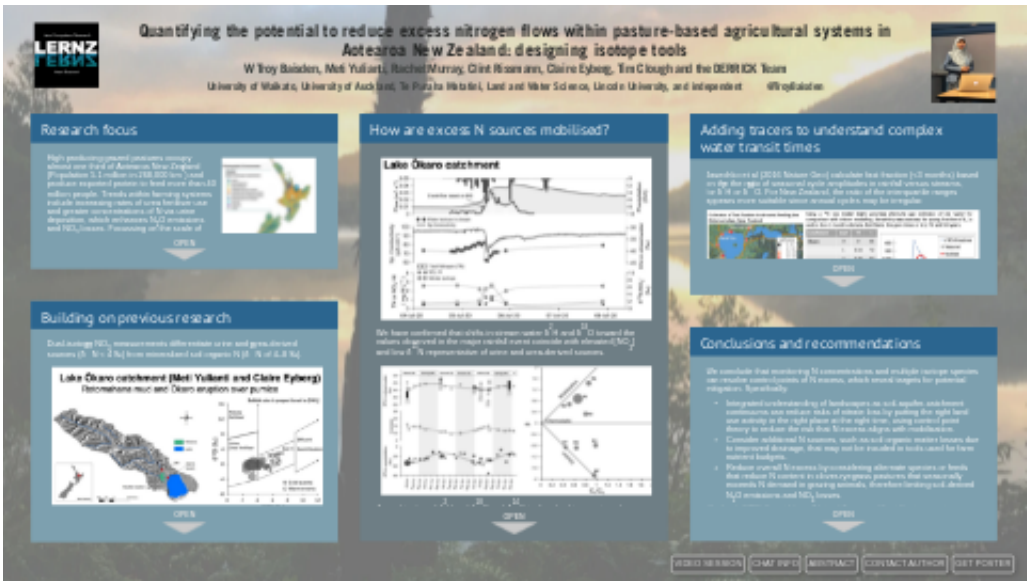
Quantifying the potential to reduce excess nitrogen flows within pasture-based agricultural systems in Aotearoa New Zealand: designing isotope tools



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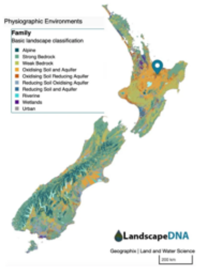
PRESENTED AT:

RESEARCH FOCUS

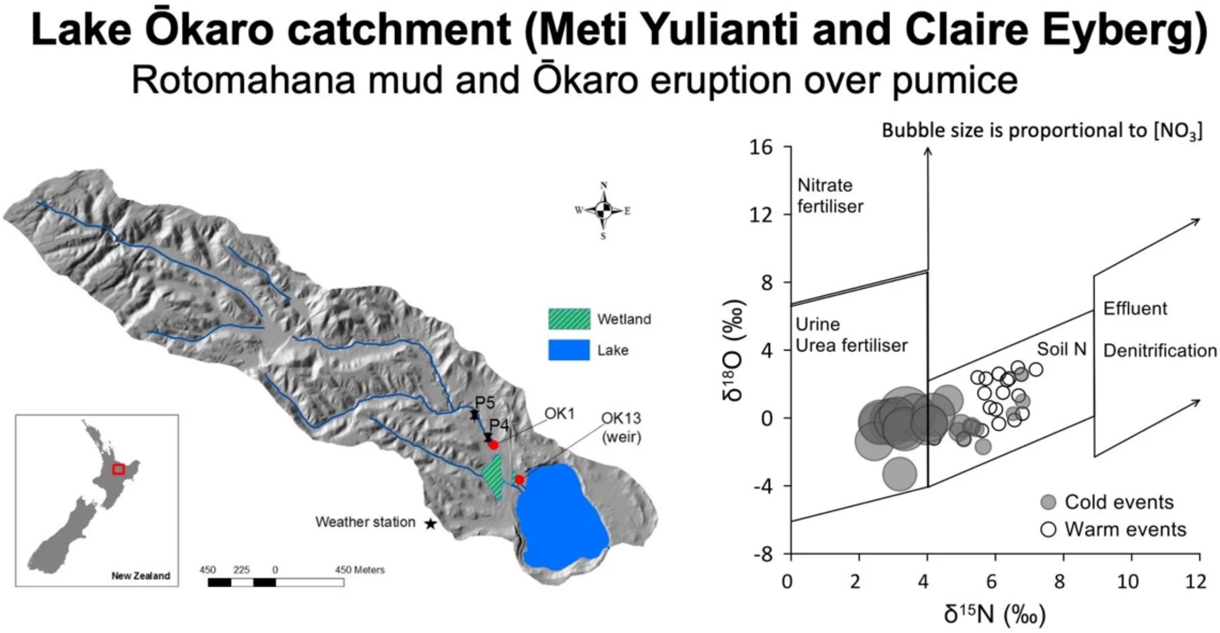
High producing grazed pastures occupy almost one third of Aotearoa New Zealand (Population 5.1 million in 268,000 km^2) and produce exported protein to feed more than 40 million people. Trends within farming systems include increasing rates of urea fertiliser use and greater concentrations of N via urine deposition, which enhances N_2O emissions and NO_3 losses. Focussing on the scale of farms and landscapes in N-sensitive lake catchments, we ask: what tools can reduce uncertainties in the sources and magnitude of N losses, quantify the potential to reduce excess N, and clarify rates of change in N budgets.



Map from the just released LandscapeDNA.org (http://LandscapeDNA.org) showing physiographic units delineated to describe the role of landscapes in the transport of key contaminants including NO_3.

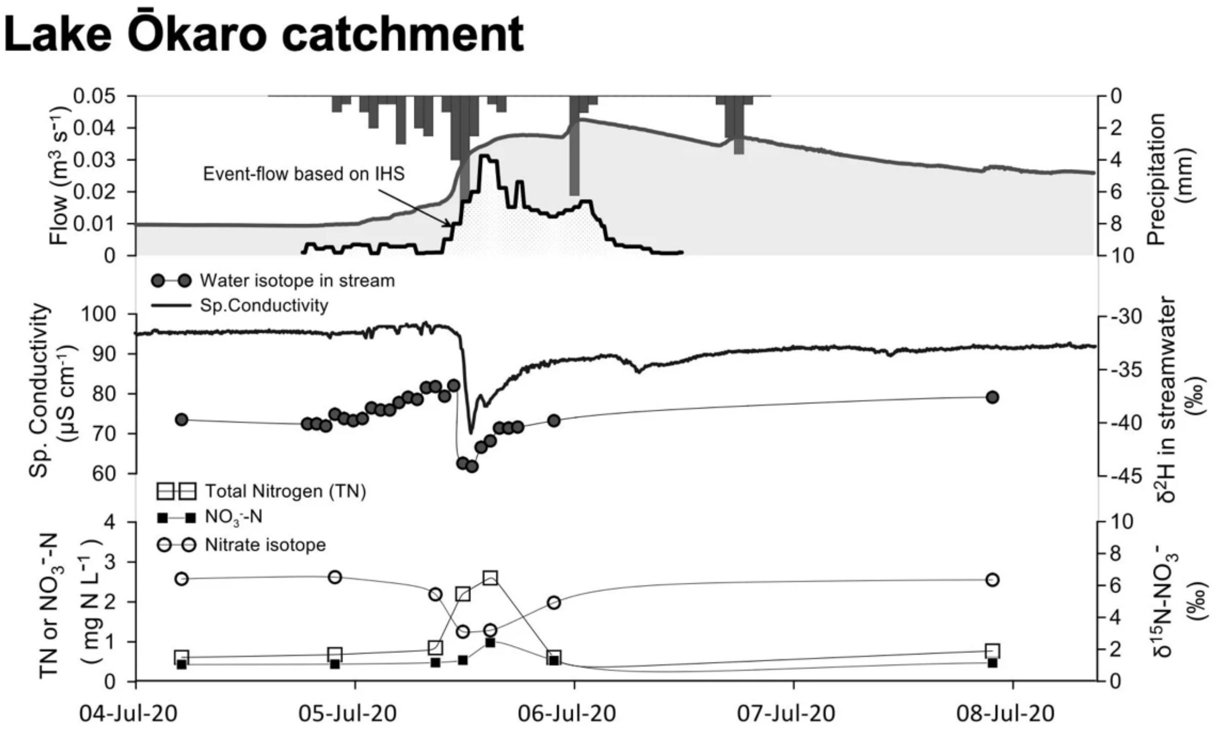
BUILDING ON PREVIOUS RESEARCH

Dual-isotope NO_3 measurements differentiate urine and urea-derived sources ($\delta^{15}N$ < 4 ‰) from mineralized soil organic N ($\delta^{15}N$ of 4–8 ‰).

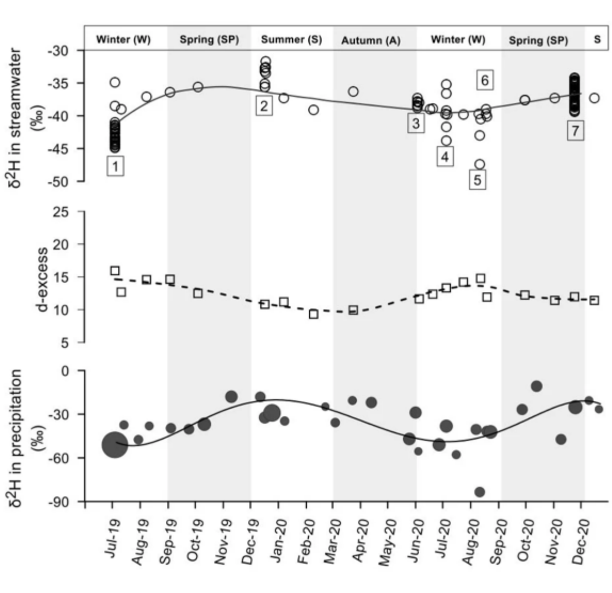


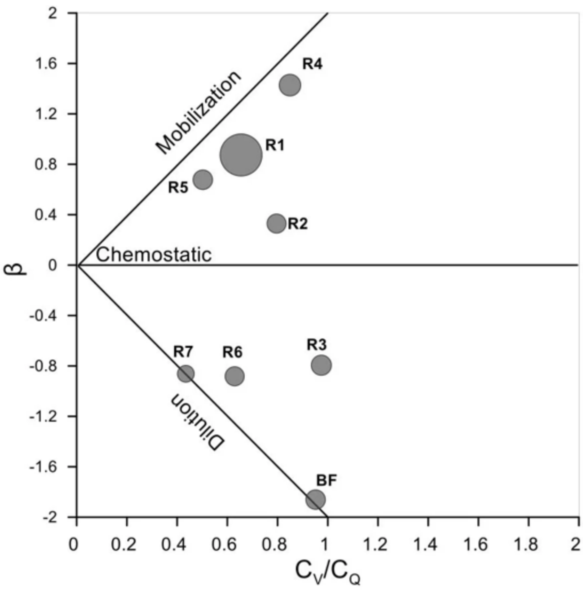
Nitrate in streams draining the Rotorua region's pumice soils and aquifers is dominated by urine and urea sources, compared to streams flowing from finer soils that only show these lower $\delta^{15}N$ values when large runoff events activate surface flow paths.

HOW ARE EXCESS N SOURCES MOBILISED?



We have confirmed that shifts in stream water δ^2H and $\delta^{18}O$ toward the values observed in the major rainfall event coincide with elevated $[NO_3]$ and low $\delta^{15}N$ representative of urine and urea-derived sources.





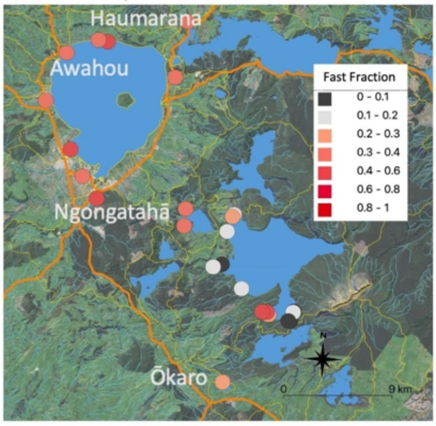
A combination of δ^2H and $\delta^{18}O$ and $\Delta^{14}C$ in dissolved inorganic carbon (DIC) largely confirmed tritium-based assessments, suggesting lag times of many decades in some aquifers, but rapid responses to recent N inputs elsewhere.

In the Southland region, where tile drainage enables effective pasture growth, we explored flow responses in a drainage tile where NO_3 consistently showed an imprint of denitrification ($\delta^{15}N > 12$ ‰). In this location following major rainfall, [NO3] remained stable but dissolved organic N concentrations increased, at times associated with stormwater δ^2H and $\delta^{18}O$ shifts. The $\Delta^{14}C$ in DIC yielded apparent ages of several hundred years during across periods, suggesting ongoing breakdown of soil organic matter releases N, which should be considered in farm and catchment N budgets.

ADDING TRACERS TO UNDERSTAND COMPLEX WATER TRANSIT TIMES

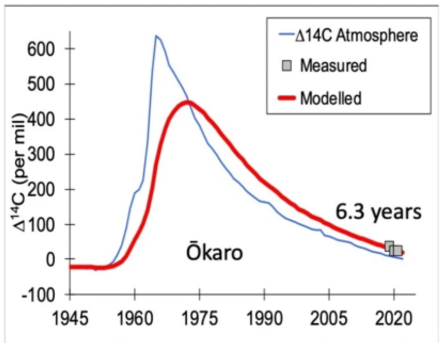
Jasechko et al (2016 Nature Geo) calculate fast fraction (<3 months) based on the the ratio of seasonal cycle amplitudes in rainfall versus streams, for δ^2H or $\delta^{18}O$. For New Zealand, the ratio of the interquartile ranges appears more suitable since annual cycles may be irregular.

Estimates of fast fraction in streams feeding the Rotorua Lakes, New Zealand.



Using a ^{14}C box model (right) provides alternate age estimates of old water for comparison with tritium modelling. Sensitivity was assessed for young fraction of 0, 1x and 2x the <3 month estimate. For Ōkaro, this gave times of 6.3, 7.0 and 9.0 years.

Catchment	mult	YF	τ
Ōkaro	0	0	6.3
	1	0.14	7.0
	2	0.29	9.0
Ngongatahā	0	0	84
	1	0.15	111
	2	0.31	153
Haumarana	0	0	84
	1	0.27	141
	2	0.56	262



For assessing the fast fraction potentially needed to correct the calculation groundwater with decadal or centennial components, we assume <1 year fast fraction is roughly twice the <3 month estimate. After calculating transit times of the old fraction, there may be a wider split between young and old fractions than previously estimated, with implications for nitrate 'loads to come'.

CONCLUSIONS AND RECOMMENDATIONS

We conclude that monitoring N concentrations and multiple isotope species can resolve control points of N excess, which reveal targets for potential mitigation. Specifically:

- Integrated understanding of landscapes as soil-aquifer-catchment continuums can reduce risks of nitrate loss by putting the right land use activity in the right place at the right time, using control point theory to reduce the risk that N excess aligns with mobilisation.
- Consider additional N sources, such as soil organic matter losses due to improved drainage, that may not be incuded in tools used for farm nutrient budgets.
- Reduce overall N excess by considering alternate species or feeds that reduce N content in clover-ryegrass pastures that seasonally exceeds N demand in grazing animals, therefore limiting soil-derived N_2O emissions and NO_3 losses.

We thank MBIE Smart Ideas (Natural Tracers of Fast Contaminant Dynamics C05X1711), BOPRC, an MFAT PhD Scholarship, Ray McCrostie, John Mering, the DERRICK Team and many others for funding and support that contributed to this work.

ABSTRACT

High producing grazed pastures occupy almost one third of Aotearoa New Zealand (268,000 km^2) and produce exported protein to feed more than 40 million people. Trends within farming systems include increasing rates of urea fertiliser use and greater concentrations of N via urine deposition, which enhance N_2O emissions and NO_3 losses. Focussing on N-sensitive lake catchments, we ask: what tools can reduce uncertainties in the sources and magnitude of N losses, quantify the potential to reduce excess N, and clarify rates of change in N budgets.

Dual-isotope NO_3 measurements differentiate urine and urea-derived sources ($\delta^{15}N$ < 4 ‰) from mineralized soil organic N ($\delta^{15}N$ of 4–8 ‰). Nitrate in streams draining the Rotorua region's pumice soils and aquifers is dominated by urine and urea sources, compared to streams flowing from finer soils that only show these lower $\delta^{15}N$ values when large runoff events activate surface flow paths. We have confirmed that shifts in stream water δ^2H and $\delta^{18}O$ toward the values observed in the major rainfall event coincide with elevated [NO_3] and low $\delta^{15}N$ representative of urine and urea-derived sources. A combination of δ^2H and $\delta^{18}O$ and $\Delta^{14}C$ in dissolved inorganic carbon (DIC) largely confirmed tritium-based assessments, suggesting lag times of many decades in some aquifers, but rapid responses to recent N inputs elsewhere.

In the Southland region, where tile drainage enables effective pasture growth, we explored flow responses in a drainage tile where NO_3 consistently showed an imprint of denitrification ($\delta^{15}N$ > 12 ‰). In this location following major rainfall, [NO_3] remained stable but dissolved organic N concentrations increased, at times associated with stormwater δ^2H and $\delta^{18}O$ shifts. The $\Delta^{14}C$ in DIC yielded apparent ages of several hundred years during low-flow periods, suggesting ongoing breakdown of soil organic matter releases N, which should be considered in farm and catchment N budgets.

We conclude that monitoring N concentrations and multiple isotope species can resolve control points of N excess, which reveal targets for potential mitigation. Specifically, N content in clover-ryegrass pastures seasonally exceeds N demand in grazing animals, suggesting alternate species or feeds could reduce animal urinary N excretion, and therefore limit soil-derived N_2O emissions and NO_3 losses.