Tracking nitrogen from the paddock to the reef-

a case study from the Great Barrier Reef

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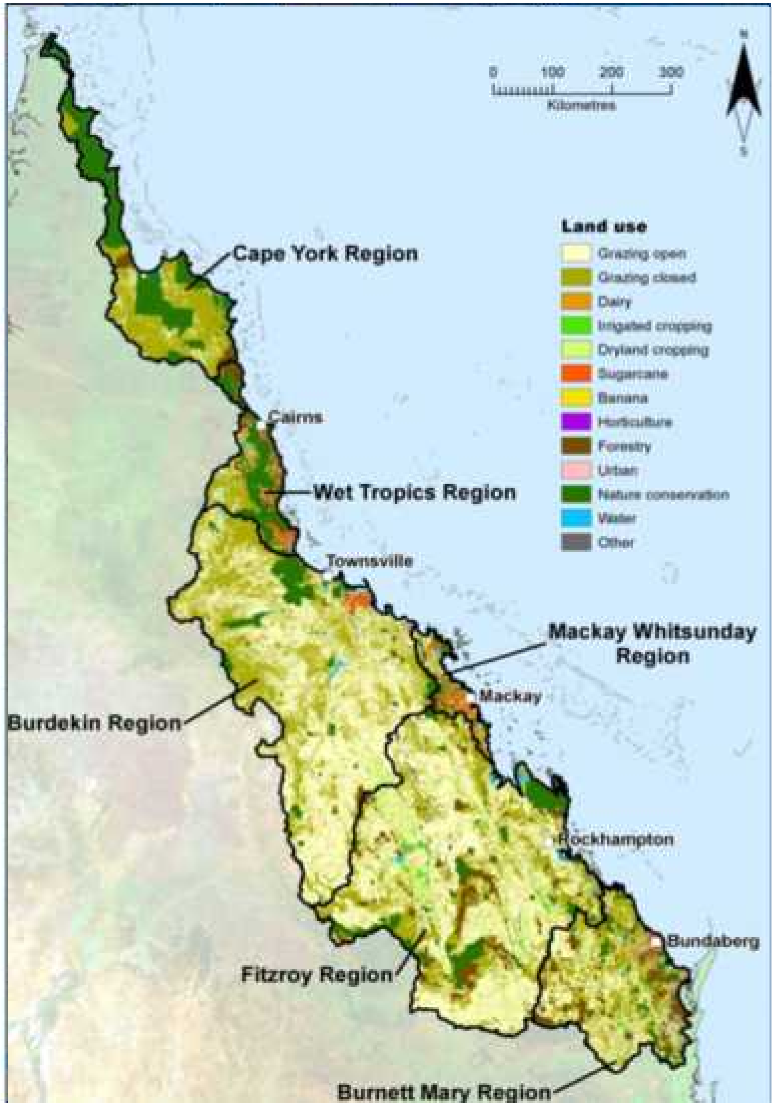
The University of Queensland Australia | Queensland Alliance for Agriculture & Food Innovation | Queensland Government | Australian Government | Australian Institute of Marine Science

The Great Barrier Reef Region



- Largest coral reef system in the world
- >3000 reefs; 2,200 km long;
- 350,000 km^2
- Adjacent catchment dominated by extensive grazing systems.
- Small areas of cropping close to the coast, in higher rainfall areas.
  (intensive sugarcane, horticulture and bananas, extensive grains)

GBR under pressure

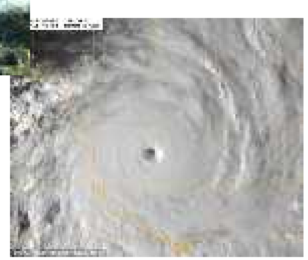
Fishing

Coastal Development

Increased ship traffic

Run off

Crown-of-thorns starfish

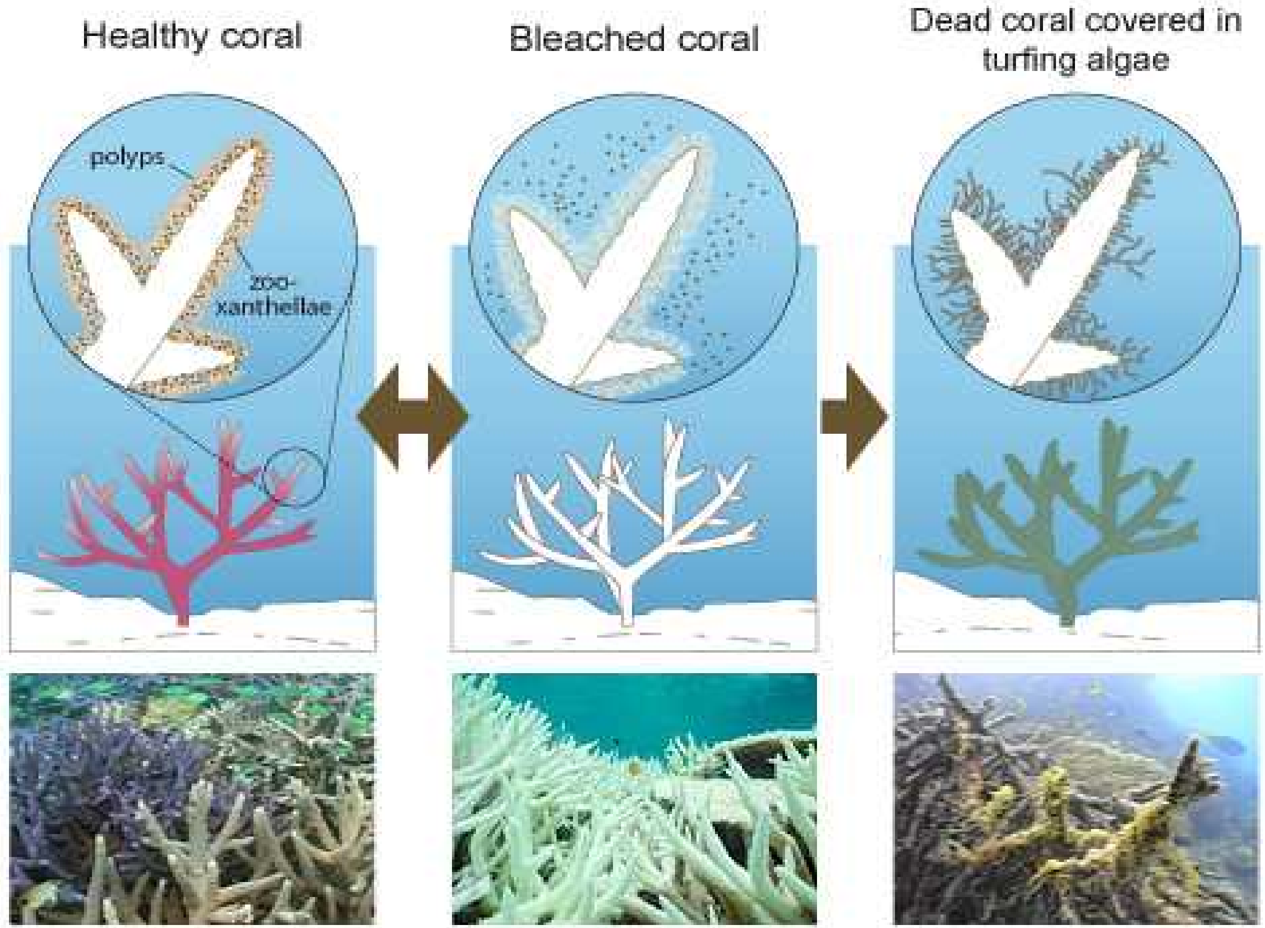


Cyclones & Storms

Increasing temperature

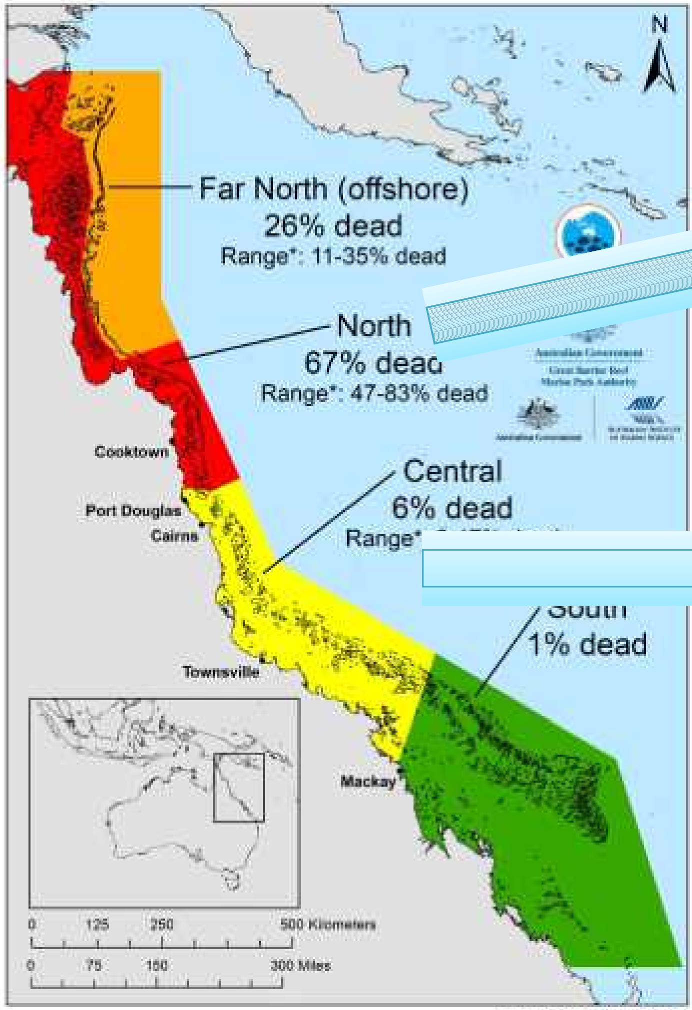
Ocean acidification

Coral bleaching



Source: GBRMPA

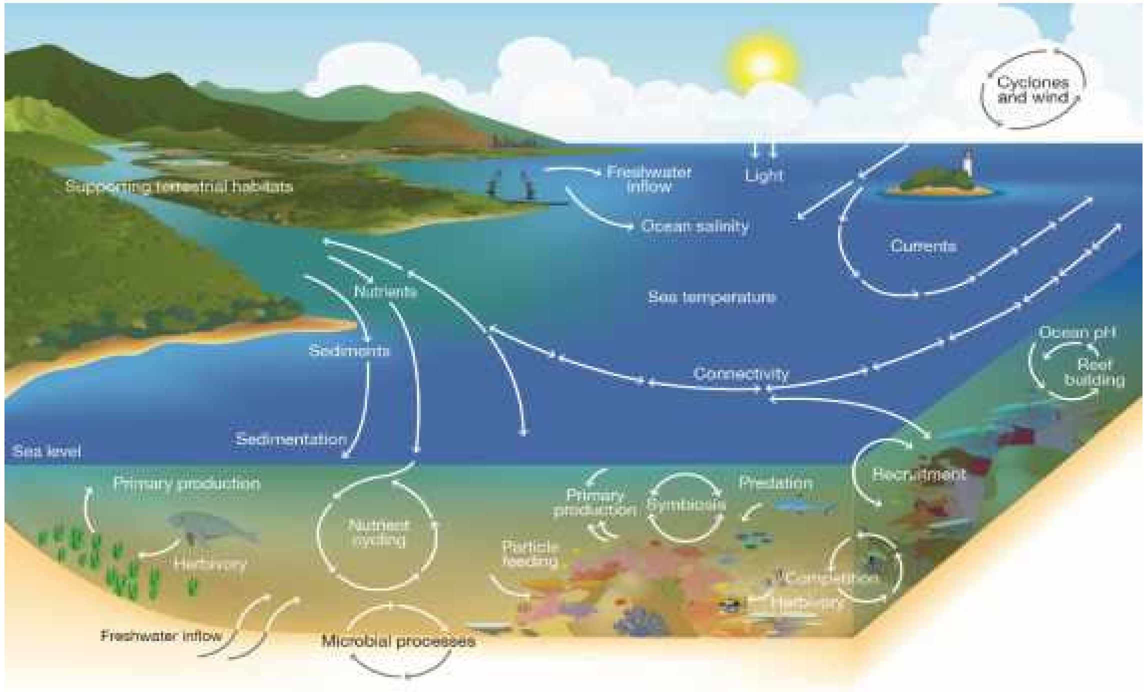
2016 Coral bleaching event



*upper and lower quartiles

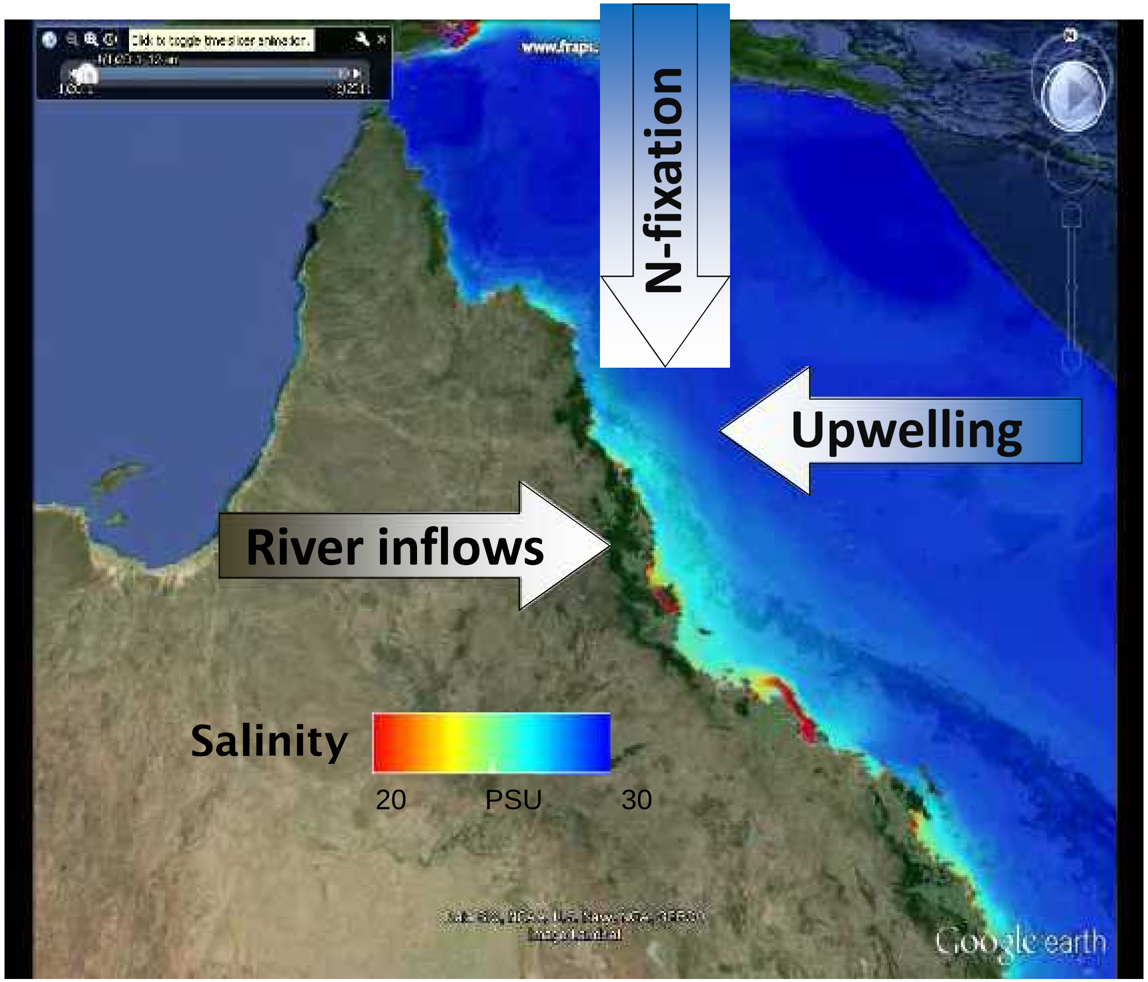
The GBR catchment to reef connection

Exposure to runoff from broad-scale land use is a key pressure for the ecosystems of the GBR

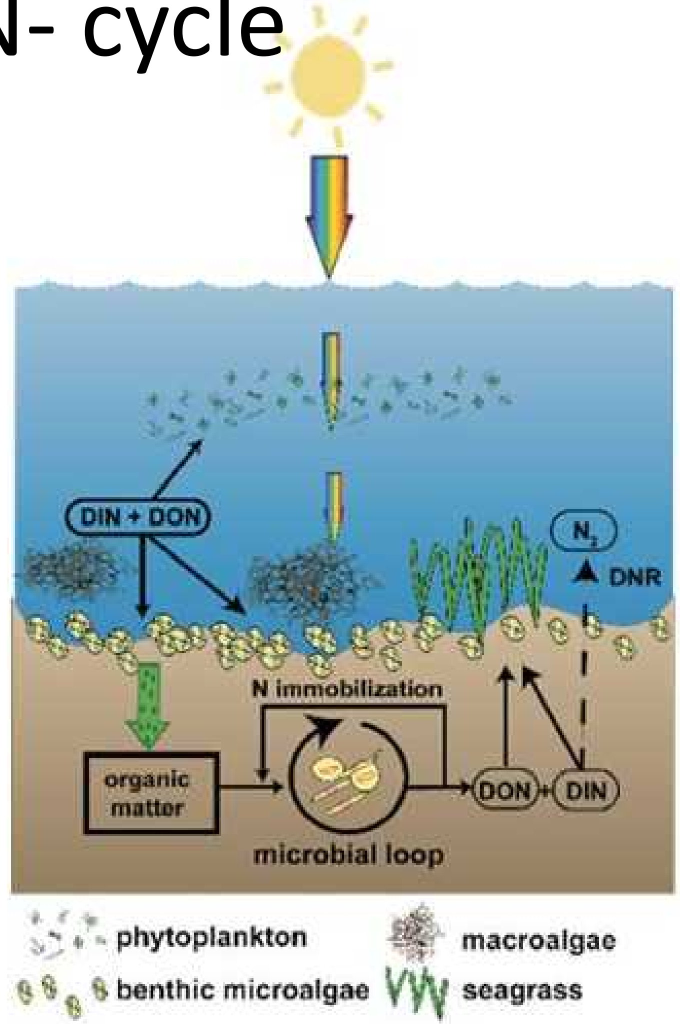


Loads have increased: Sediment (3-5 x) , Nitrogen (2-6 x), Phosphorus (2-9 x) + herbicides

3 main N sources



The marine N- cycle



Source: Virginia Coast Reserve Long-Term Ecological Research project

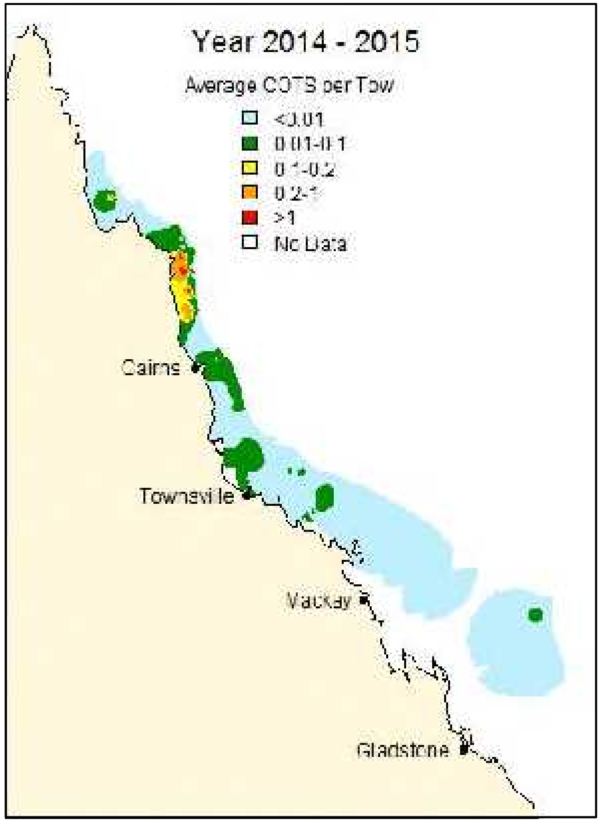
Coral bleaching & nutrients

Breakdown of symbiosis:

- Too much heat
- Too much light
- Too much N
  - Increased zooxanthellae density
  - N/P imbalance
  - Too much organic carbon, triggering higher N-fixation on corals

Wiedenmann et al 2013. Nature Climate Change 3: 160-164.
Rädecker et al. 2015. Trends in Microbiology, 23: 490-497.
Wooldrudge et al. in press. Marine Pollution Bulletin

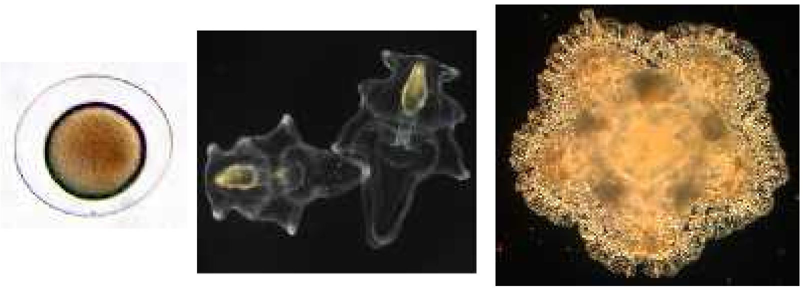
Outbreaks of the Crown-of-Thorns seastar (CoTS) & nutrients

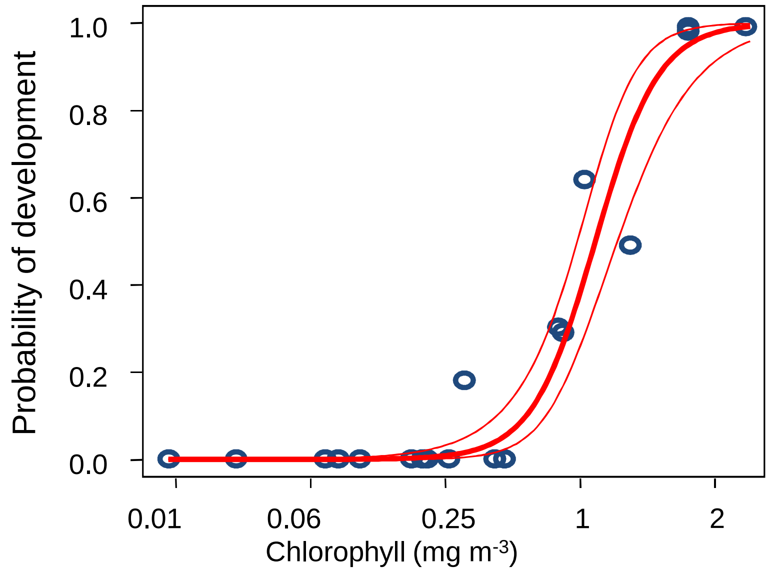


Enhanced food availability for CoTS larvae

"Nutrient Hypothesis" - A numbers game:

Higher survival of larvae due to increased food availability



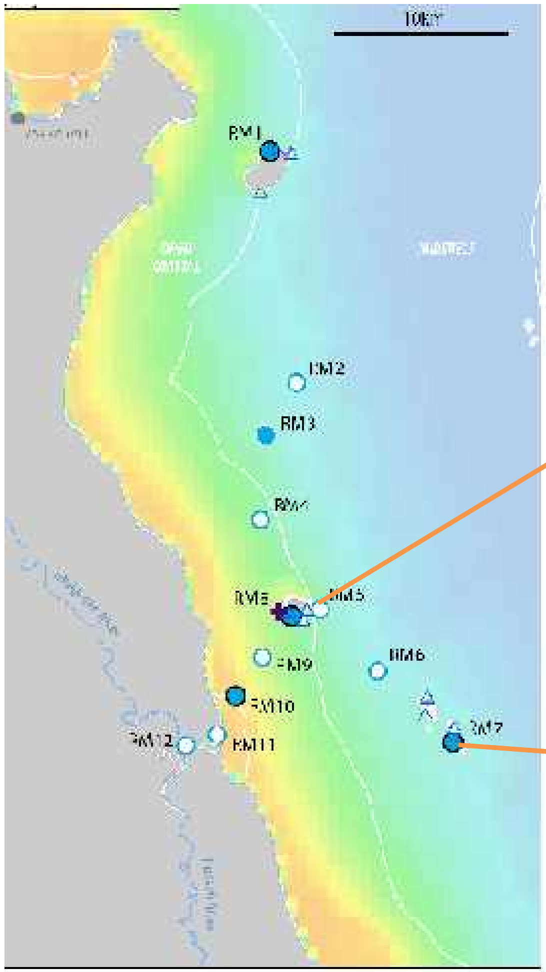


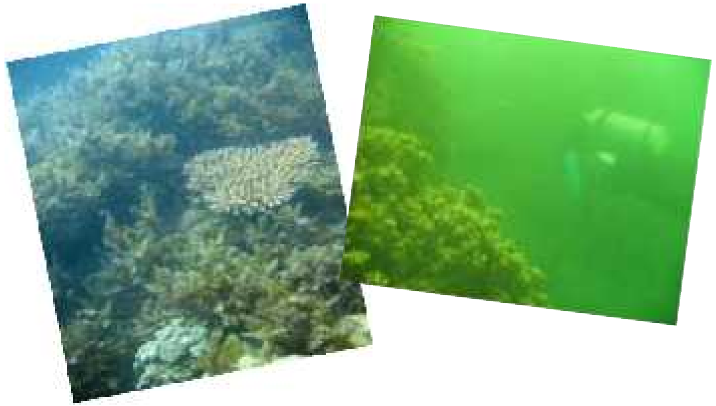
Likely in combination with:

- Hydrodynamic conditions that retain larvae
- Reduced predators
- Increasing temperature

Fabricius et al. 2010. Coral Reefs 29: 593-605.

Reefs condition & nutrients

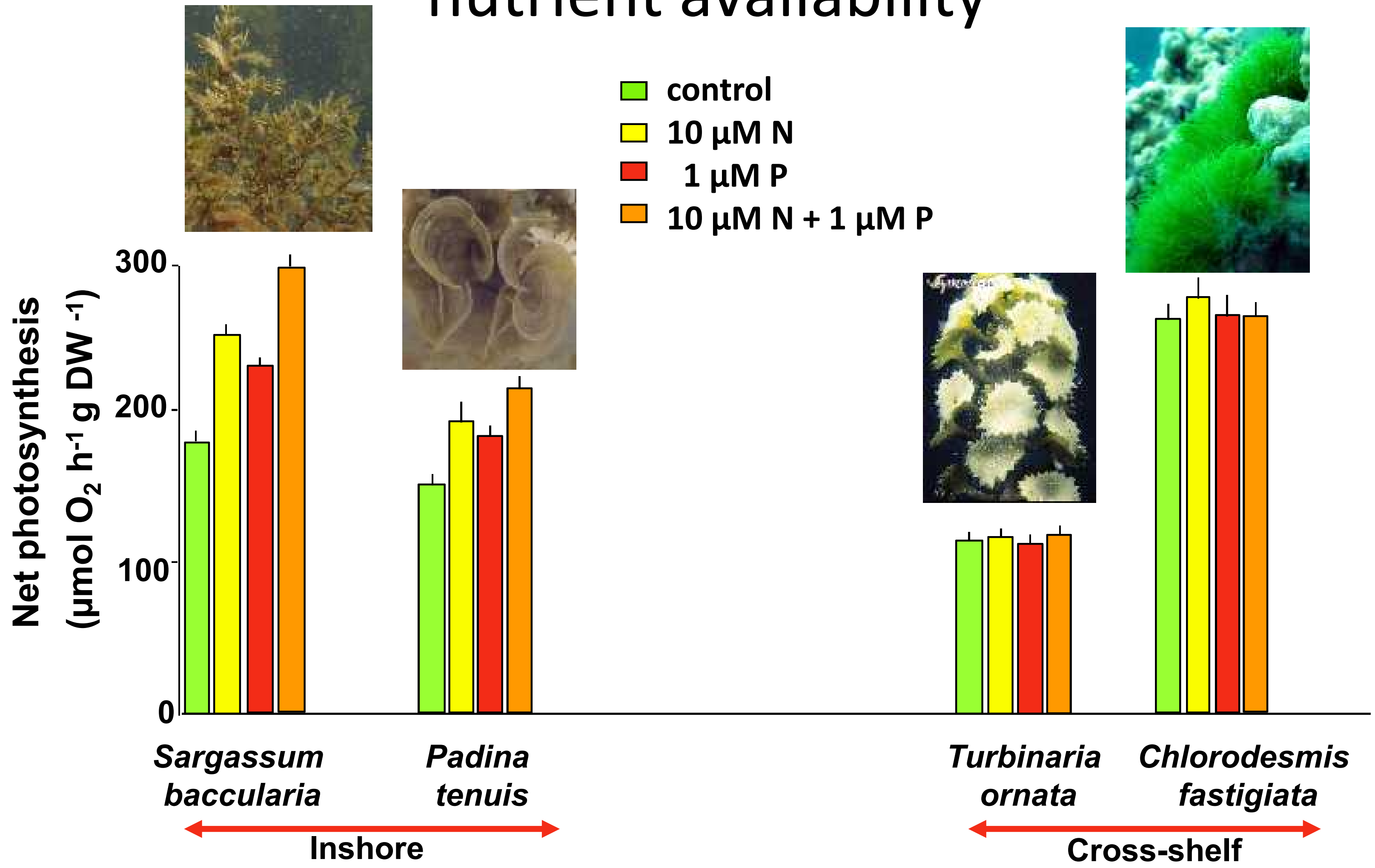




High nutrients,
High sediments

Low nutrients,
Low sediments

Inshore seaweeds benefit from higher nutrient availability



Schaffelke 1999, Mar Ecol Prg Ser 182: 305-310.

Recovery of reefs after disturbance

Water quality is an important factor

- moderate algal growth, mainly turfs
- coral recruitment & growth

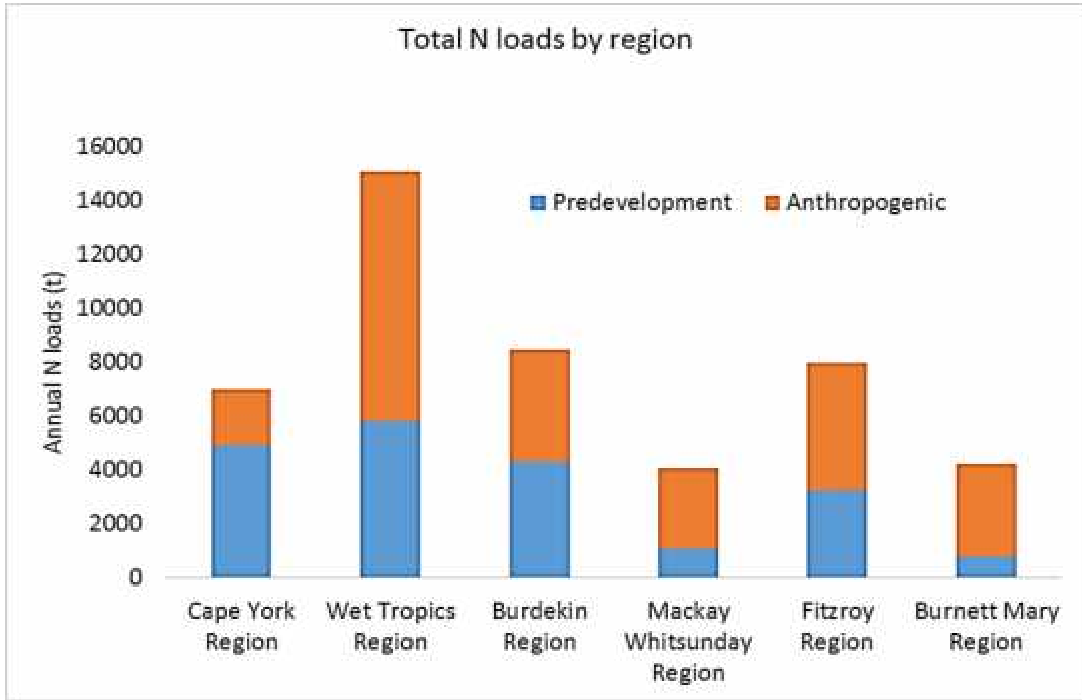
→ Recovery

- enhanced algal growth
- coral recruitment reduced
- coral/algal competition

→ slow or no recovery, reduced diversity

Regional variability in loads, pre- and post-development

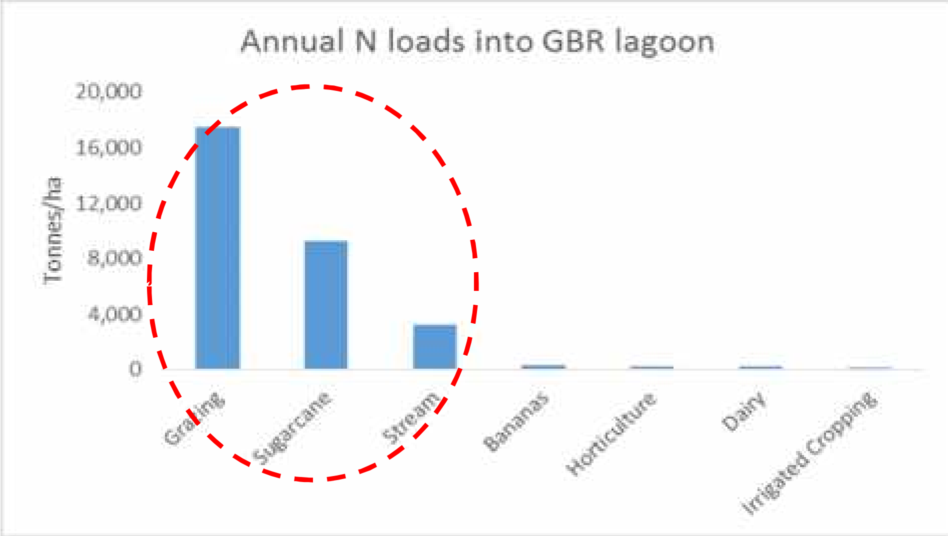
- Large regional variation in predevelopment loads.
- Anthropogenic activity has increased loads substantially.
- Largest relative increases in regions where predevelopment loads were quite low.

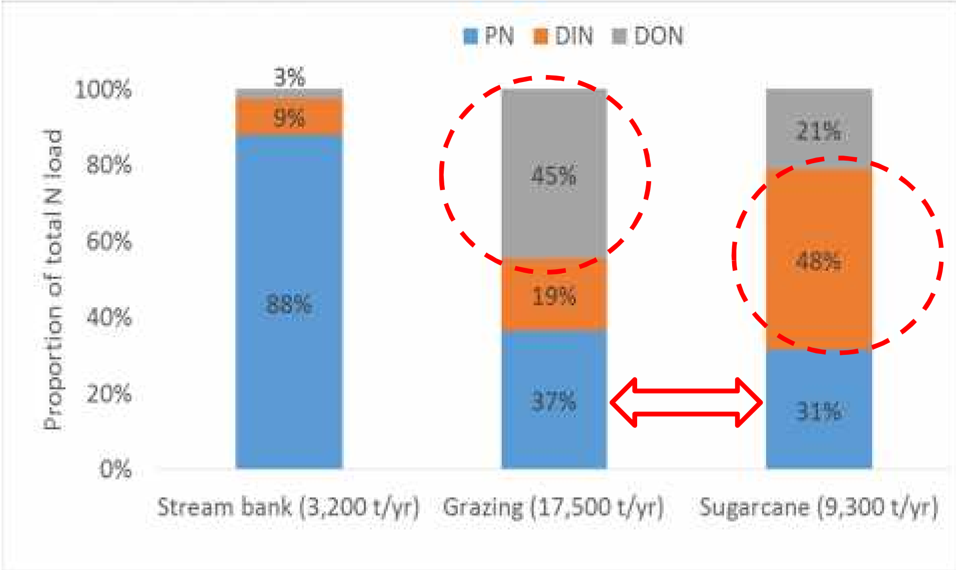


McCloskey et al. (2016) Reef Report Card 2015. Whole of GBR, Technical Report, Volume 1

Sources of N in loads entering the GBR.

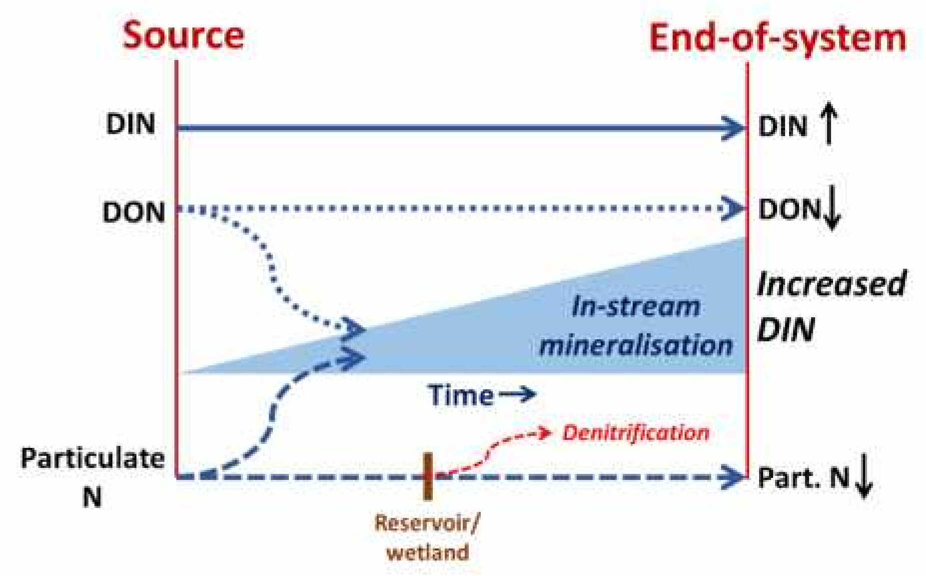
- There are 3 dominant sources of N.
- Grazing and sugarcane cropping are the dominant agricultural land uses in terms of N loads.
- The 3rd ranked source (stream bank erosion) is linked to development and loss of riparian vegetation.
- The constituent N forms from each source are quite different, and are the product of the N inputs and the loss processes in each system.





Are these N constituents what left the field (i.e. do we know what we are trying to manage?).

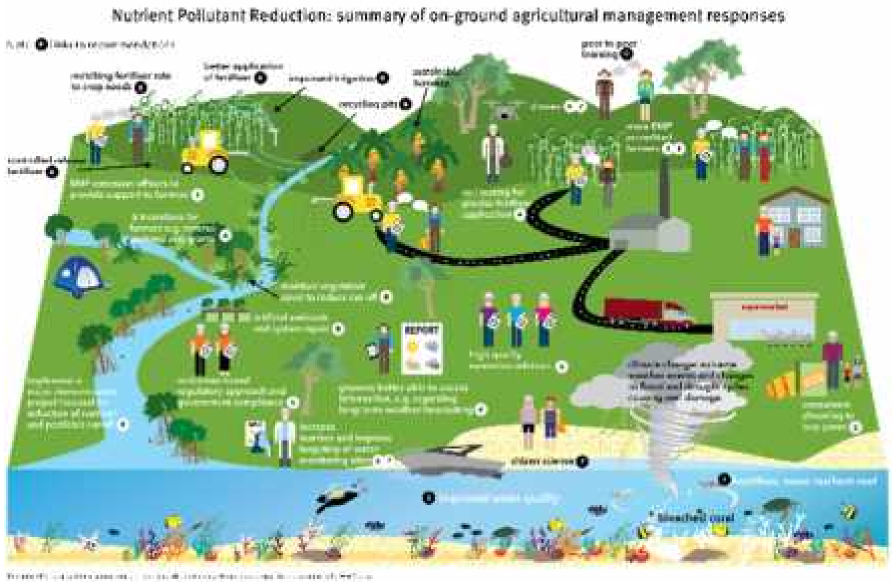
- Loads modelling calibrated against end of catchment loads monitoring.
- A series of N transformations and losses can occur between paddock and river mouth.
- These can result in DIN enrichment, as well as lower N loads.
- Residence times will have a major impact on these processes

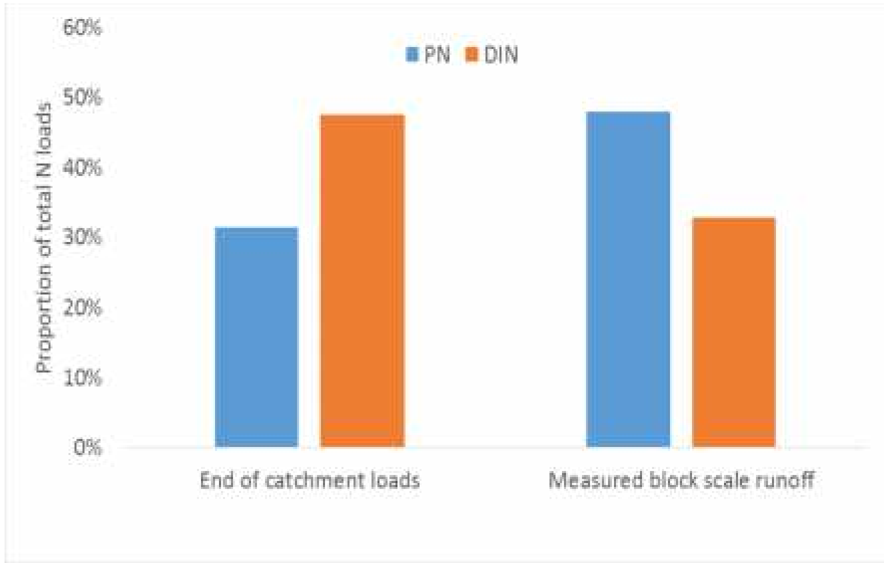


The form and pathway of N loss will determine water quality impact and the effectiveness of management strategies

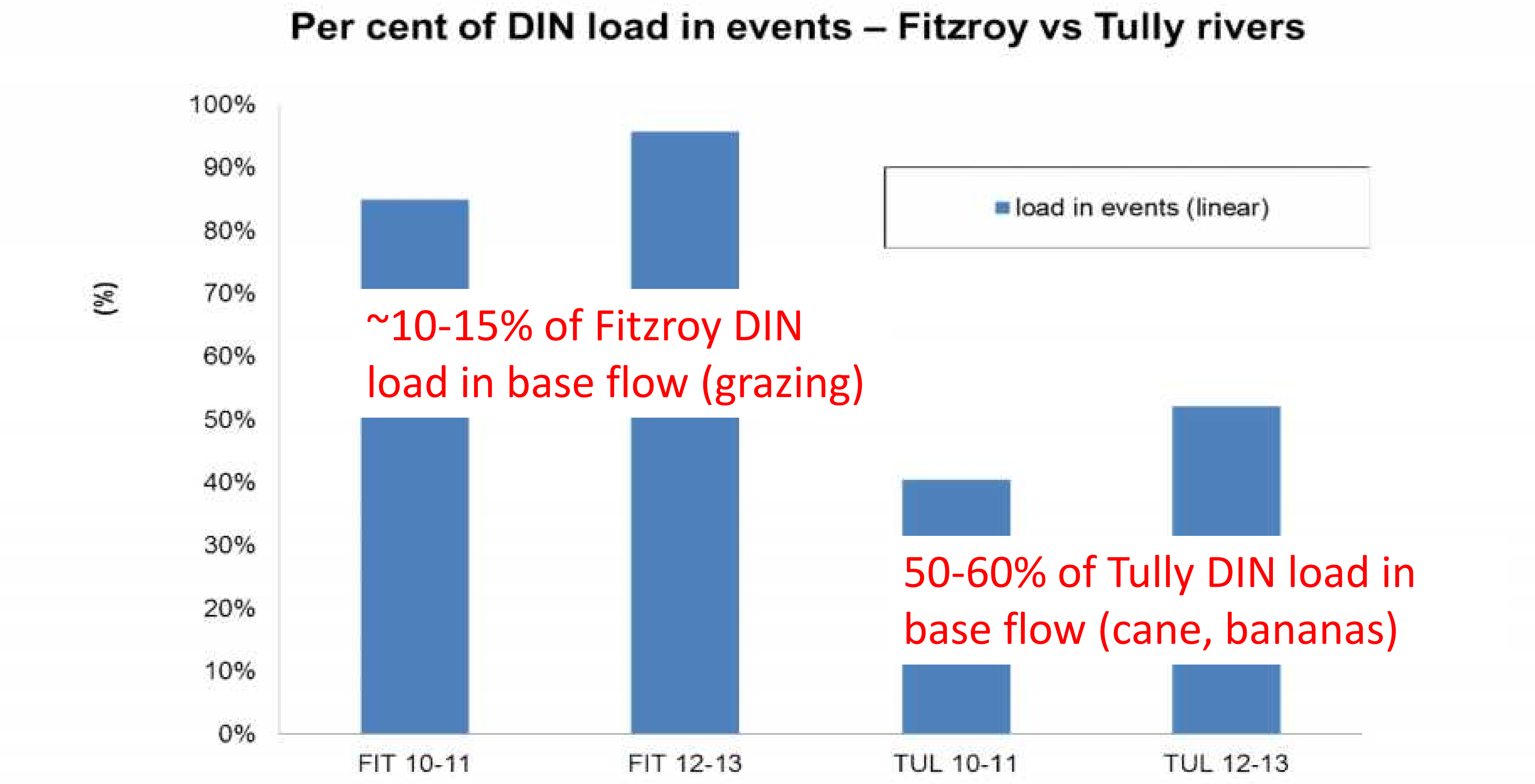
- Denitrification losses will have no direct water quality impact
- The proportions of PN and DIN will influence the zone of impact (inshore v outer reef).
- Minimizing runoff will reduce PN loads but not necessarily DIN.

An example from *sugarcane*, comparing measured runoff losses at block scale and modelled loads at end-of-catchment



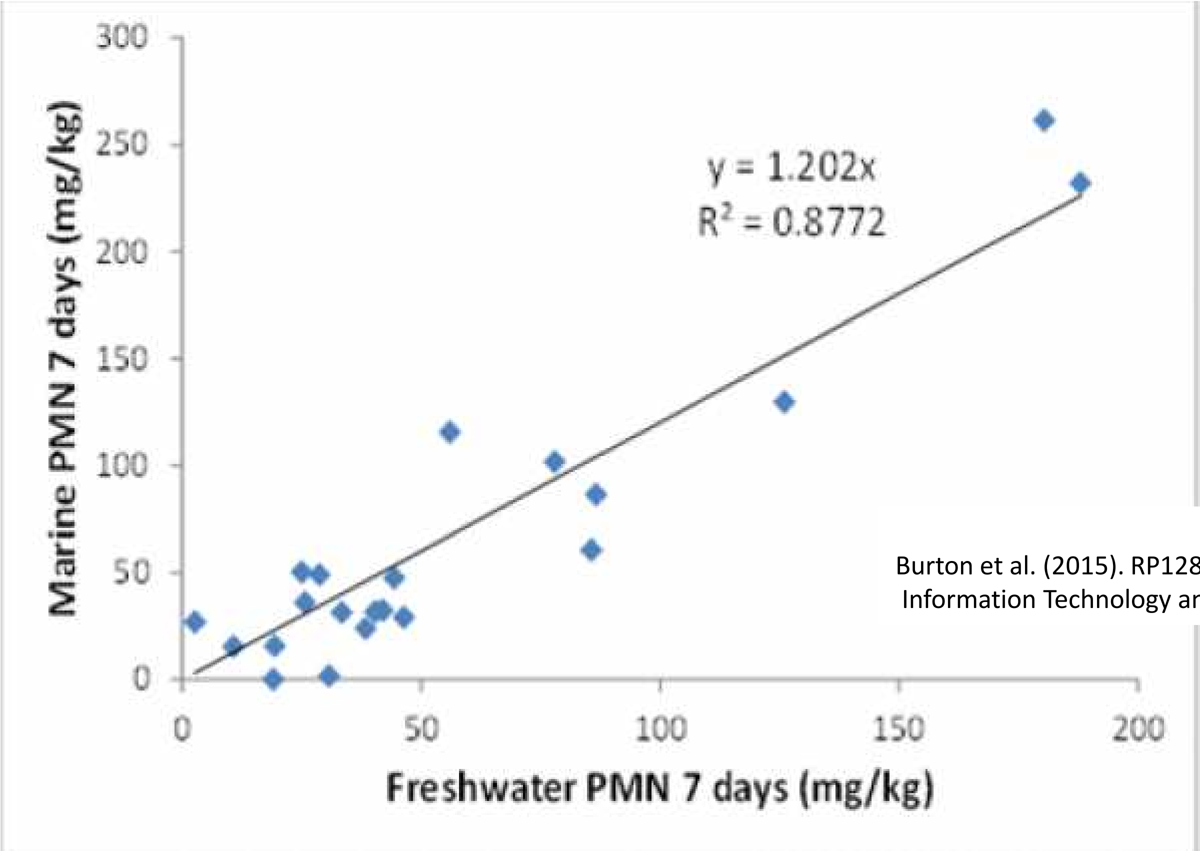


Monitoring suggests leaching and lateral movement are a major DIN source in sugar catchments.



Pers. Comm. Ryan Turner, GBR Loads Monitoring Program

These transformation processes don't stop at the river mouth



Burton et al. (2015). RP128G - Department of Science, Information Technology and Innovation.

Reducing DIN loads may seem a logical first step to reducing the biologically active N loads. However, the risks posed by labile organic N cannot be ignored.

Minimizing N losses from grazing systems – controlling erosion…

Hillslope/sheet erosion

Gully erosion

Extensive areas

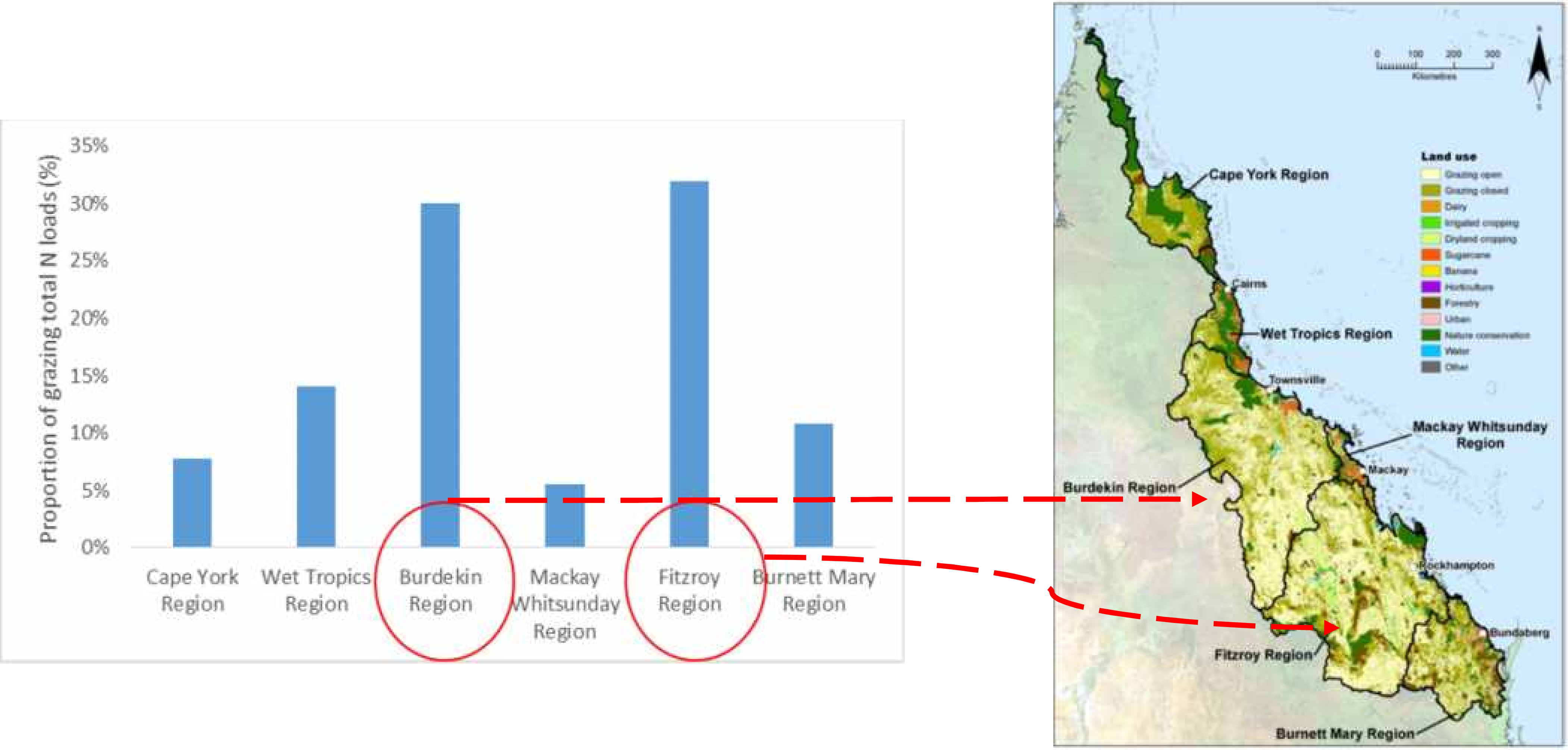
- Managed by retaining groundcover
- A focus of grazing BMP programs
- Only delivers ~ 20% of total sediment

Small, defined areas

- Intensive remediation/stabilization
- A focus of on ground activity
- Delivers ~ 80% of total sediment

Bartley et al (2017). Chapter 2 – GBR Science Consensus statement

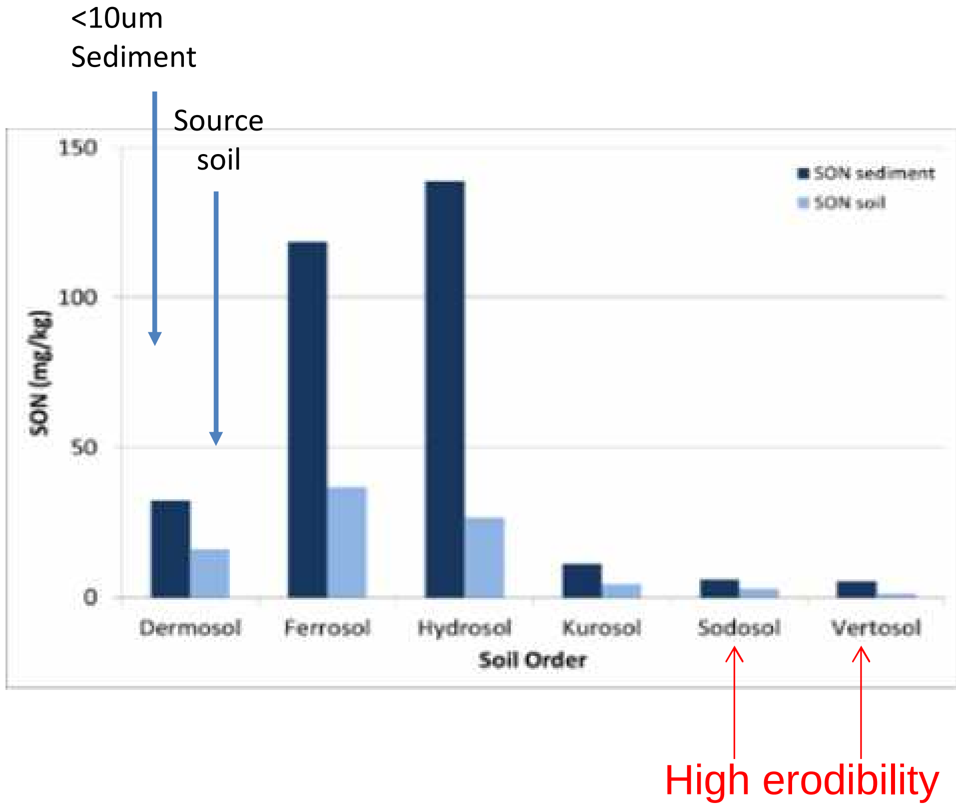
Where to focus?



N enrichment ratios will help focus activity on soil types with greatest N delivery risk

- Bioavailable nutrient levels in surface soil varied widely between soil types

- Enrichment ratios (sediment/soil) also varied widely

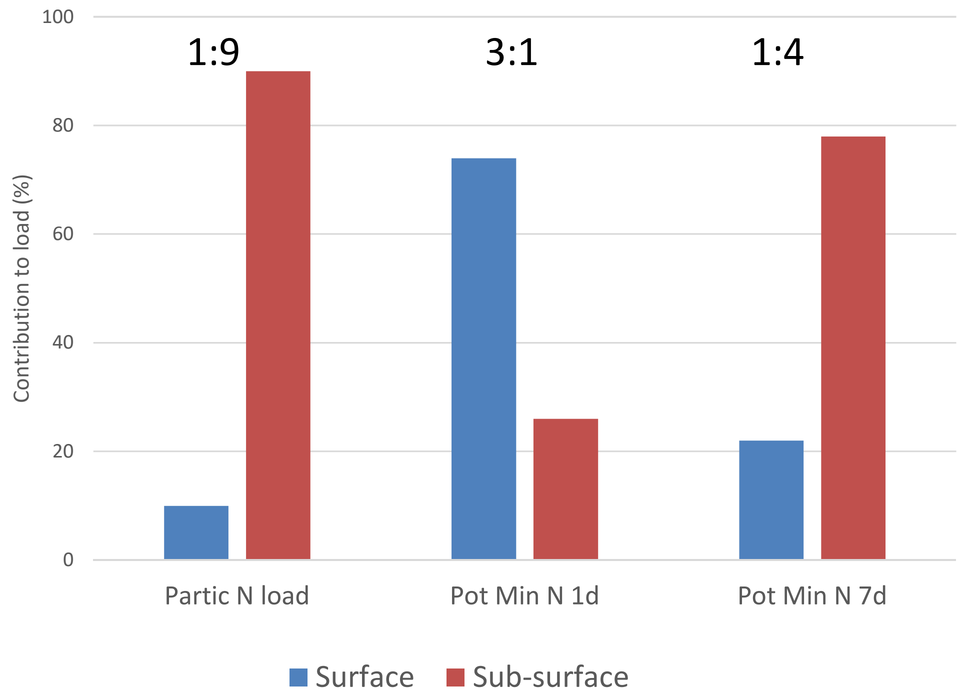


Burton et al. (2015). RP128G - Department of Science, Information Technology and Innovation.

Labile N in the fine sediment fraction represents the greatest water quality risk to the outer reef

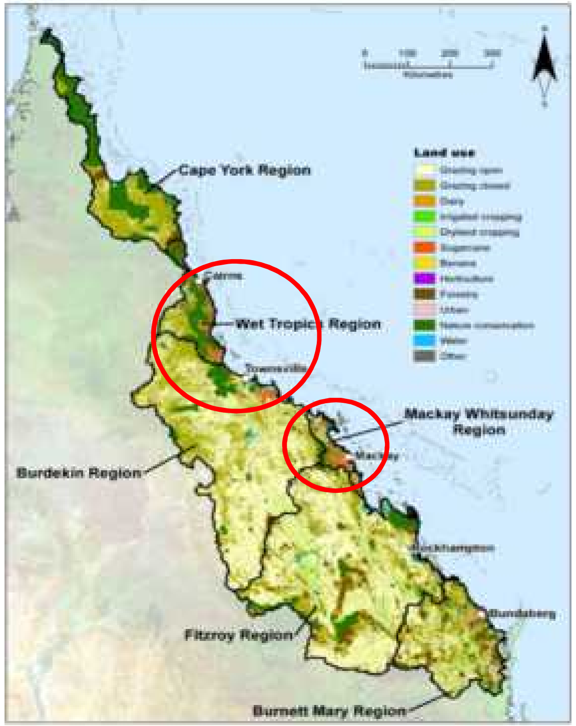
For fine (<10um) sediment:

- Sub-surface sediment contributes most of PN load (90% in this eg. – Wilkinson *et al*. 2015)
- Surface sediment contributes significantly more mineralisable N than its load proportion
- ***Management intervention must consider both hillslope and streambank/gully erosion processes***



Wilkinson et al. (2015); Burton et al. (2015); Bartley et al. (in press).

Minimizing N losses from sugarcane
- managing surplus N…..

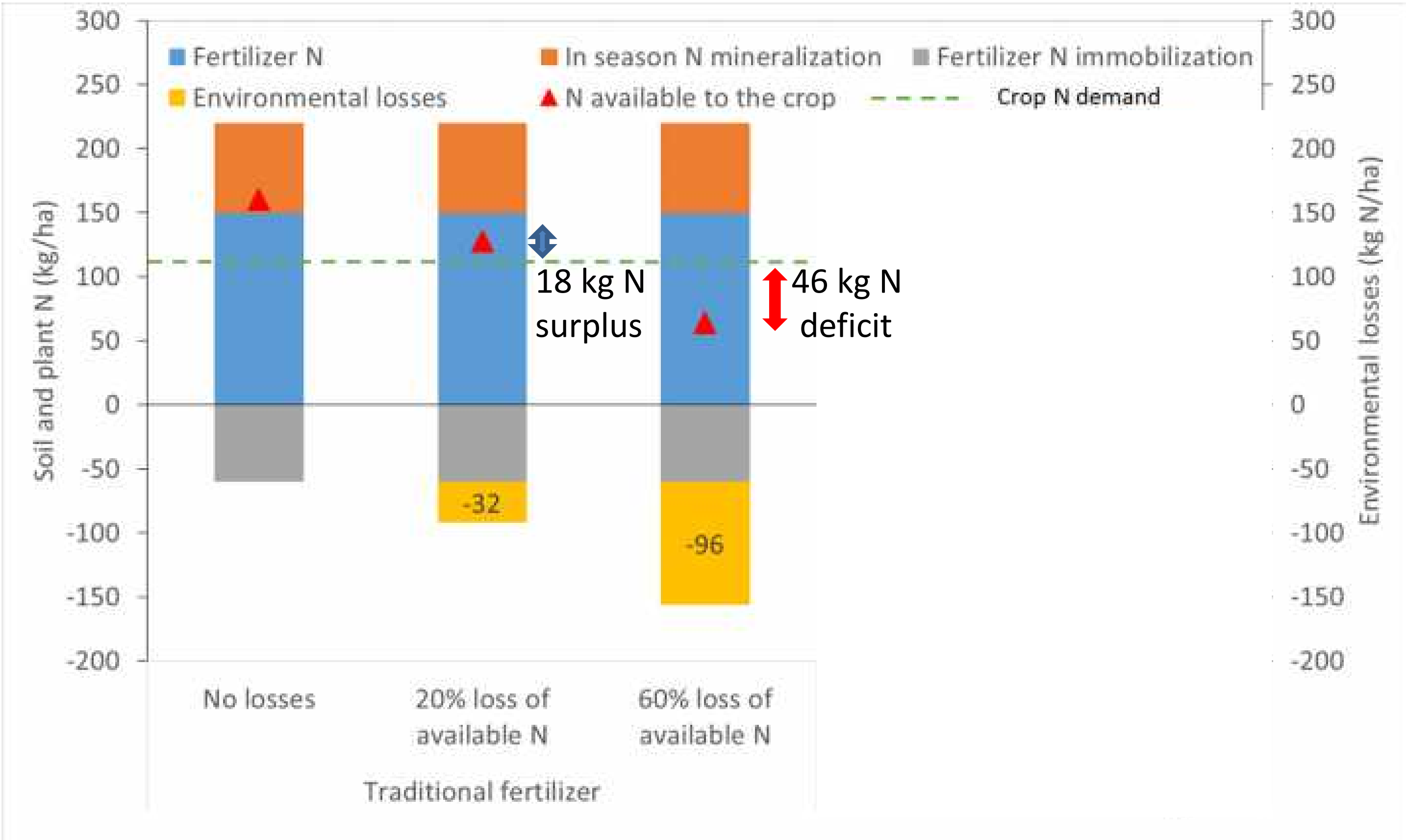


An example for an 80 t/ha cane crop in the wet tropics

Urea and the current N surplus

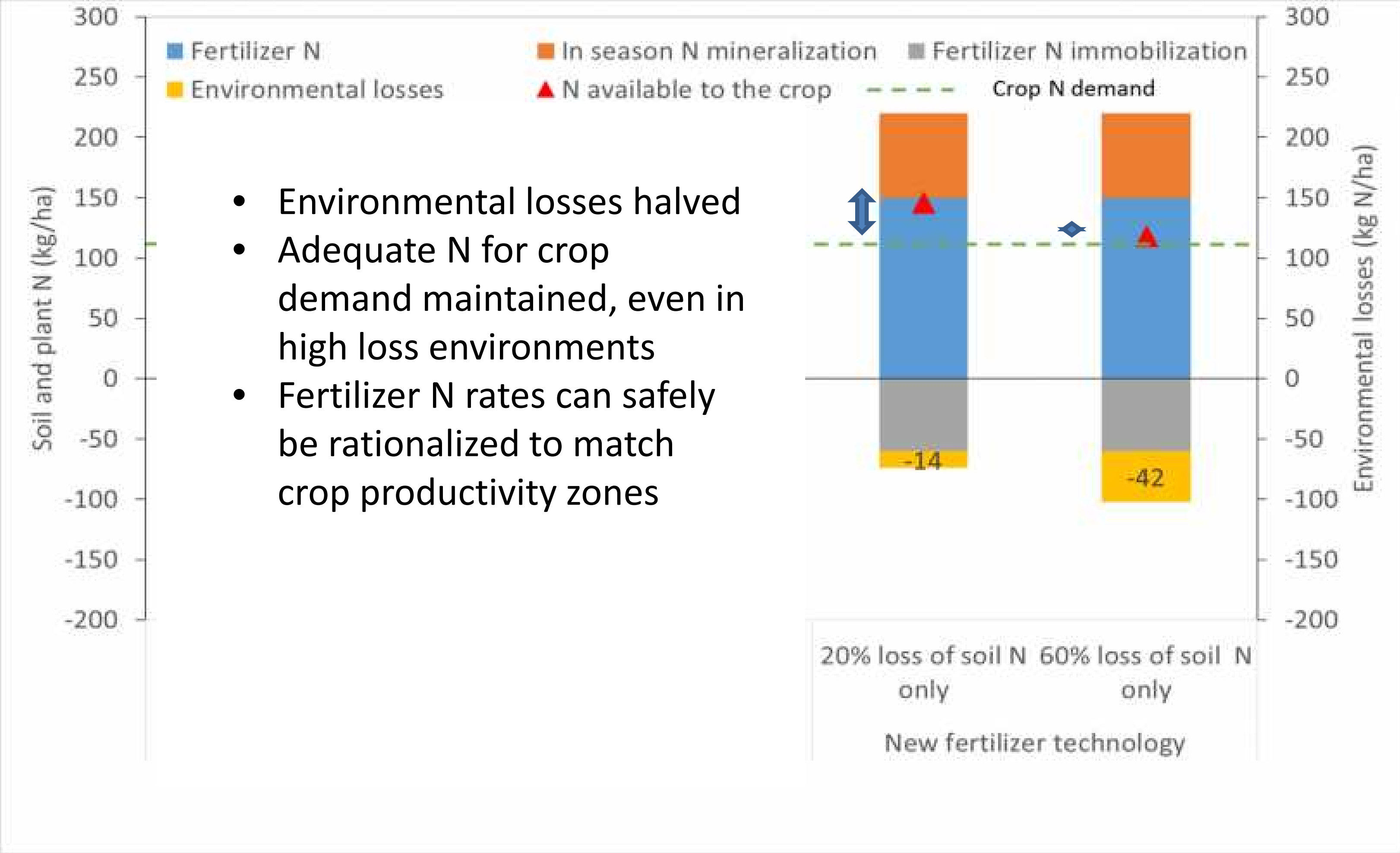
With no environmental losses, growers could reduce conventional N rates by ~40 kg N/ha and still meet crop demand in this example

The reality - losses to the environment can be high and crop N supply may become suboptimal



Environmental losses remove the option to safely reduce N rates. In high loss situations, increasing N rates can be a reasonable risk management strategy!

Improved fertilizer technology will break this nexus



- Environmental losses halved
- Adequate N for crop demand maintained, even in high loss environments
- Fertilizer N rates can safely be rationalized to match crop productivity zones

Conclusions

- Elevated bioavailable N in the GBR lagoon is affecting ecosystem health, and process level understanding of the ecological mechanisms is developing rapidly
- The major sources of anthropogenic N are the grazing and sugar industries
- Changed management practices are reducing loads, but not far enough or fast enough.
- Management interventions to limit N loads may not be the same as for sediments and pesticides
- Enhanced efficiency fertilizers offer solutions in sugar
- Climate variability and the feasibility of increased management intensity in extensive grazing systems remain challenging
- Climate change remains the biggest threat to the longer term health of the Great Barrier Reef

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