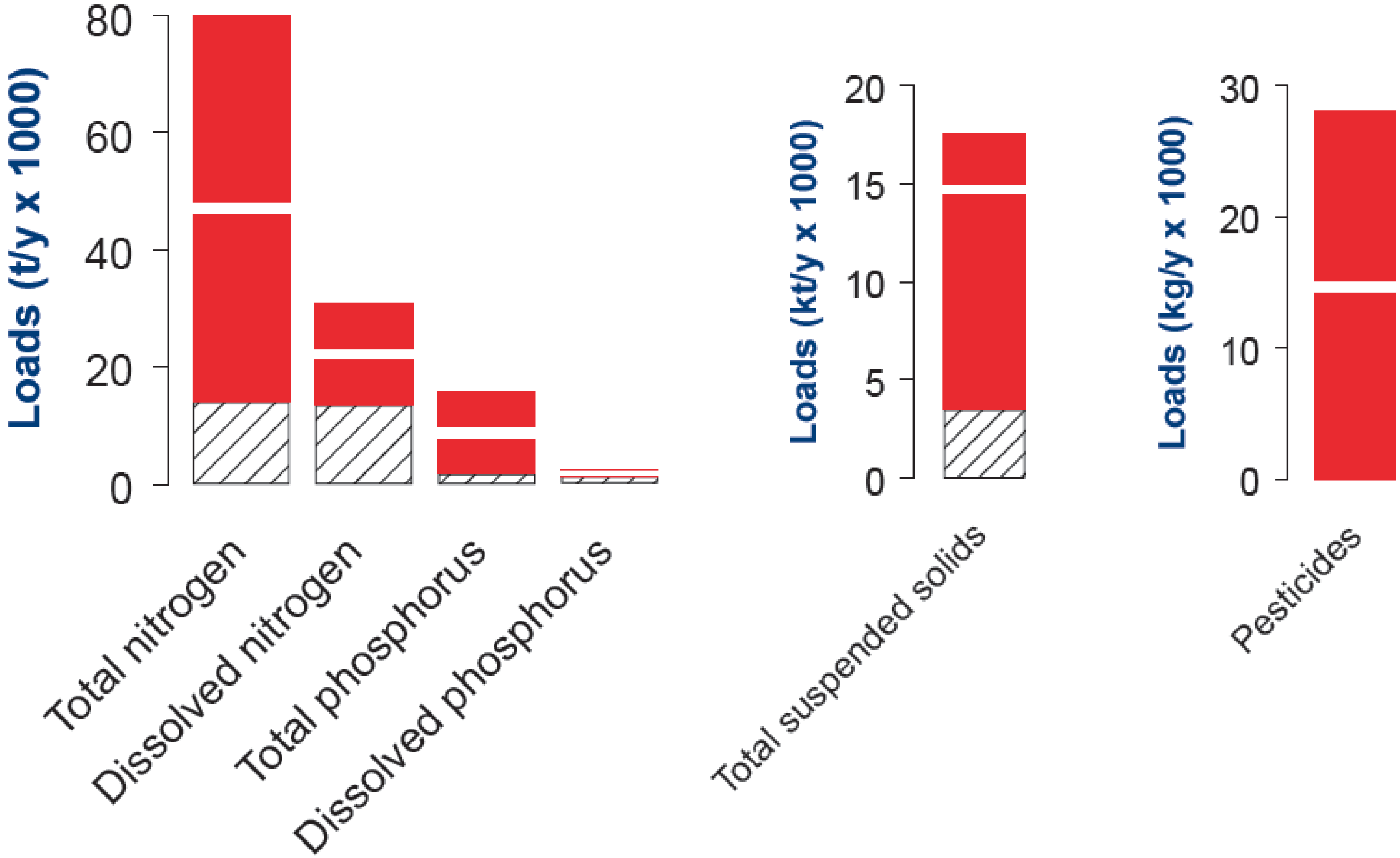
Policy and Science

- 2003 “Reef Plan”
  - “Halt the decline in water quality”
- 2005 Catchment modelling
- WQ Improvement Plans
- 2007 Reef Rescue
  - $200M over 5 years
  - 1300 farmers adopted practices that will improve water quality
  - % reductions in pollutant discharge
- 2008 Reef Regulation
  - Property planning
- 2009 Reef Plan 2

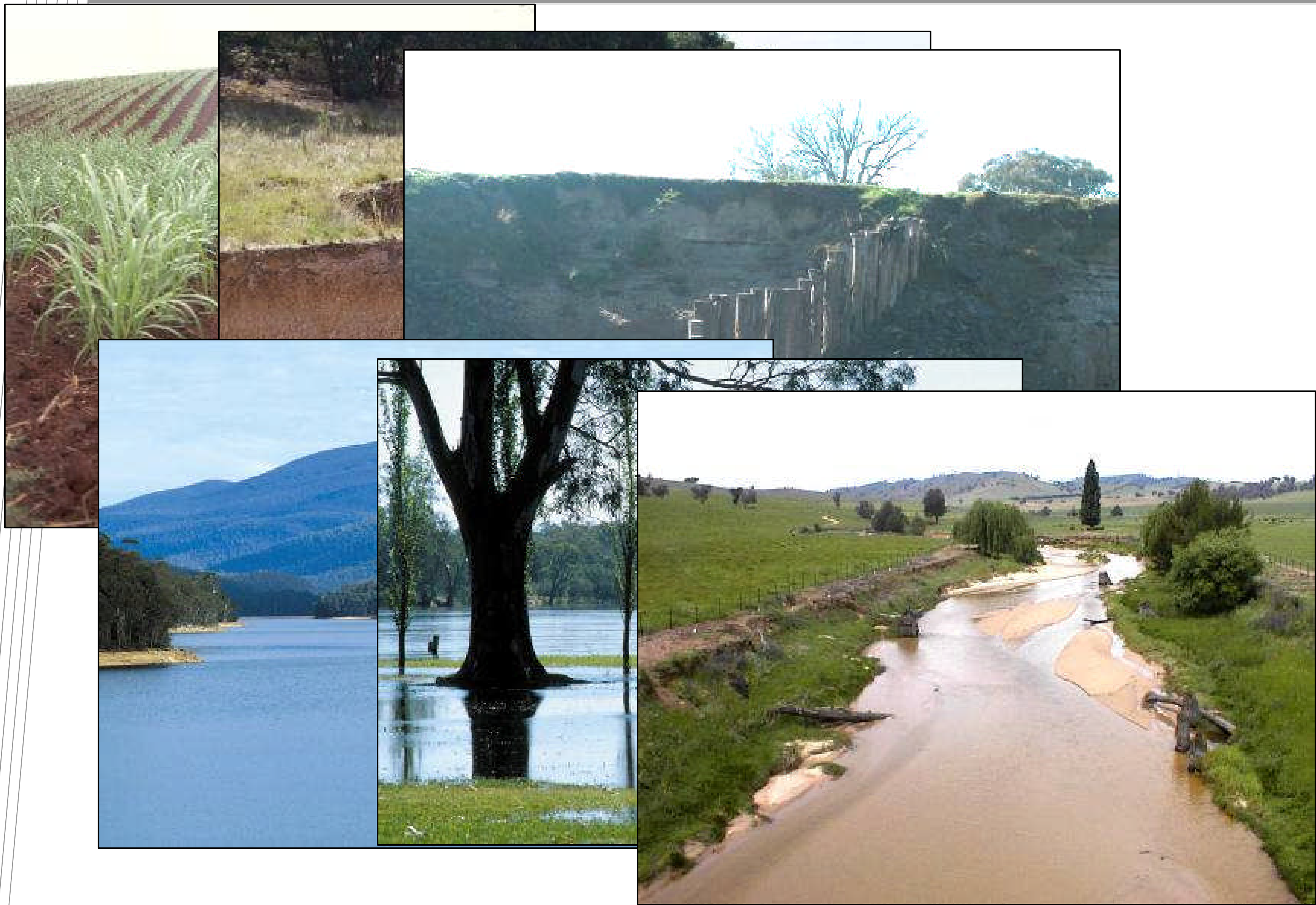


Policy and Science

(GBR Report Card, 2011)

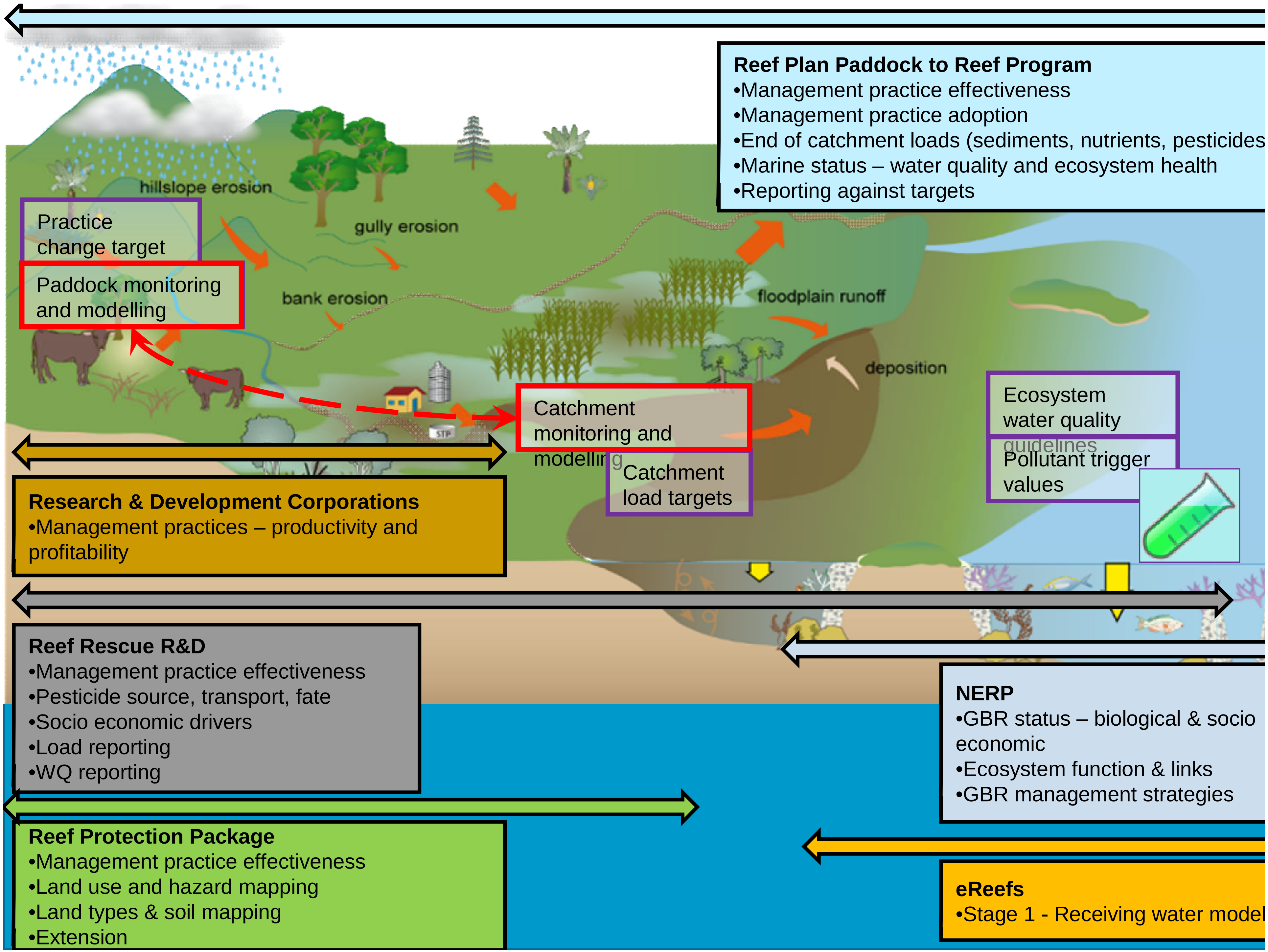


Catchment sources and connectivity



Management practices (paddock scale)

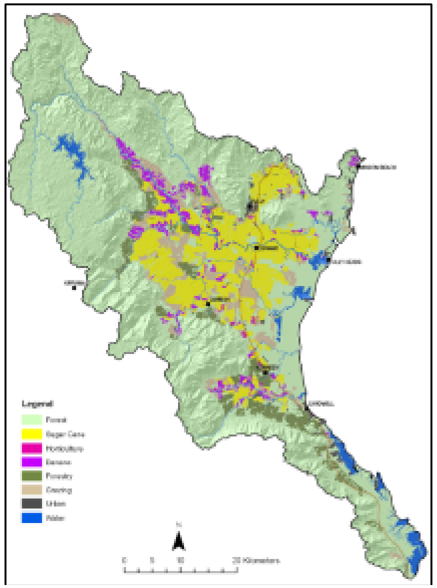
(J Armour DERM)



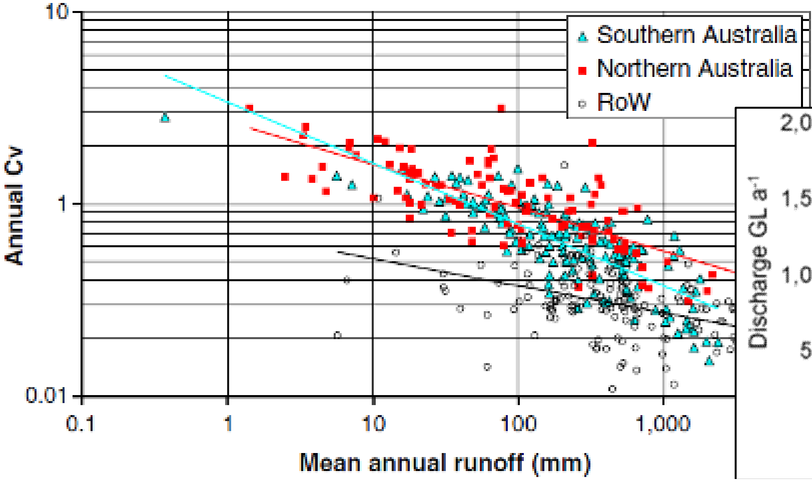
Reef Plan Paddock to Reef Program
•Management practice effectiveness
•Management practice adoption
•End of catchment loads (sediments, nutrients, pesticides
•Marine status – water quality and ecosystem health
•Reporting against targets
hillslope erosion
gully erosion
bank erosion
floodplain runoff
deposition
Practice change target
Paddock monitoring and modelling
Catchment monitoring and modelling
Catchment load targets
Ecosystem water quality guidelines
Pollutant trigger values
STP
Research & Development Corporations
•Management practices – productivity and profitability
Reef Rescue R&D
•Management practice effectiveness
•Pesticide source, transport, fate
•Socio economic drivers
•Load reporting
•WQ reporting
NERP
•GBR status – biological & socio economic
•Ecosystem function & links
•GBR management strategies
Reef Protection Package
•Management practice effectiveness
•Land use and hazard mapping
•Land types & soil mapping
•Extension
eReefs
•Stage 1 - Receiving water model

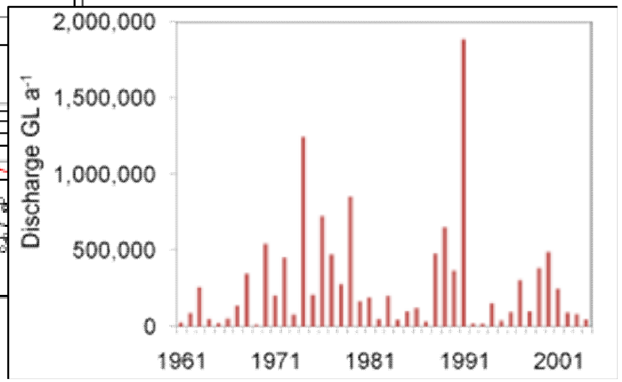
Challenges in identifying pollutant sources and connectivity

- Spatial variability in landuse, practices, rainfall, delivery processes
- Variable climate
- Time-lags in detecting response
- Quantifying pollutant loss, and connectivity to receiving waters



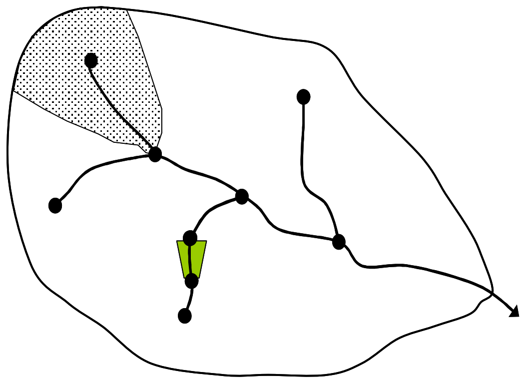
(Petheram et al., 2008)

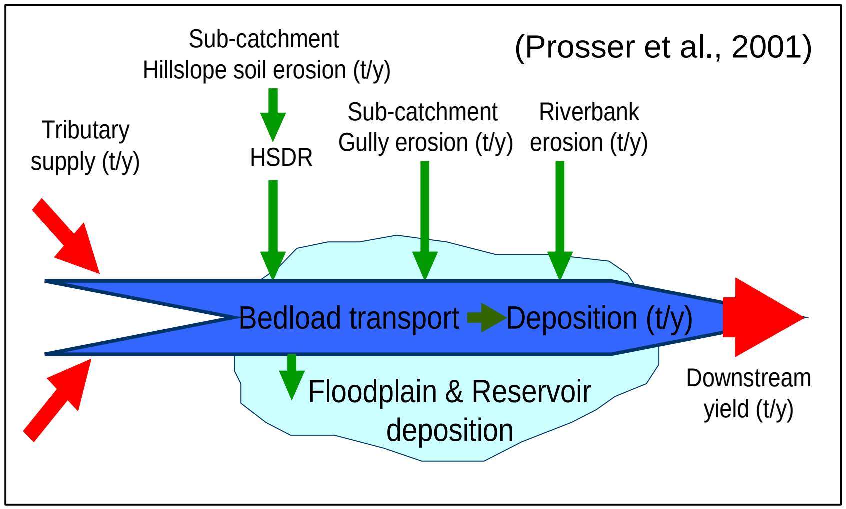




Sediment budget modelling (SedNet)

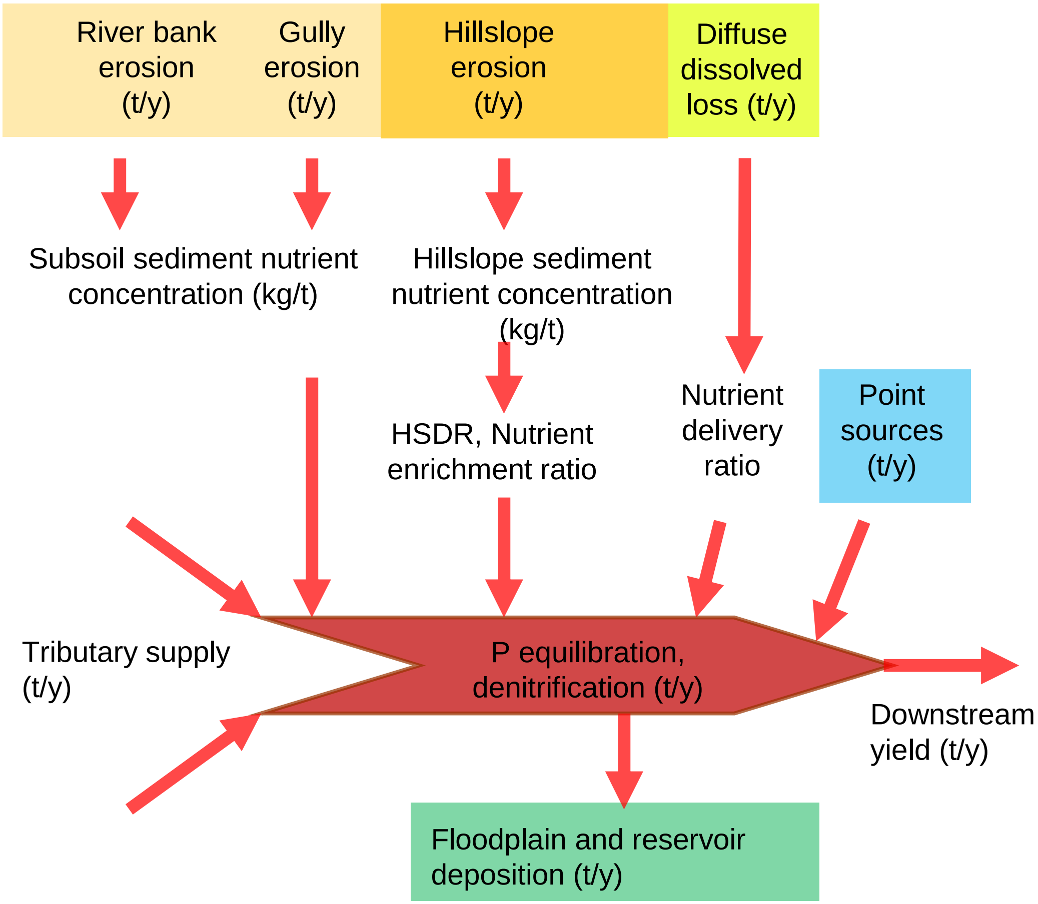
- Spatially-distributed account of sources and sinks
- Sheet/rill $H_x = f(Cov.Rain.Soil.Length.Slope.Practice)$
- Gully $G_x = f(BulkDens.Activity.Vol/Age)$
- Riverbank $B_x = f(k.\Omega.Erodability)$
- Floodplain $F_x = f(Load.PropFlood.ResTime)$
- Reservoir $R_x = f(Capacity/Inflow)$
- Bedload & suspended budgets





Nutrient budgets

- N and P budgets for each form (some interactions)
  - Particulate-attached
  - Dissolved inorganic
  - Dissolved organic



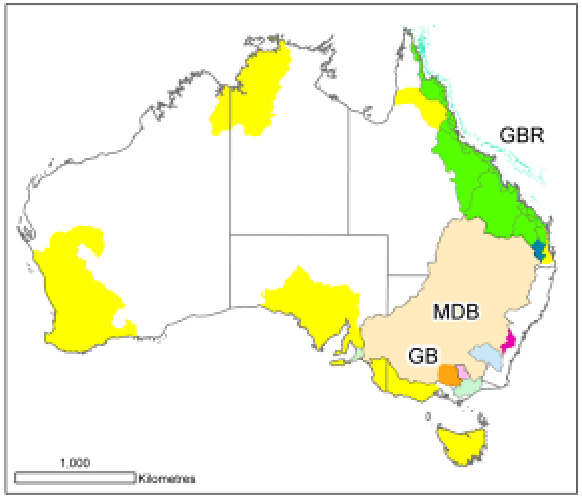
SedNet software (www.toolkit.net.au/sednet)

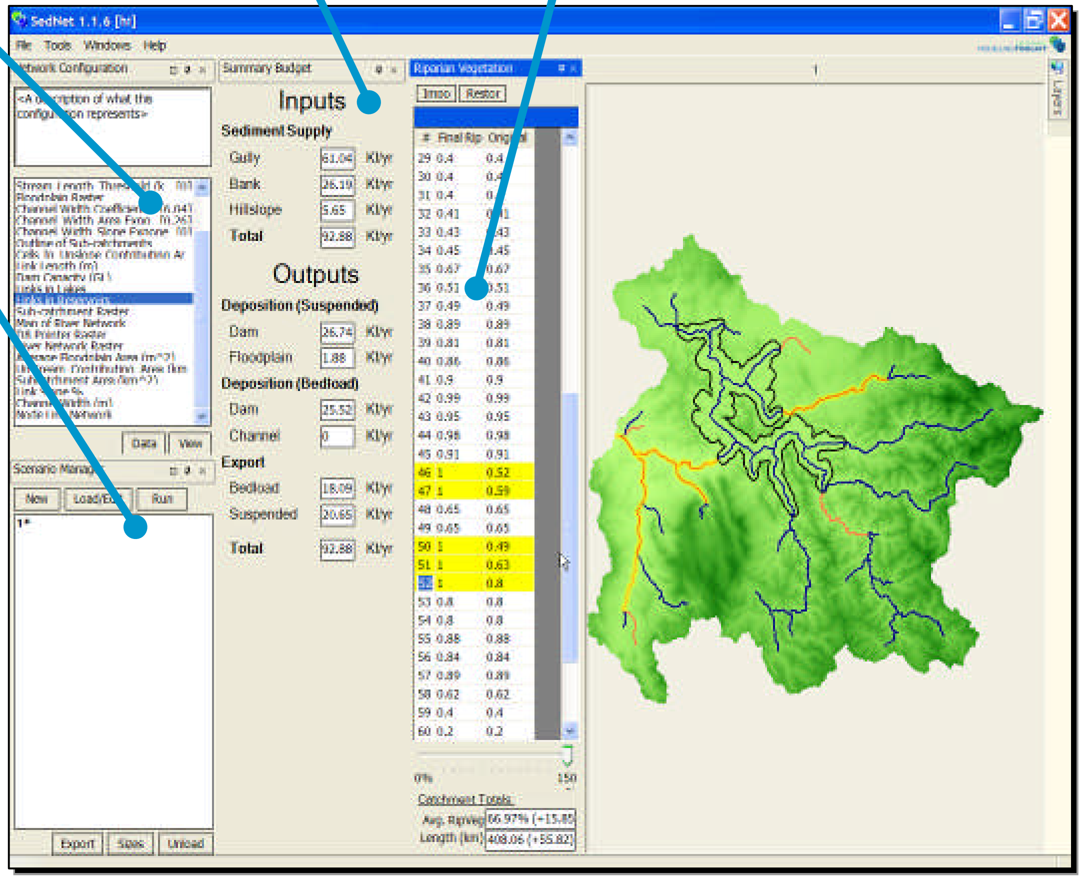
Subcatchment revegetation

Catchment budget

River network attributes

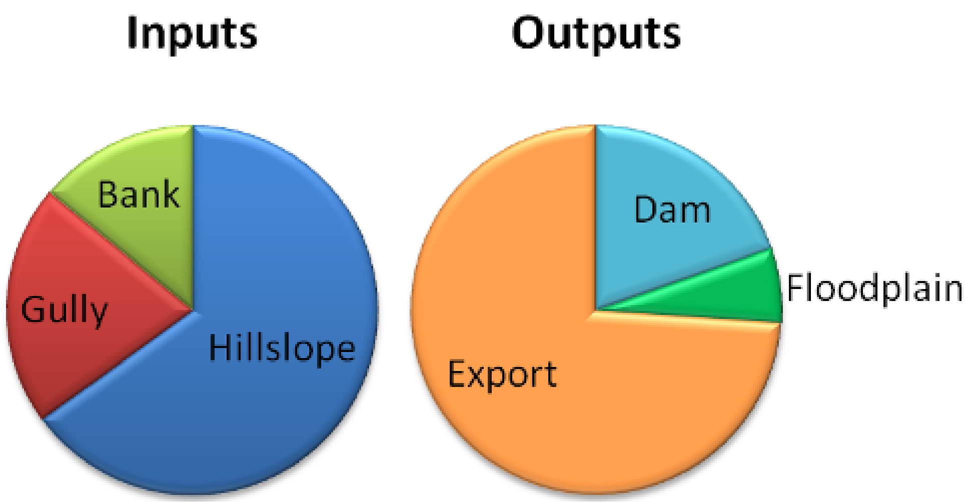
Management scenarios

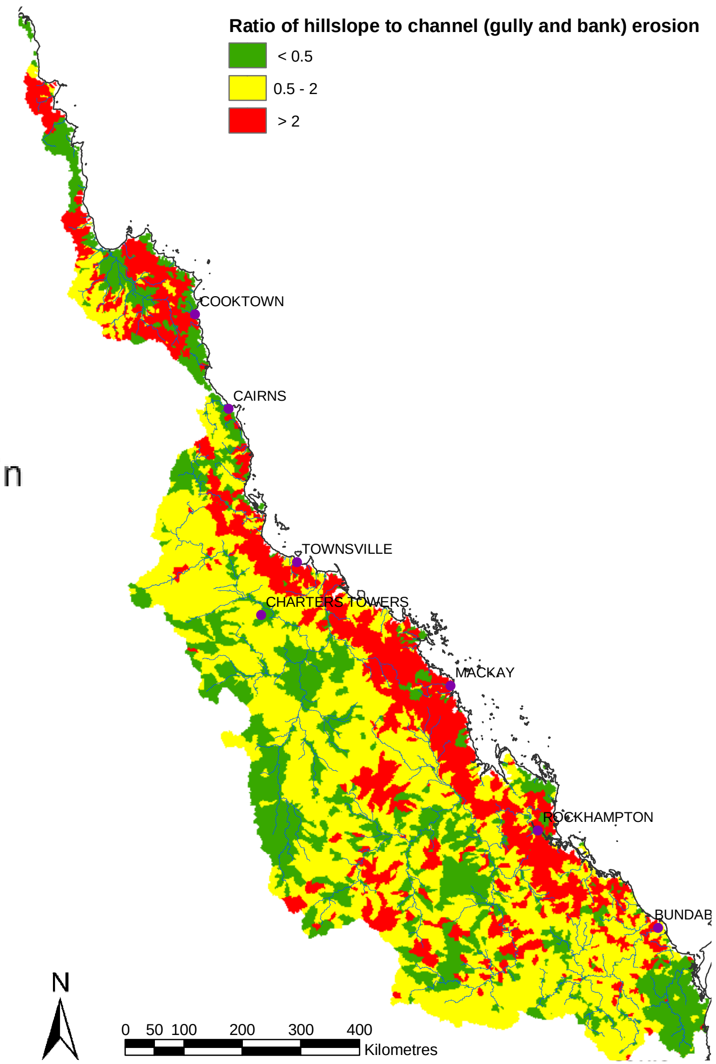




Exploring the model predictions

- Multiple sources
- Different spatial pattern for each source



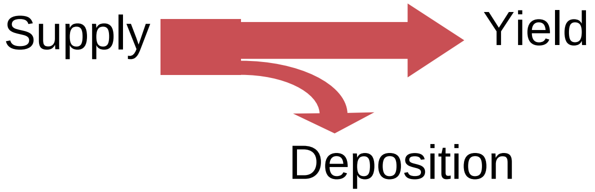


(McKergow et al, 2005; Cogle et al. 2006)

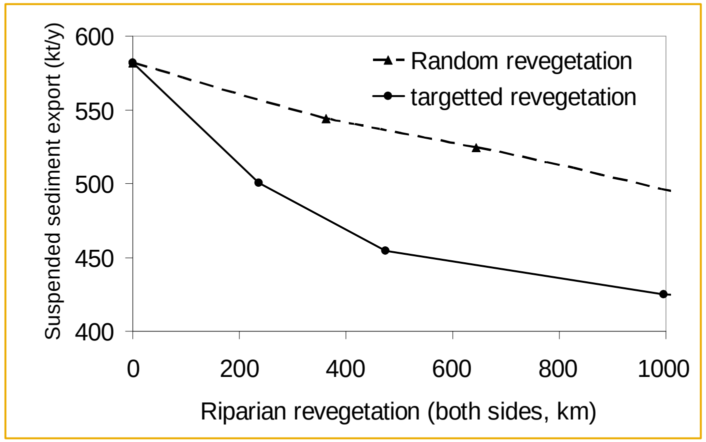
Maximising investment efficiency

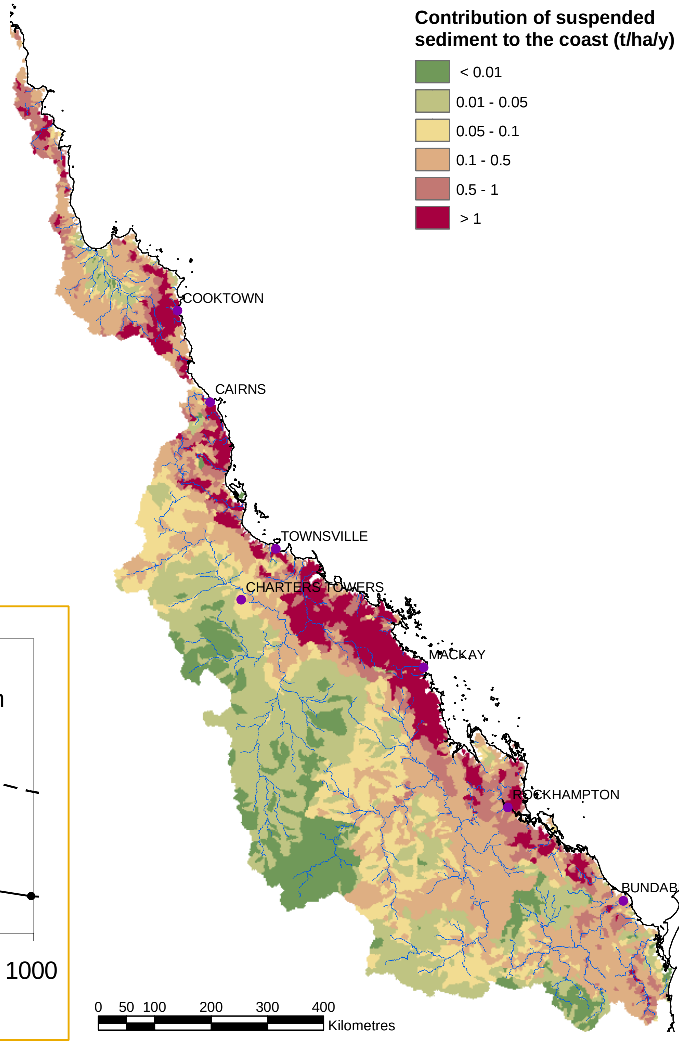
- Contribution = Erosion × Connectivity

(McKergow et al., 2005; Wilkinson et al., 2005)



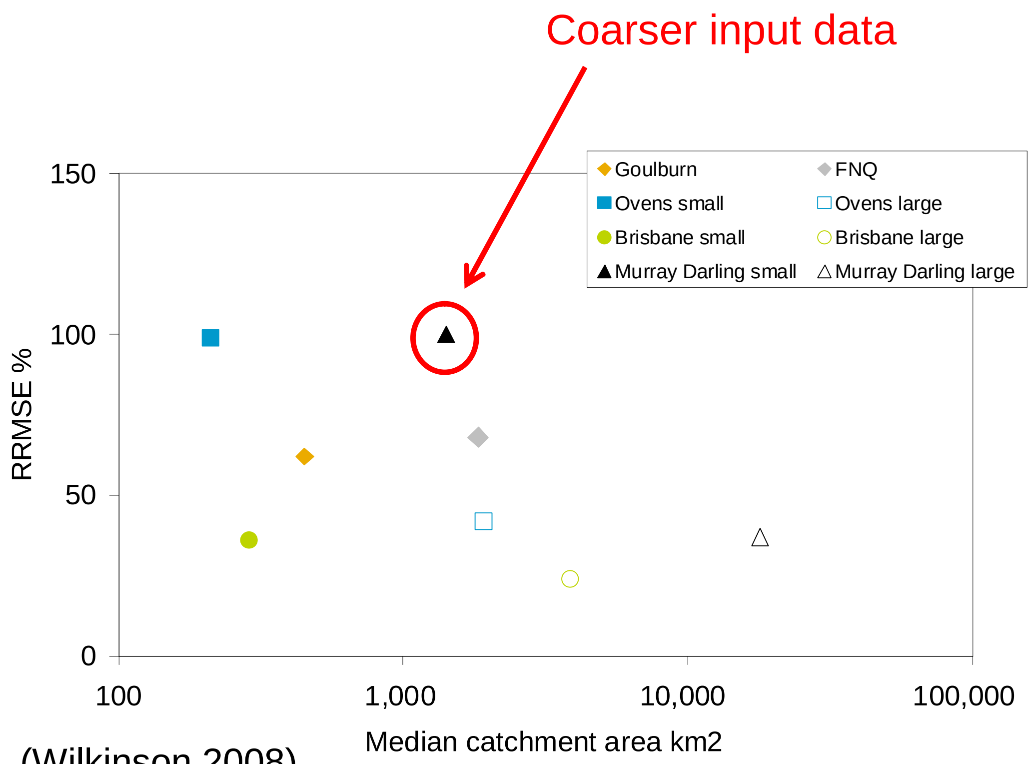
- Targeting practice changes to erosion hotspots
  - Potential effectiveness of change?
  - Cost of change?
  - Co-investment?
  - Capacity for change?
  - Supporting networks?





Evaluating catchment model predictions

- 30–100% uncertainty in predicted load
- Spatial variability in supply is 2–12 times larger than uncertainty
- Better performance with high resolution data

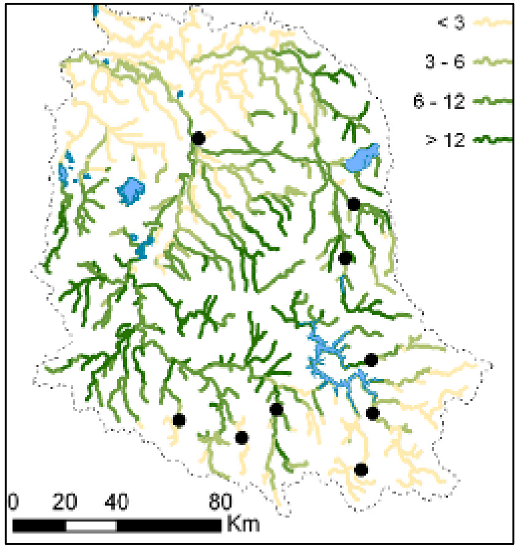


(Wilkinson 2008)

Stepwise parameter adjustment

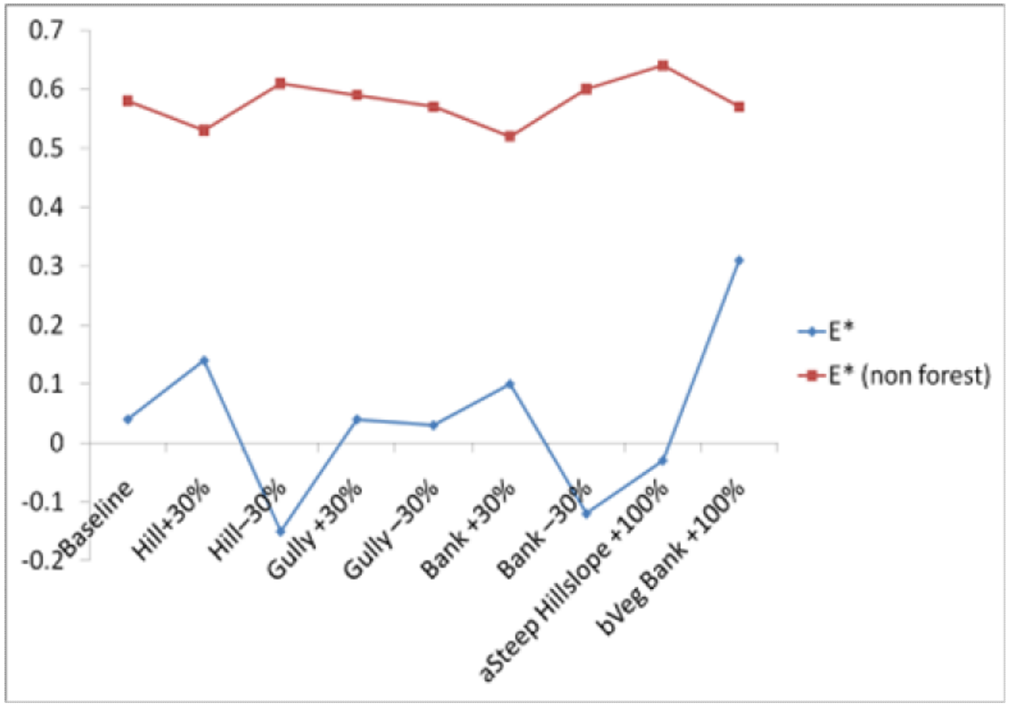
- Compare predictions with measured loads
  - 8 catchments 200–700 km^2

Specific sediment yield

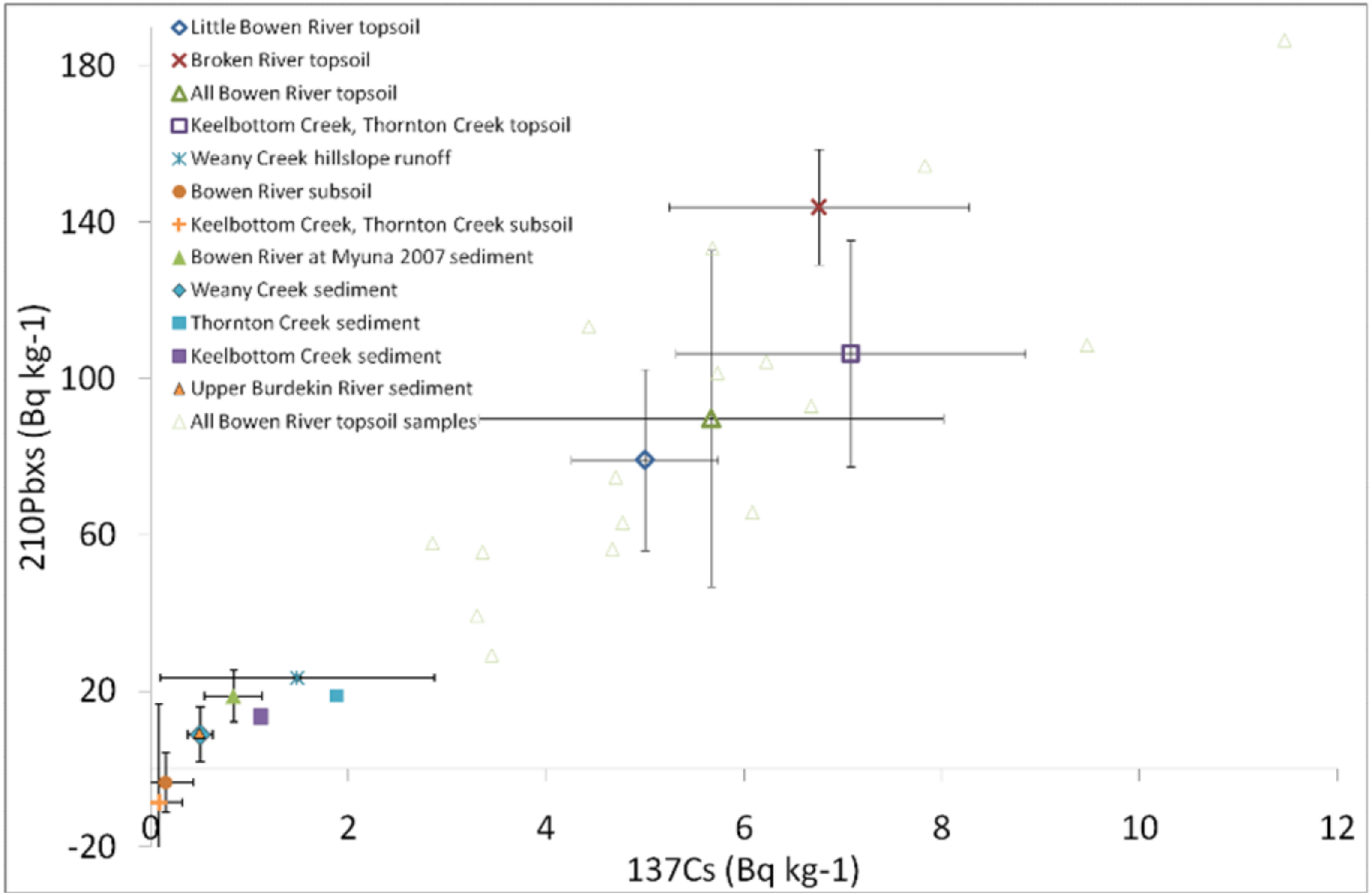


(Wilkinson et al., 2009)

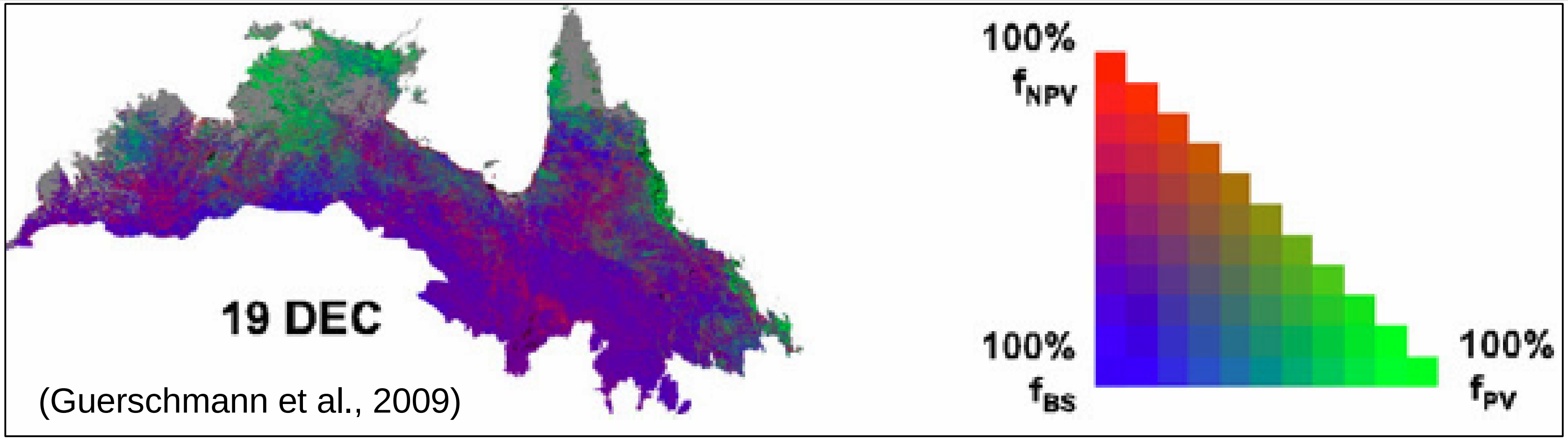
Nash-Sutcliffe efficiency (t ha^{-1} a^{-1})



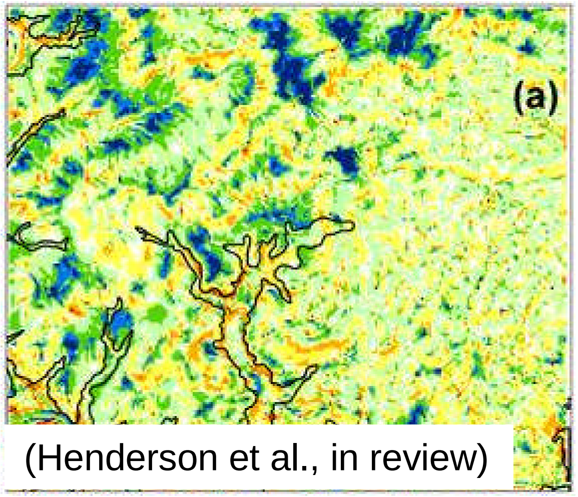
Sediment tracing – surface soil contribution



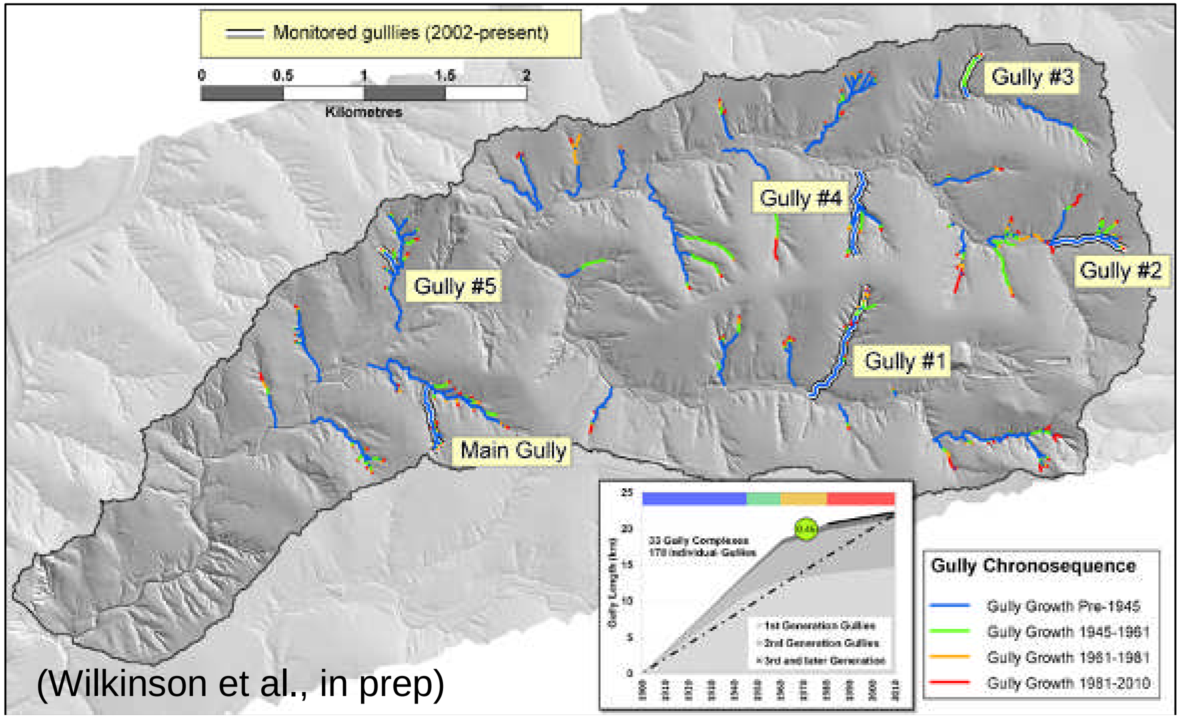
Ongoing data developments



(Guerschmann et al., 2009)

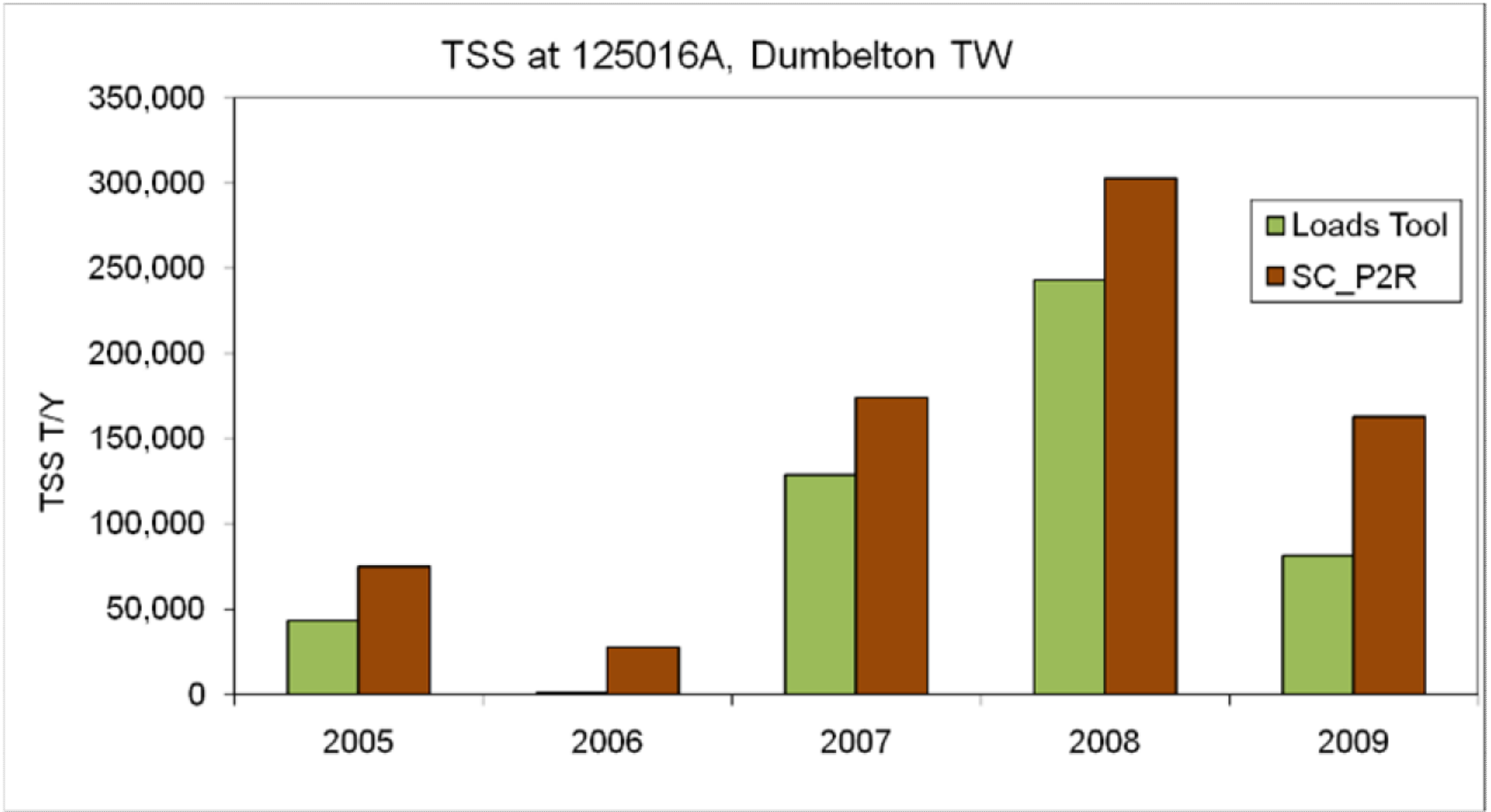


(Henderson et al., in review)



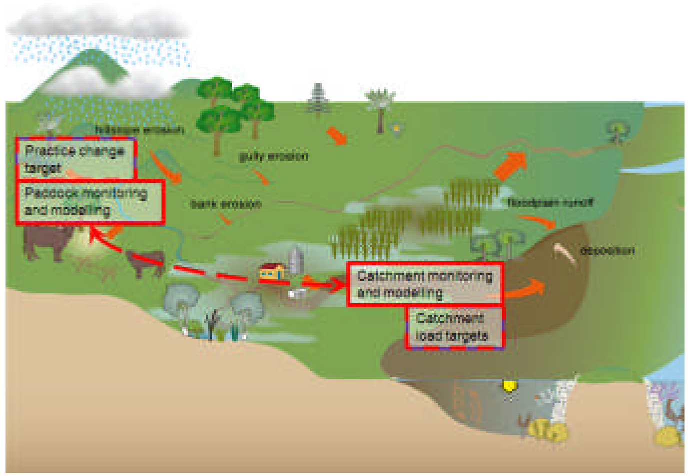
(Wilkinson et al., in prep)

Time-stepping SedNet model



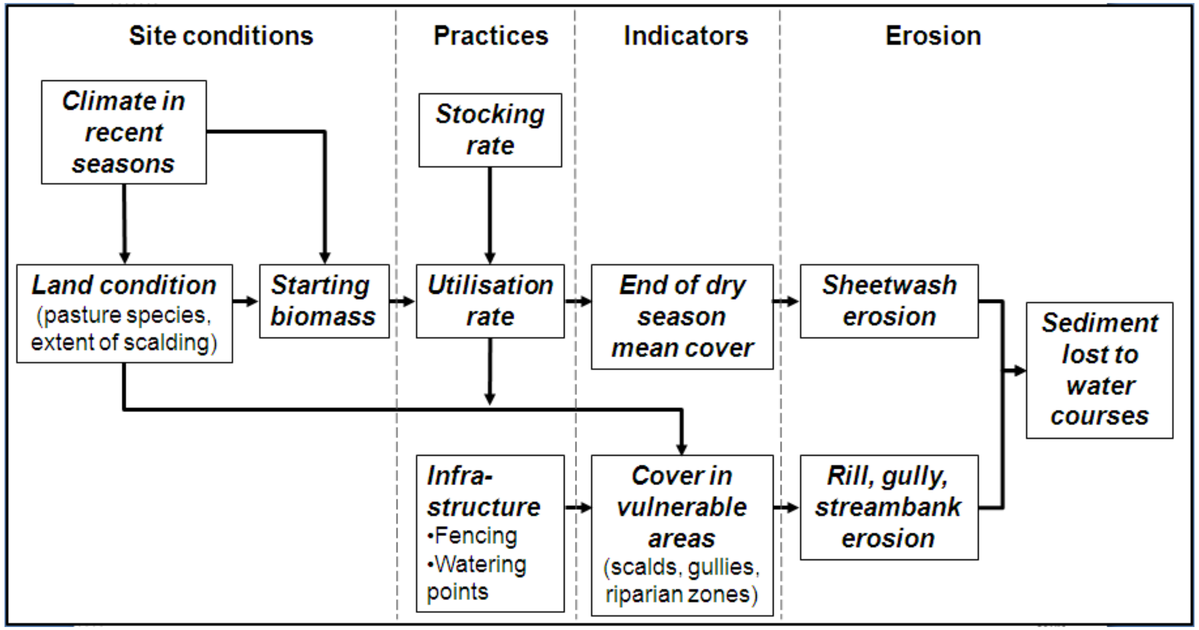
Agricultural practices and pollutant losses

- Practice change priorities needed
- Coupled modelling is underway...
  - APSIM, GRASP, HowLeaky
  - SedNet
- Conceptual frameworks of the physical controls on generation and loss
  - Assumptions about delivery efficiency

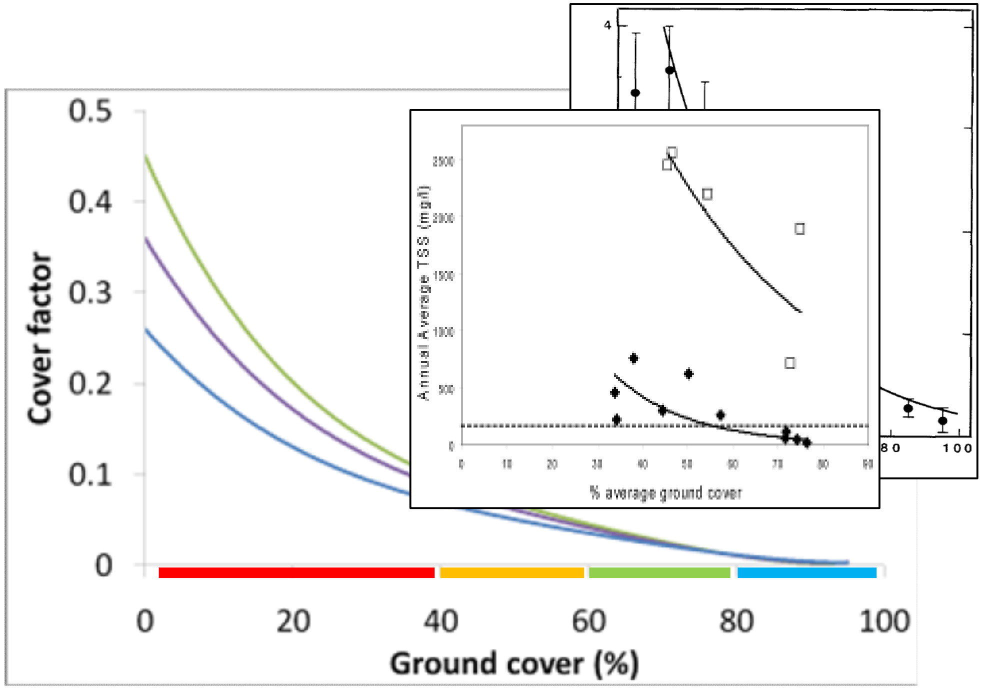


Grazing practices conceptual framework

- Grazing reduces vegetation cover
- Grazing is associated with gully erosion and riparian degradation



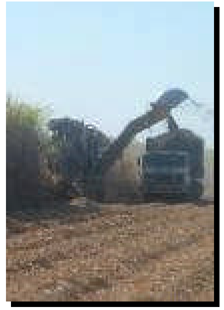
Populating the grazing practices framework



Cover class change	D ➡ C	C ➡ B	B ➡ A
Change in hillslope erosion rate (%)	-65	-22	-10
Change in gully erosion rate (%)	-35	-10	-20
Change in streambank erosion rate(%)	-10	-30	-20

Long-term fate of N applied to crops

Crop



Soil ***(Constant, i.e. not important in the long-term)***

Environment

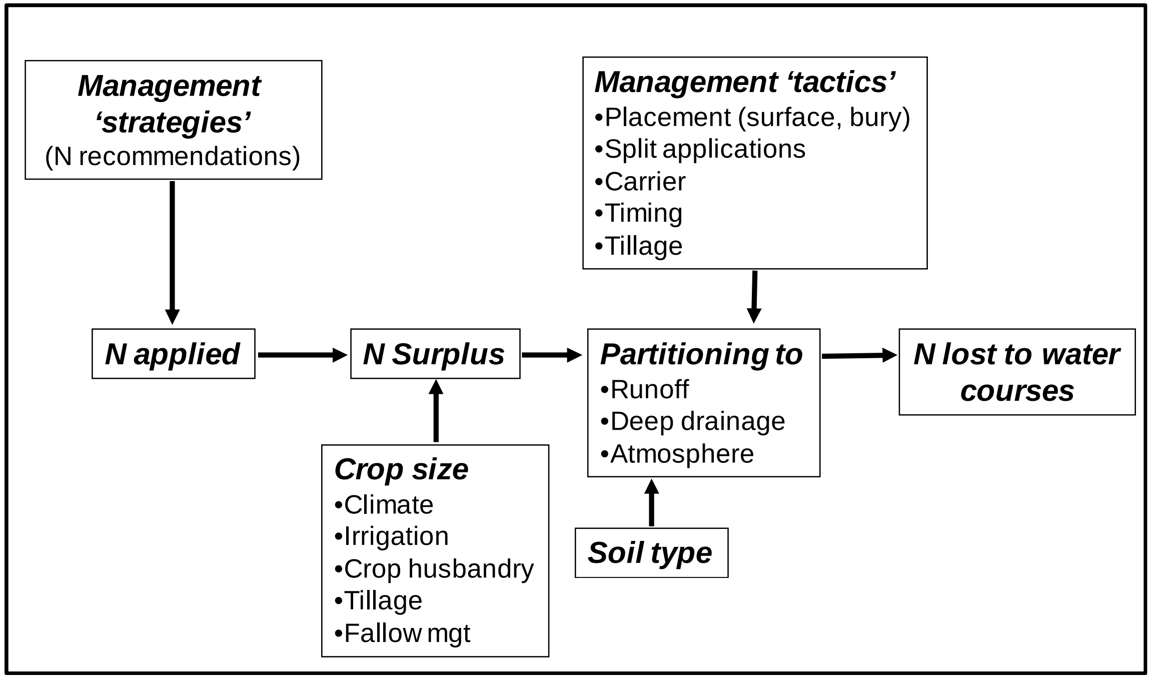
Atmosphere
(NH_4 volat + NO_3 denitr)

Leached below the root-zone

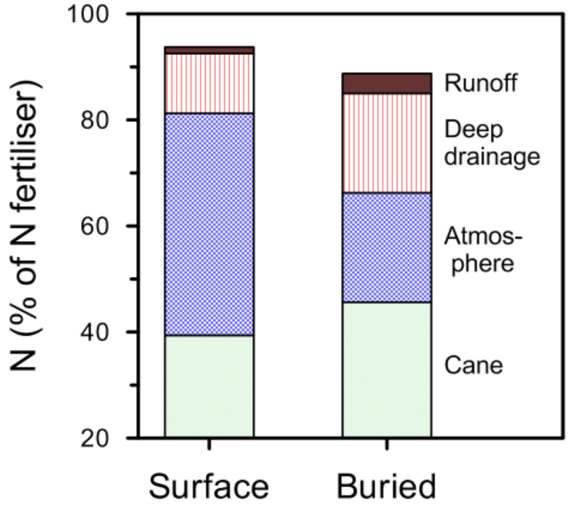
Runoff

Cropping practices conceptual framework

- Practices can have benefit productivity without reducing loss to streams
- Offsite loss proportion to N-surplus

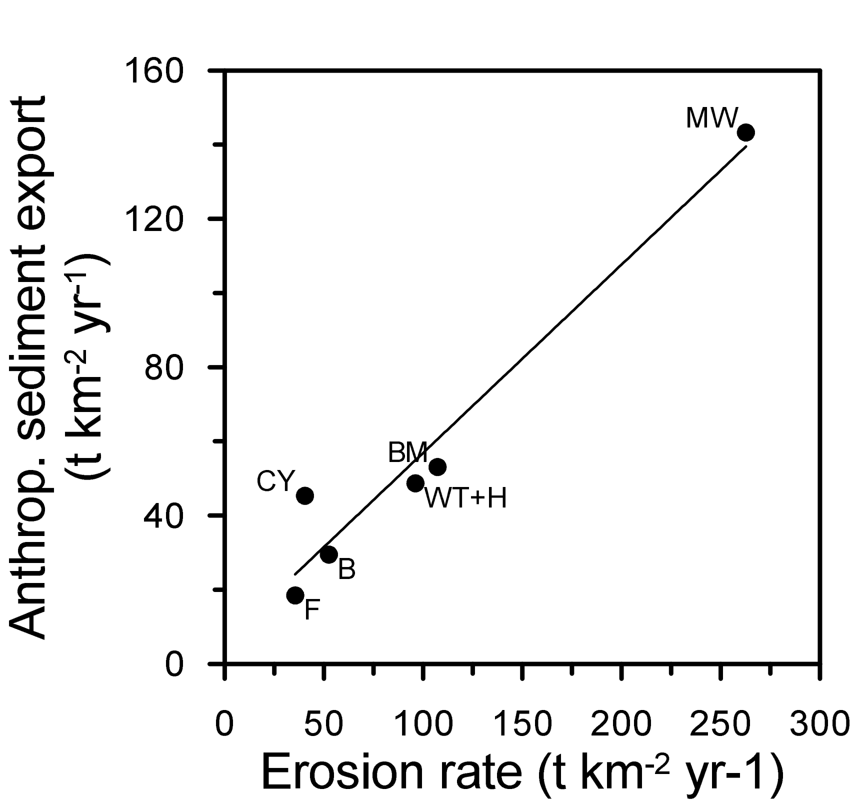


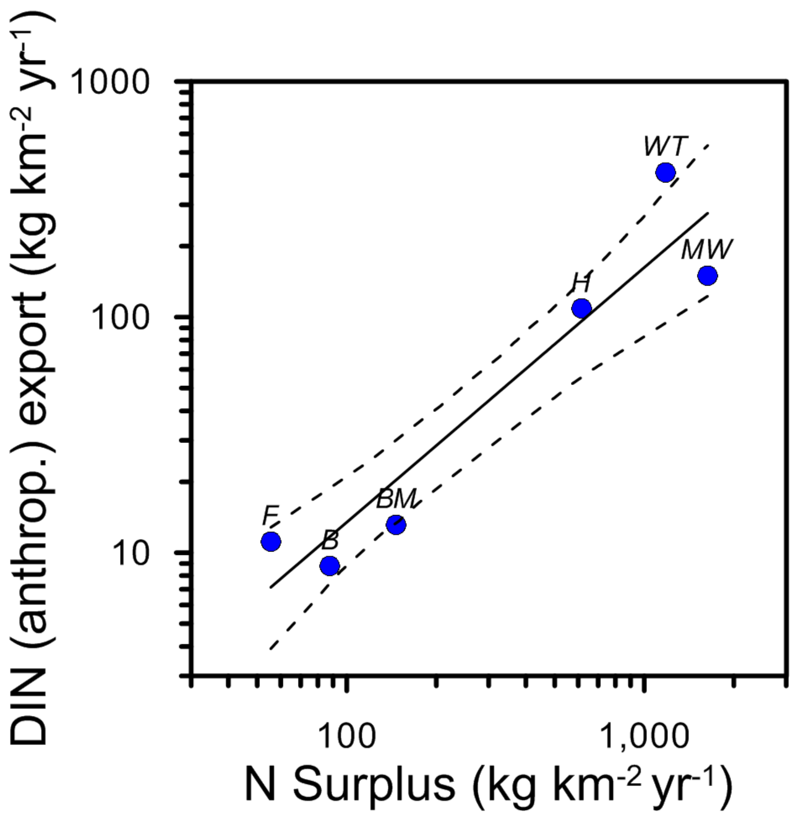
Thorburn et al 2003



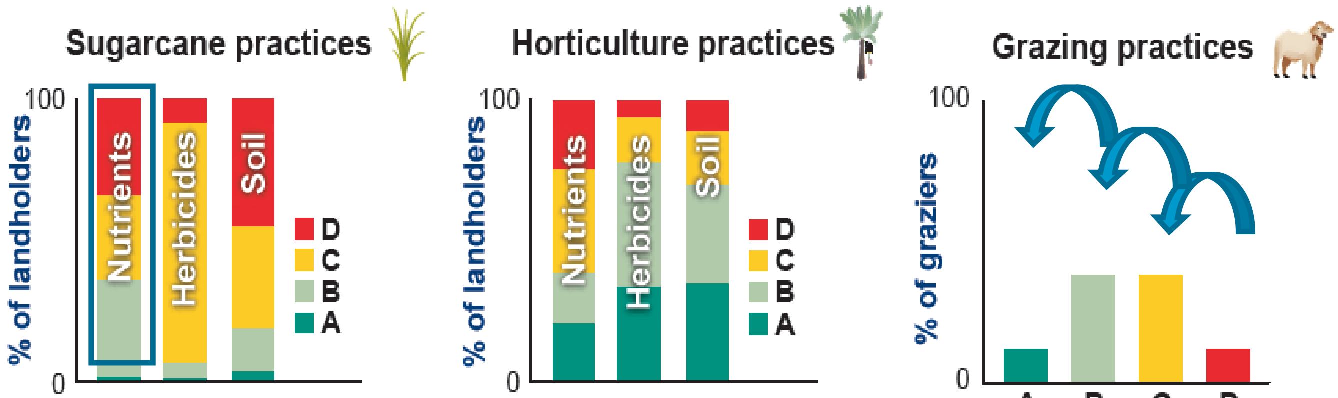
Scaling to catchment exports

- Assumption: Delivery efficiency not affected by practice change



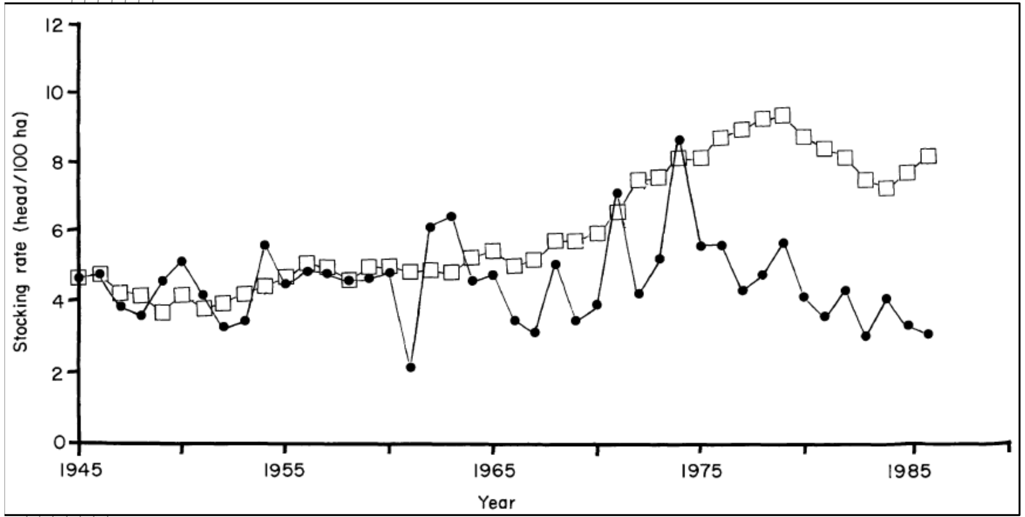


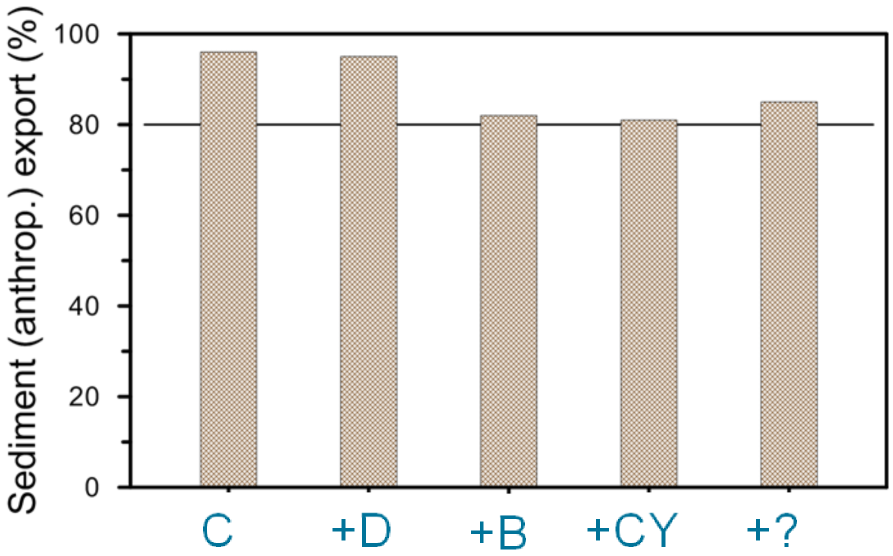
Practice scenarios

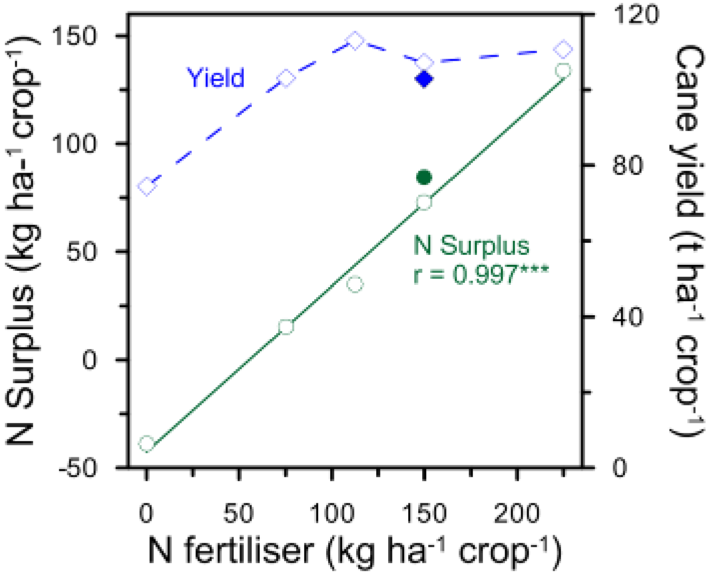


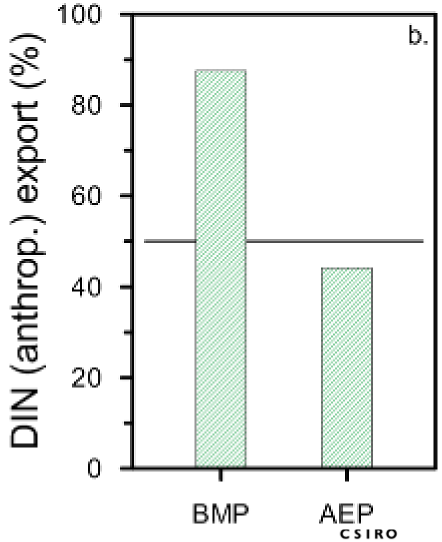
(GBR Report Card 2011)

Practice scenarios



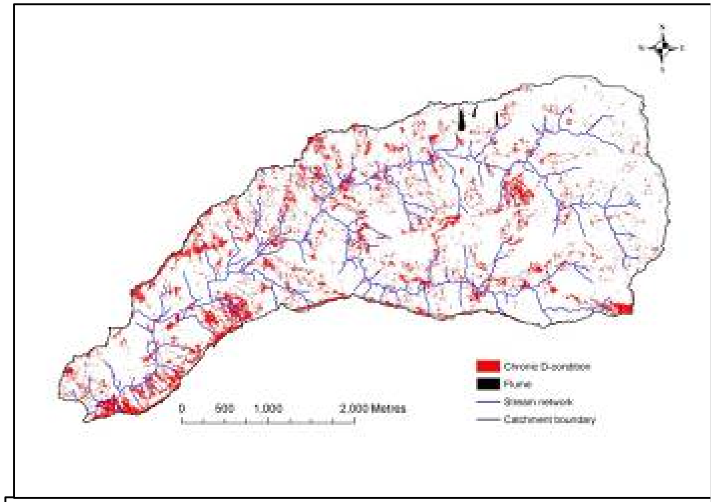


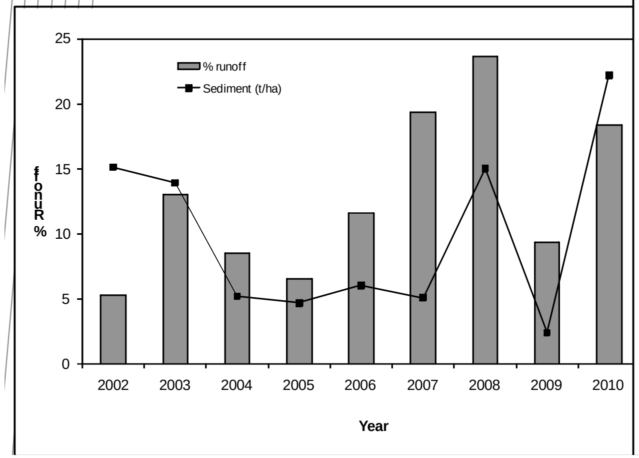


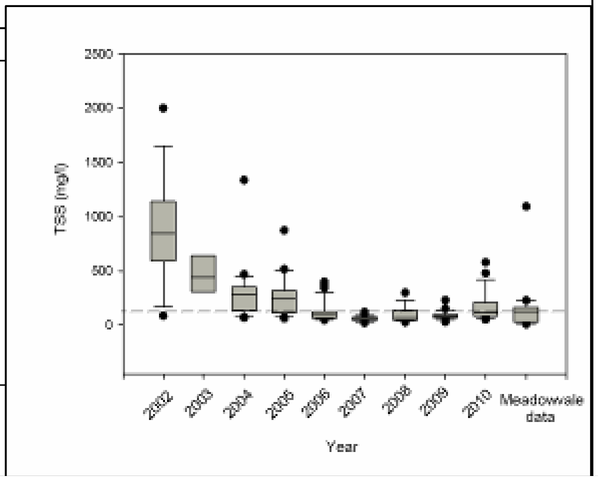


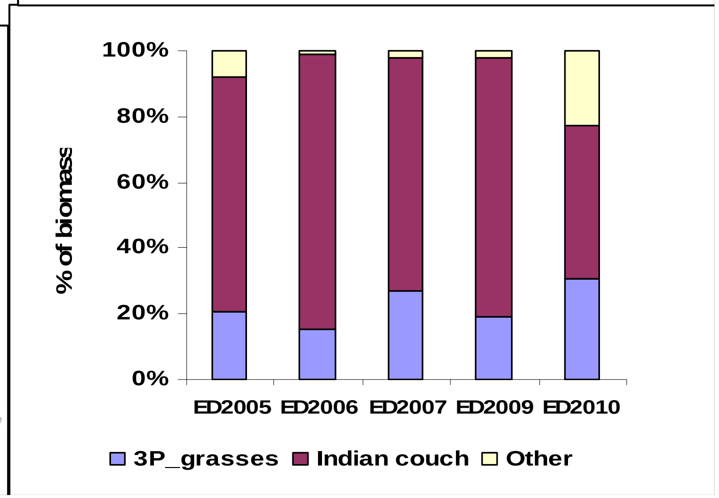
Ongoing work:
Monitoring practice change effectiveness

- Variables that define the WQ problem
- Variables that identify cause and effect
  - Scale
- "Slow variables for speedy learnings" (Lynam et al)
- Variables at the leading-edge of response









Ongoing work:
Monitoring practice change effectiveness

METRIC	SCALE	ADVANTAGE	DISADVANTAGE
Mean cover	Paddock	Remote sensing	Cover is patchy
Area wo. cover	Paddock	Correl with S-loss	High-res imagery expensive
Pasture compos	Paddock	No instrumentatn, leads soil health	Location-spec. Expert knowledge
Application rate	Paddock	Correl with N-loss	Sensitive - private
Runoff	Hillslope	Correl with S-loss	Soil, geomorphic, replicates reqd
Runoff	Catchment	Integrates spatial variability	Slow to respond
Concentration	Hill,Catch	Less sensitive to climate than flux	Instrumentation, replicates, dilution
Flux	Hill,Catch	Correl with reef impact	Slow to respond, temporal variation

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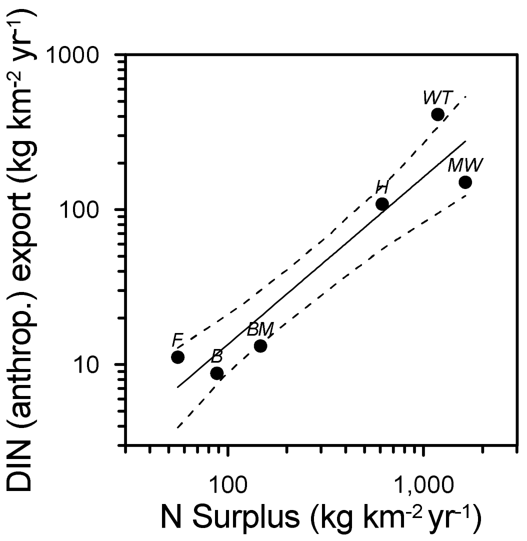
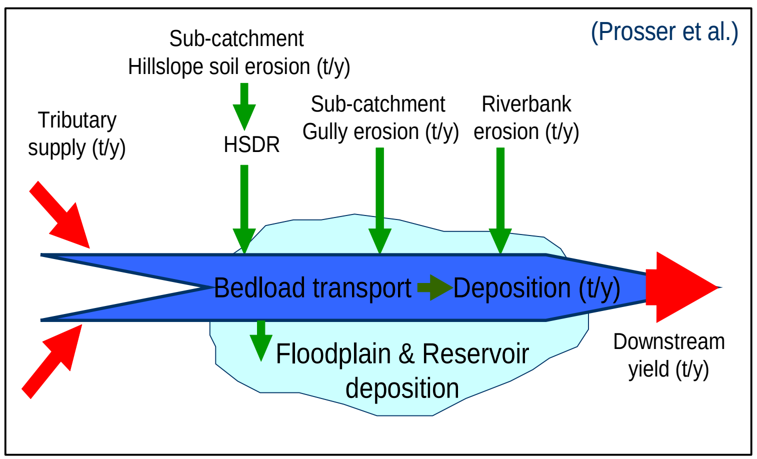
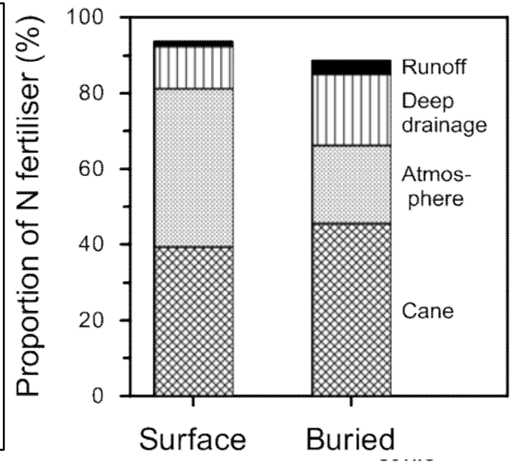
Conclusions

- Agricultural pollutant losses do not scale directly from paddock to catchment scales
- Represent pollutant fluxes at each scale considering the data and process knowledge available
  - Catchment budget modelling for assessing the spatial patterns in pollutant loss and connectivity
  - Conceptual frameworks to quantify how practice changes affect pollutant loss from paddock to stream







Where to from here?

- Improving catchment modelling datasets
- Coupling paddock and catchment models
- Data Assimilation in catchment modelling
- Refining metrics for monitoring the impacts of practice change

References

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- **McKergow** L et al. (2005) Sources of sediment to the Great Barrier Reef World Heritage Area. *Marine Pollution Bulletin*.
- **Prosser** IP et al. (2001) Large-scale patterns of erosion and sediment transport in river networks, with examples from Australia. *Marine and Freshwater Research*.
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- **Wilkinson** SN et al., (2006) Predicting the distribution of bed material accumulation using river network sediment budgets. *Water Resources Research*
- **Wilkinson** SN (2008) Testing the capability of a sediment budget model to target remediation measures to reduce suspended-sediment yield. *IAHS Publ. 325*.
- **Wilkinson** SN et al. (2009) Modelling and testing spatially distributed sediment budgets to relate erosion processes to suspended sediment yields. *Env.Modelling & Software*.