MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Assessing and matching landuse with land suitability – the model development and landuse implications

Innovative Solutions for Sustainable Management of Nitrogen, Aarhus University, Denmark, June 2017

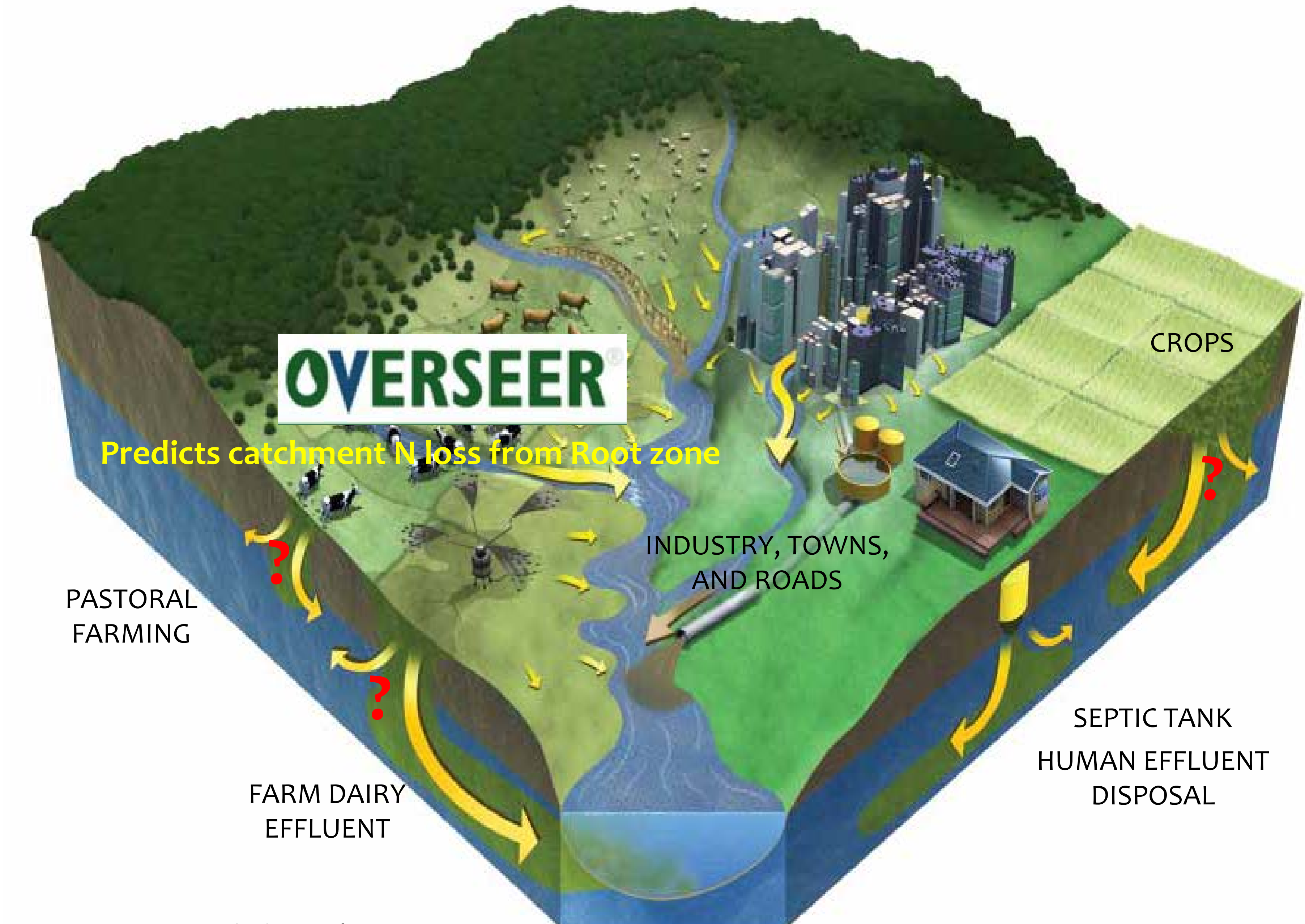
Ranvir Singh[1], Ahmed Elwan[1], David J Horne[1], Aldrin Rivas[1], Andrew Manderson[2], Jon Roygard[3] and Mike Hedley[1]

[1]Fertilizer and Lime Research Centre, Massey University, , Palmerston North
[3]Landcare Research, Palmerston North
[3]Horizons Regional Council, , Palmerston North

THE ENGINE OF THE NEW NEW ZEALAND


Productive Farms - Economic Benefits and Social Welfare
Reduce Negative Environmental Impacts – Improve Water Quality

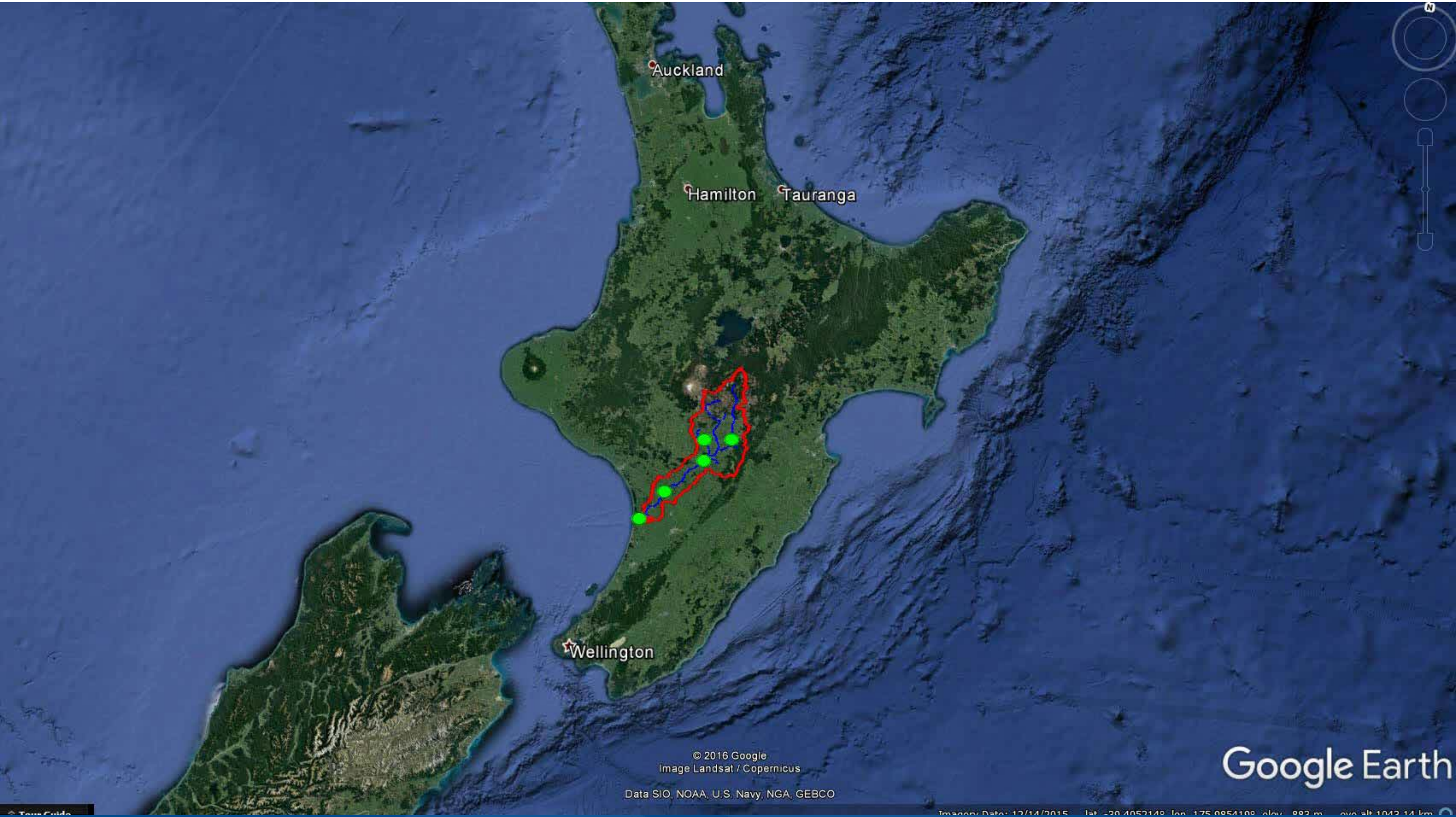
Sources and contributions to nutrient loadings?



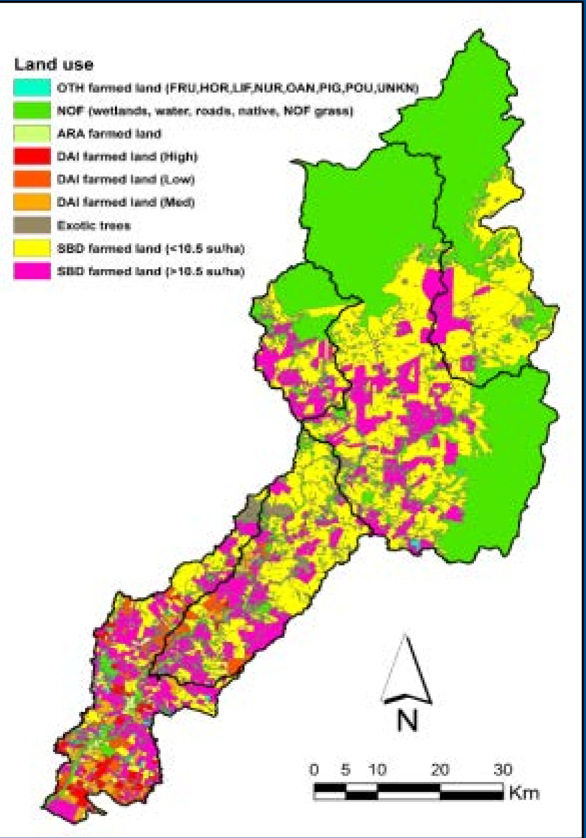
Source: Environment New Zealand 2007, MfE.

Rangitikei Catchment

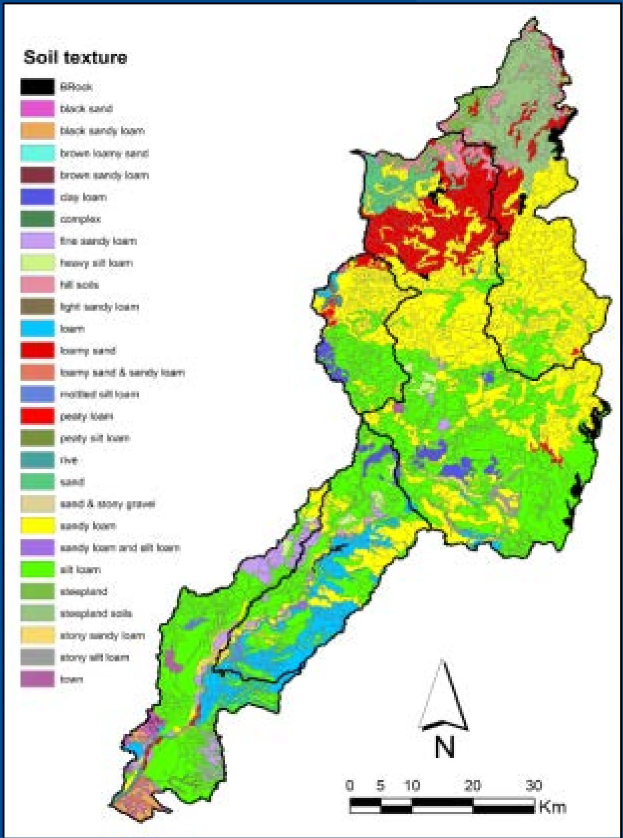
MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND



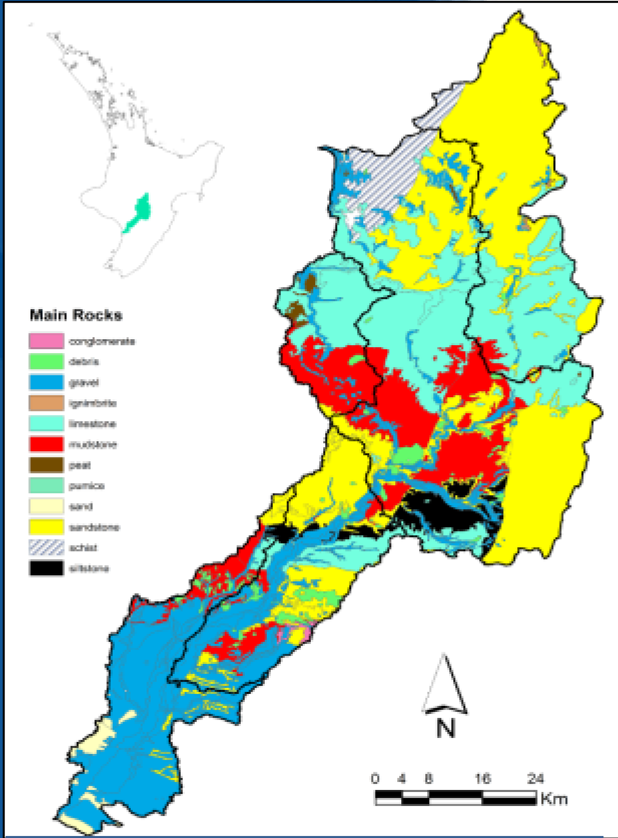
Rangitikei Catchment (~3887 km²)



Major land use - Sheep/beef/dairy (~50%) ; and NOF "i.e. Blocks not otherwise used for farming" (~42%). ~ 18,000 ha of dairy farming and 1,100 ha of arable farmed land mainly in the lower parts of the catchment.

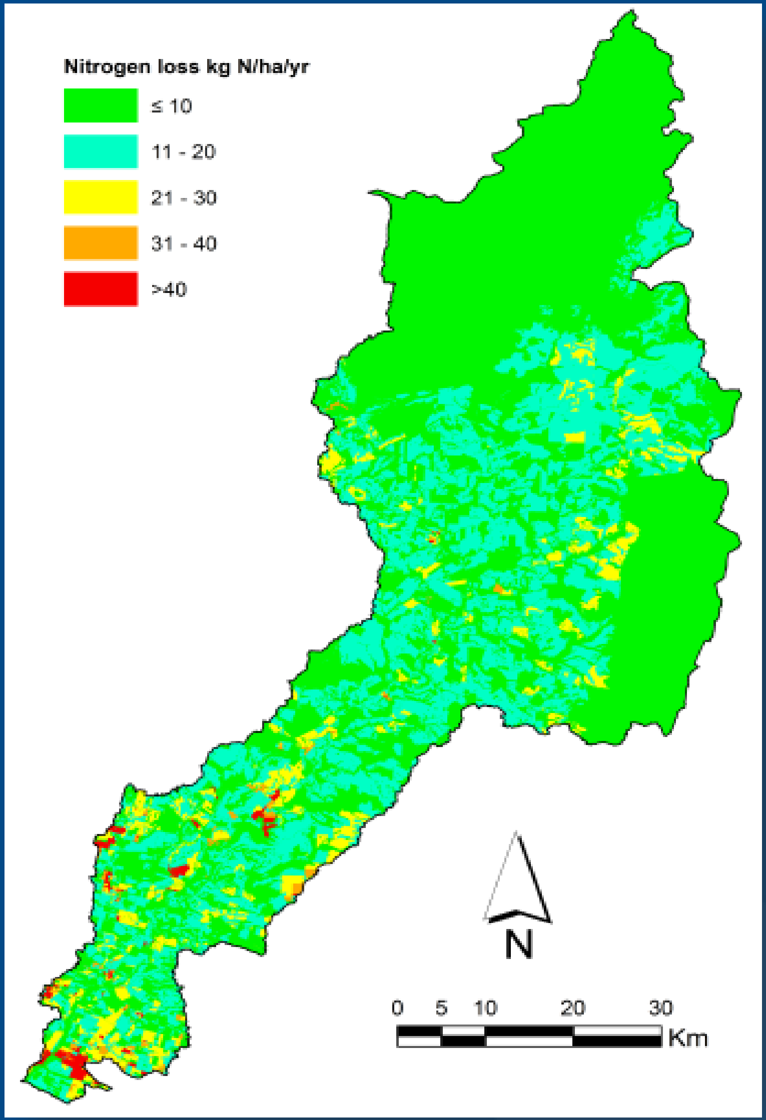


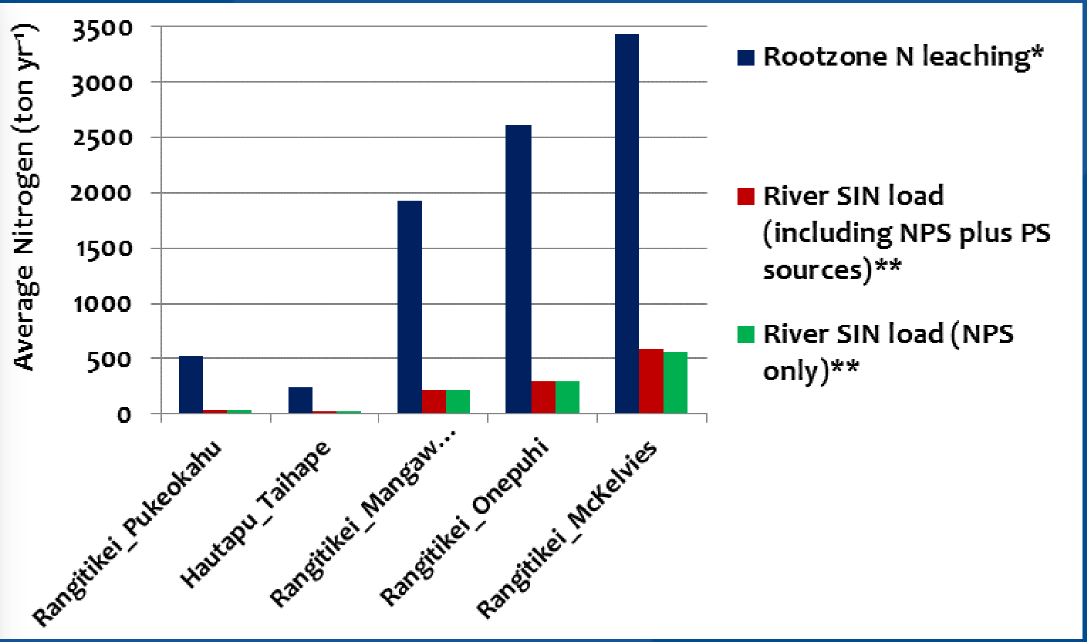
Major soil types are silt loam (~36%), sandy loam (~30%) and loam/loamy sand (~13%)



Major rock types in the catchment are sandstone (~32%), limestone (~23%), gravel (~22%) and mudstone (~12%)

Estimates of N leaching and river loads in the Rangitikei catchment





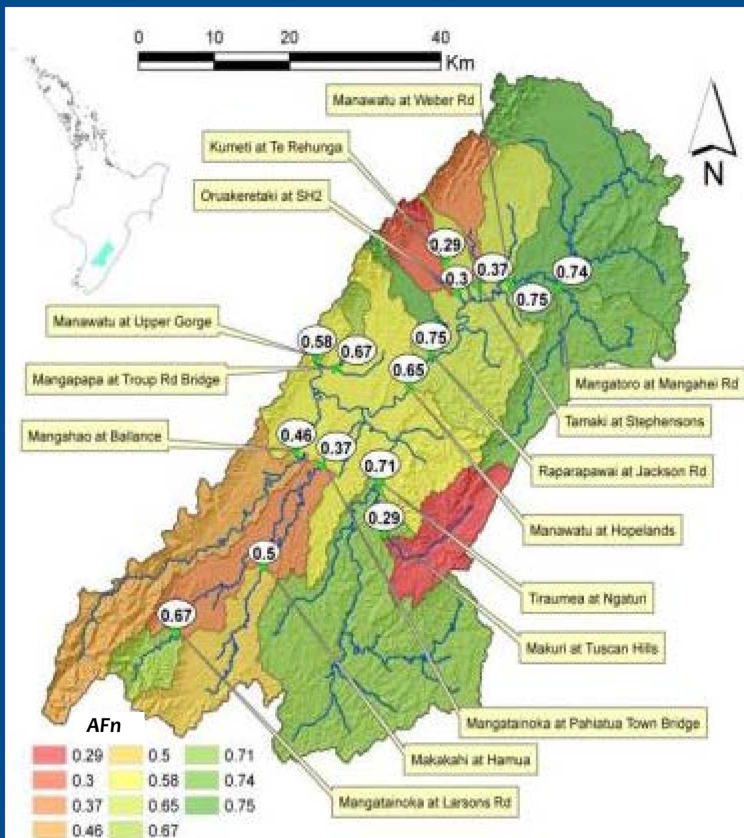
* Root zone leaching based on spatial OVERSEER modelling (by Dr. Andrew Manderson, Landcare Research)

** River soluble inorganic nitrogen (SIN) loads calculated based on river water quality monitoring from July-2008 to June-2015 (by Mr. Ahmed Elwan, PhD Student, Massey University)

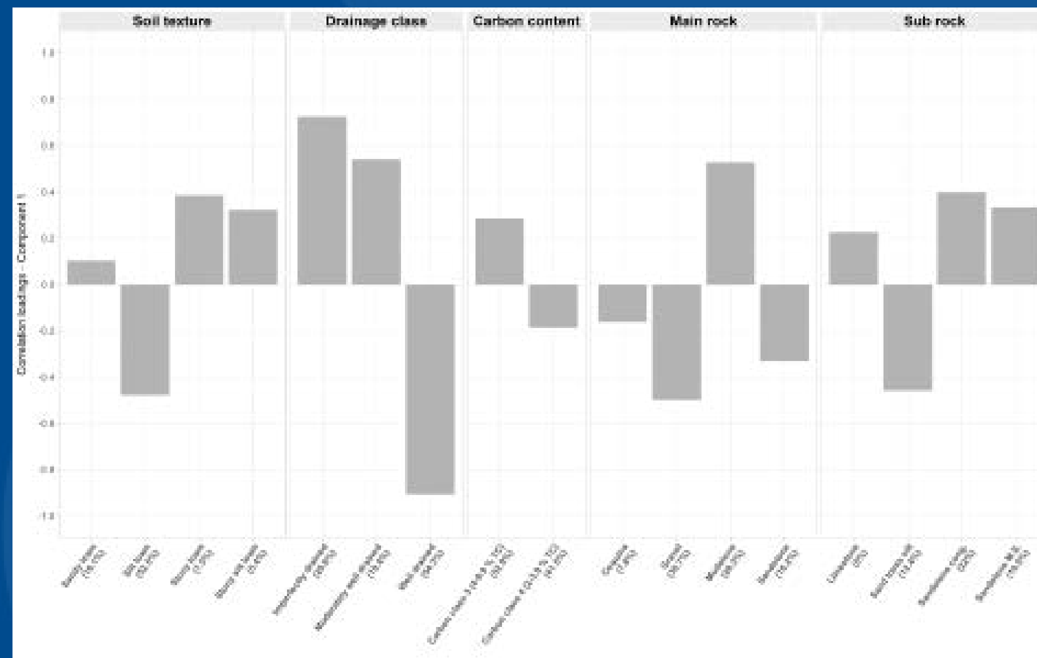
Relationships between nitrogen attenuation and catchment characteristics

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Nitrogen attenuation factor (AF_n) $= (N_{rootzone} - N_{river}) / N_{rootzone}$



Spatial distribution of the nitrogen attenuation factor for 15 sub-catchments in the Tararua Groundwater Management Zone (TGWMZ).

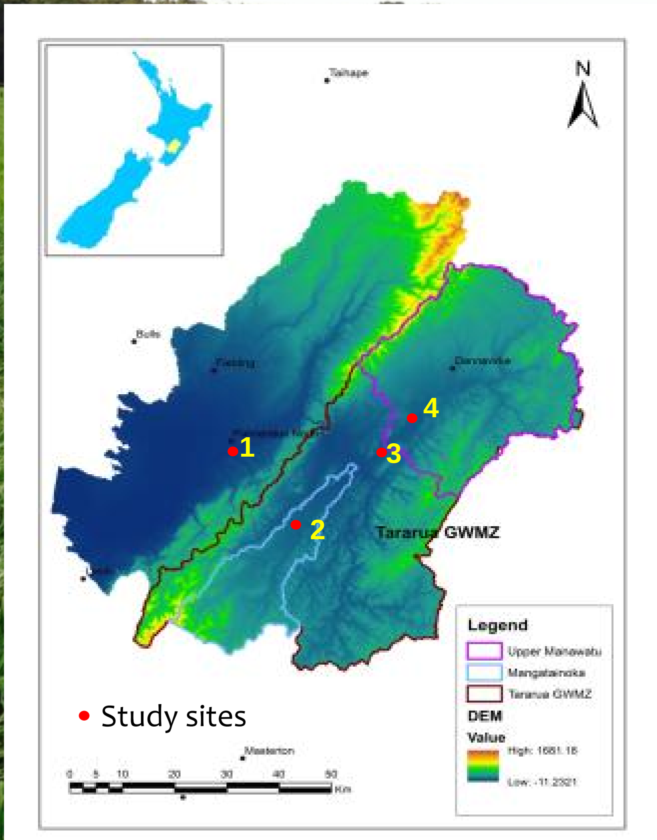


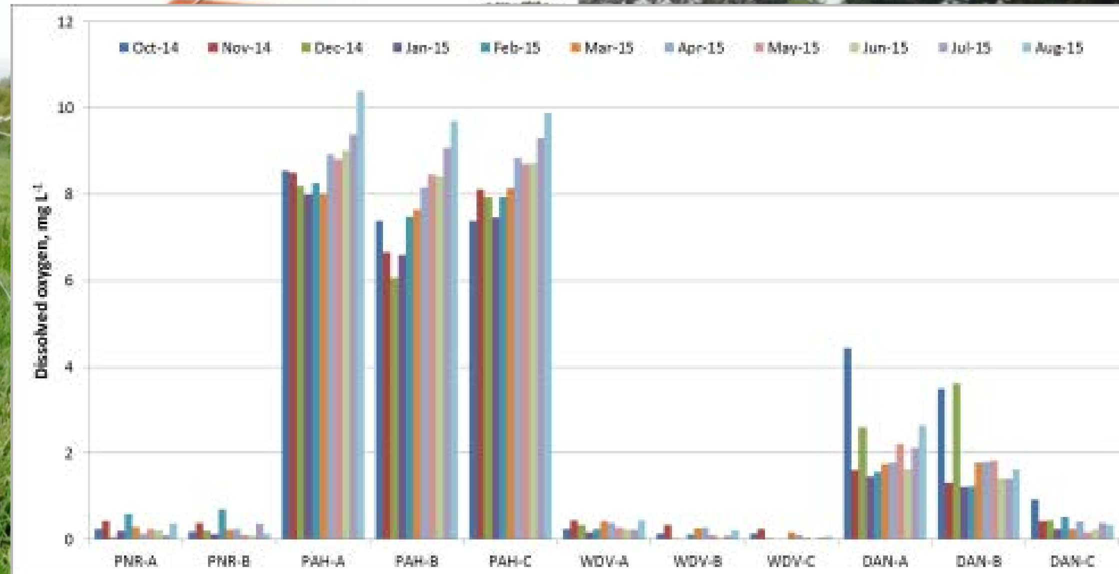
PLSR correlation loadings (component 1) for different catchment characteristics (independent variables)

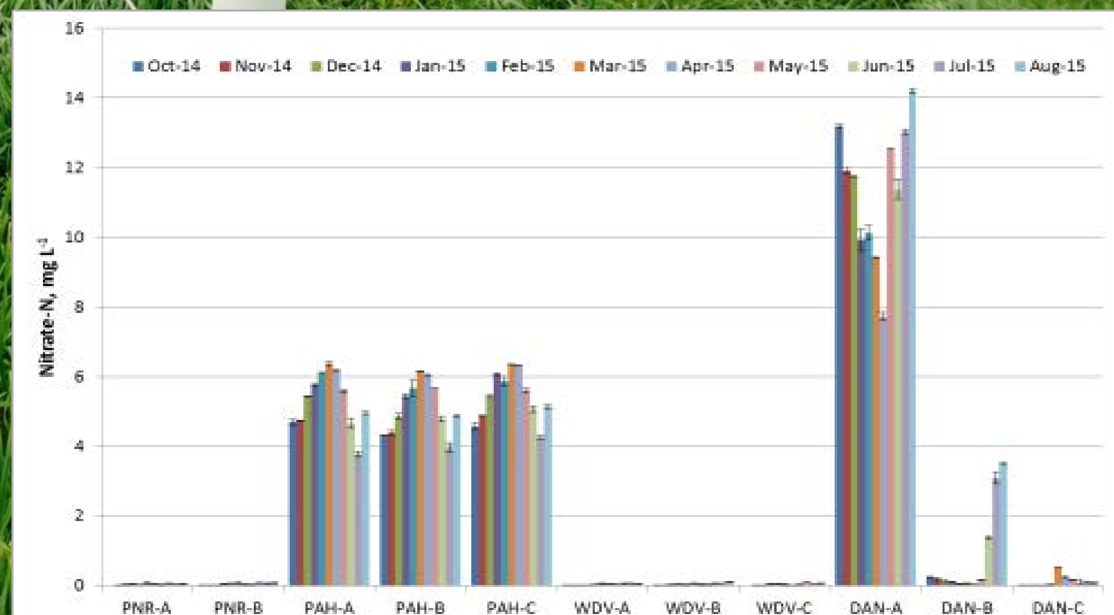
THE ENGINE OF THE NEW NEW ZEALAND

Source: Elwan, A., **Singh, R.**, Horne, D., Roygard, J., & Clothier, B. (2015). Nitrogen attenuation factor: Can it tell a story about the journey of nitrogen in different subsurface environments? In: *Moving farm systems to improved attenuation*. (Eds L.D. Currie and L.L Burkitt). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 28. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 12 pp. *Non-Peer-Reviewed* (*full paper*).

Field Experiments and Monitoring







1. Dairy over fine sand loam and alluvium
2. Dairy over stony silt loam and gravels
3. Sheep & Beef over silt clay loam and alluvium
4. Dairy over silt loam and gravels/ alluvium

Source: Aldrin Rivas, PhD Student, Massey University

Prediction of nitrogen loads in the Rangitikei River

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Assignment of nitrogen attenuation capacity classes and factors to different soils and rocks types

AF_n class	AF_n value	Soil types (soil texture, drainage and carbon classes)*	Rock Types
Low	0.10 – 0.30	e.g. Stony sandy loam, and sand & stony gravel; soil carbon class 5; and soil drainage classes 4 and 5, and artificial drainage	e.g. Gravels
Medium	0.35 – 0.60	e.g. Sandy and silt loams; soil carbon classes 3 and 4; and soil drainage class 3	e.g. Sandstone, limestone, and siltstone
High	0.80 – 0.95	e.g. Heavy silt loam, clay loam and peaty loam; soil carbon classes 1 and 2; and soil drainage classes 1 and 2	e.g. Mudstone and peat

*According to the FSL, soil carbon is classified into 5 classes where 1 is very high soil total carbon content (>20%) and whereas 5 is very low soil total carbon content (<2%).
Soil drainage classes (1 to 5) where drainage class 1 is assigned to very poorly drained soil and drainage class 5 to well drained soils.

THE ENGINE OF THE NEW NEW ZEALAND

Prediction of nitrogen loads in the Rangitikei River

Model 1 - Uniform nitrogen attenuation factor

$$River\ N\ load\ (ton\ \mathrm{yr}^{-1}) = m \sum_{i=1}^{n} A_i * N_i * (1 - AF_{N\,0.5})$$

Model 2 - Variable nitrogen attenuation factor (soil types only – *FSL* layer)

$$River\ N\ load\ (ton\ \mathrm{yr}^{-1}) = m \sum_{i=1}^{n} A_i * N_i * (1 - AF_{N\,ST})$$

Model 3 - Variable nitrogen attenuation factor (rock types only - *QMAP* layer)

$$River\ N\ load\ (ton\ \mathrm{yr}^{-1}) = m \sum_{i=1}^{n} A_i * N_i * (1 - AF_{N\,RT})$$

Model 4 - Variable nitrogen attenuation factor (soil and rock types – *FSL* and *QMAP* layers)

$$River\ N\ load\ (ton\ \mathrm{yr}^{-1}) = m \sum_{i=1}^{n} A_i * N_i * (1 - AF_{N\,RT})(1 - AF_{N\,ST})$$

Where:

$\boldsymbol{m}$ = Conversion factor;

$\boldsymbol{A_i}$ = Area of different land use type (ha);

$\boldsymbol{N_i}$ = Estimates of nitrogen loss rate (kg ha^{-1} yr^{-1}) for different land use types;

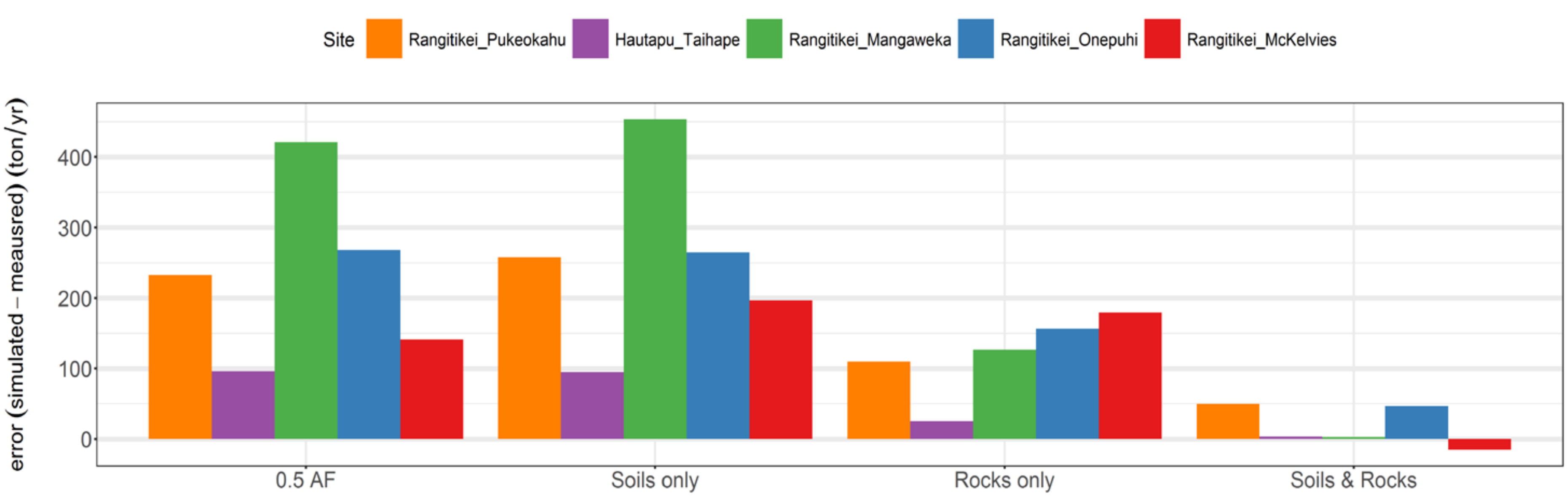
$\boldsymbol{AF_N}$ = Subsurface nitrogen attenuation capacity (fraction) specific to soil types ($AF_{N\,ST}$) and rock types ($AF_{N\,RT}$)

THE ENGINE OF THE NEW NEW ZEALAND

Prediction of nitrogen loads in the Rangitikei River

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Comparison of predicted vs. measured average annual soluble inorganic nitrogen (SIN) loads in different sub-catchments of the river



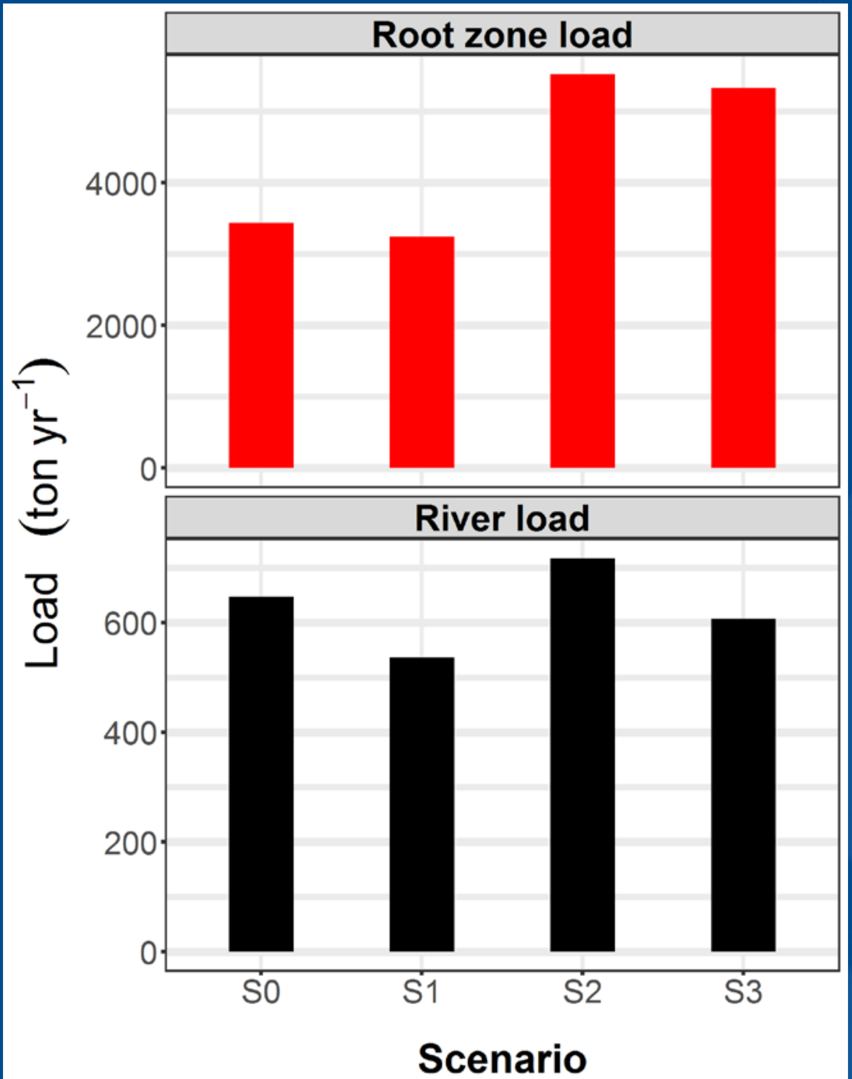
Come and see our poster S2-10

Modelling spatial nitrogen attenuation and land-based nitrogen loads to rivers

Ahmed Elwan, Ranvir Singh, Dave Horne, Andrew Manderson, Jon Roygard, Brent Clothier, Geoffrey Jones

THE ENGINE
OF THE NEW
NEW ZEALAND

De-intensify and Intensify landuse scenarios



Consider 3 scenarios

(S1) De-intensify landuse (< 15 kg N ha^{-1} yr^{-1}) on low-medium attenuation areas (9,800 ha),

(S2) Intensify landuse (30 - 45 kg N ha^{-1} yr^{-1}) on high attenuation areas (83,000 ha), and

(S3) Combination of de-intensify and intensify landuse.

Root zone losses increase by 55%

N load in river decreases by 6%

THE ENGINE OF THE NEW NEW ZEALAND

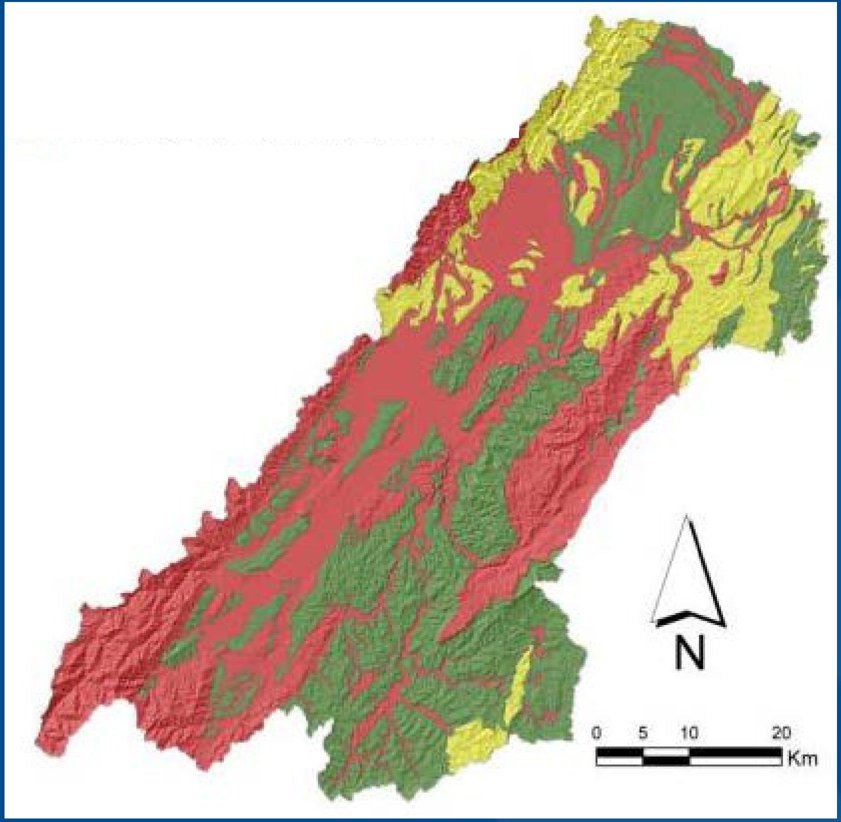
Concluding remarks

Catchment-scale accounting of nitrogen flows in the Rangitikei River catchment suggests that

- ✓ soluble inorganic nitrogen (SIN) loads measured in the river are significantly smaller (~ 80%) than the estimates of nitrogen leached from the root zone;
- ✓ estimates of potential in-stream nitrogen uptake are relatively smaller (~4 to 7%) when compared with the estimates of nitrogen leached from the root zone;
- ✓ prediction of (soluble inorganic) nitrogen loads in the river is significantly improved by incorporating the spatial effects of different soil types and underlying geologies on nitrogen attenuation in the subsurface environment.

Concluding Remarks

Research hypothesis



Upper Manawatu River Catchment, New Zealand

	Nitrogen Attenuation Capacity	Targeted investment in solutions, e.g.
Green	> 80 % N reduction	**High Capacity Areas:** Sustainable Land Use Intensification
Yellow	50 – 80 % N reduction	**Medium Capacity Areas:** Reduce Nitrogen Leaching via Best Effluent and Nutrient Management Practices
Red	< 50 % N reduction	**Low Capacity Areas:** Duration controlled grazing Sheep/Goat milking Cut and Carry Systems

Acknowledgements

This study is a part a wider collaborative research programme between Massey Fertilizer and Lime Research Centre (FLRC) and Horizons Regional Council (HRC).

HRC, Dairy NZ and NSC Our Land and Water provide funding and information for this study.

This funding and in-kind support is greatly appreciated.

FERTILIZER & LIME RESEARCH CENTRE

horizons regional council

DairyNZ

LANDCARE RESEARCH MANAAKI WHENUA

OUR LAND AND WATER

Toitū te Whenua, Toiora te Wai

National SCIENCE Challenges

THE ENGINE OF THE NEW NEW ZEALAND

MASSEY UNIVERSITY TE KUNENGA KI PŪREHUROA UNIVERSITY OF NEW ZEALAND

Supporting Slides

THE ENGINE
OF THE NEW
NEW ZEALAND

A hydrogeologic based model to predict river nitrogen loads

River N load = Root zone loss - Subsurface Attenuation – In-stream Attenuation

$$River\ N\ load\ (ton\ \mathrm{yr}^{-1}) = m\left[\sum_{i=1}^{n} A_i * N_i * (1 - AF_N)\right] - N_{up}$$

Where:

$\boldsymbol{m}$ = Conversion factor;

$\boldsymbol{A_i}$ = Area of different land use type (ha);

$\boldsymbol{N_i}$ = Estimates of nitrogen loss rate (kg ha^{-1} yr^{-1}) for different land use types;

$\boldsymbol{AF_N}$ = Subsurface nitrogen attenuation capacity (fraction);

$\boldsymbol{N_{up}}$ = In-stream nitrogen uptake (ton yr^{-1})

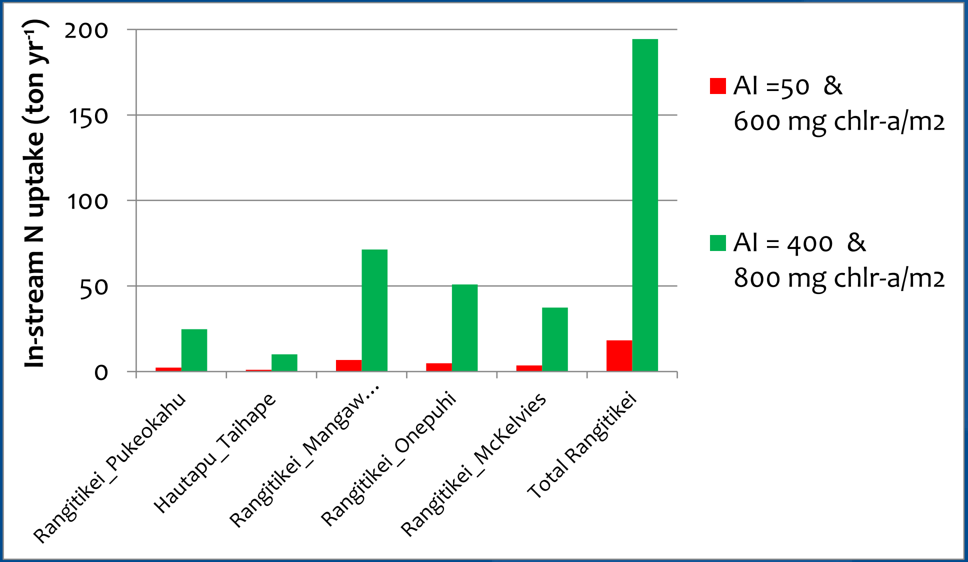
Estimates of potential in-stream nitrogen uptake in the Rangitikei River

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

$$In - stream\ N\ uptake\ (N_{up})\ (\text{ton yr}^{-1}) = m * (fn * AI * P) * (fp * W)$$

Where,

m = Conversion factor;
W = Wetted area of stream/river bed (m^2);
fp = Periphyton cover fraction (-);
P = Periphyton growth (mg *chlr-a*/m^2);
AI = Autotrophic Index (i.e. ratio of periphyton biomass (ash-free dry mass) to *chlr-a*) (-); and
fn = Periphyton biomass N content fraction.



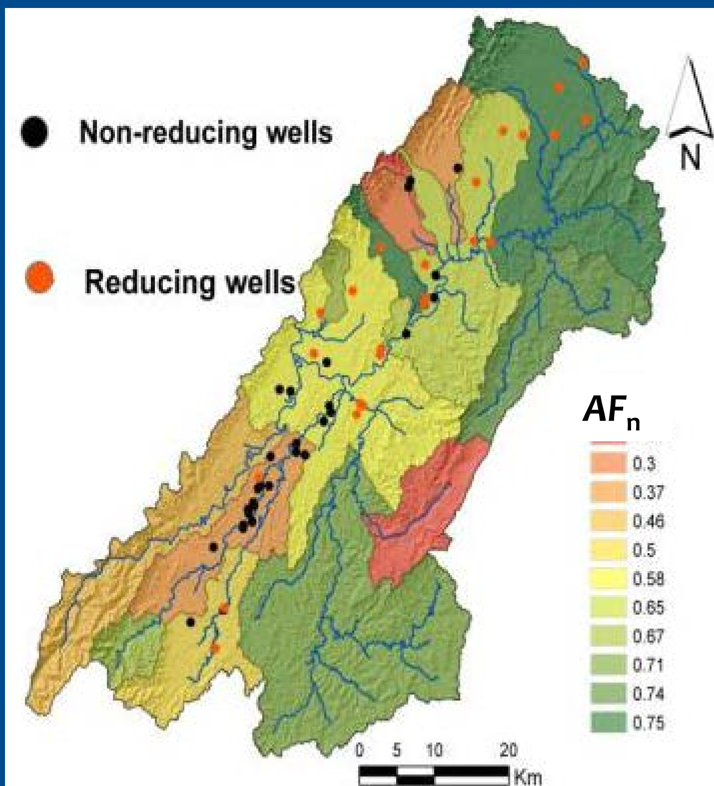
- Estimates of **potential in-stream nitrogen uptake** (in stream orders 2 and above) **accounted for a maximum of only 4 to 7% of estimated root zone N loss** in different sub-catchments

THE ENGINE OF THE NEW NEW ZEALAND

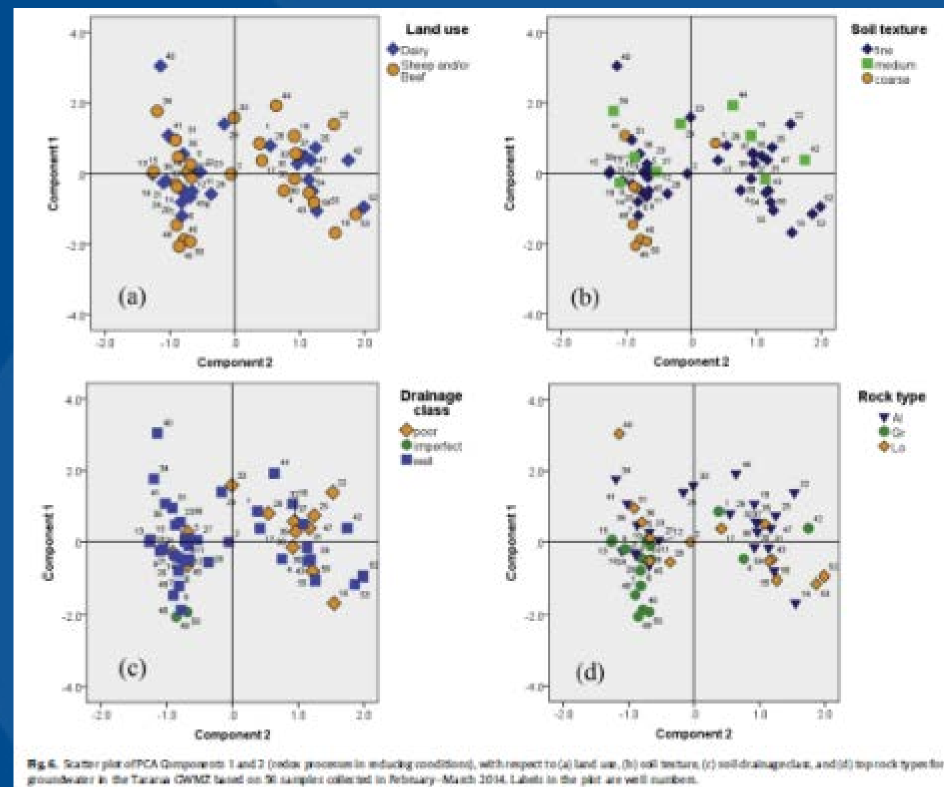
Relationships between nitrogen attenuation and catchment characteristics

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Groundwater survey (summer 2014)



Spatial distribution of the nitrogen attenuation factor for 15 sub-catchments in the Tararua Groundwater Management Zone (TGWMZ).



PCA Component 2 (redox processes in reducing conditions in the Tararua Groundwater Management Zone (TGWMZ).

Rivas, A., **Singh, R.**, Horne, D., Roygard, J., Matthews, A., and Hedley, M. (2017). Denitrification potential in the subsurface environment in the Manawatu River catchment, New Zealand: Indications from oxidation-reduction conditions, hydrogeological factors, and implications for nutrient management. Journal of Environment Management, 197 (2017), 476-489.

THE ENGINE OF THE NEW NEW ZEALAND

De-intensify landuse (S1)

- Landuse intensity was reduced on hydrogeologic units that have low/low (soils/rocks), and low/medium or medium/low capacity to attenuate nitrogen

If low/low
&
If N loss > 10 kg N ha^{-1} yr^{-1} → 10 kg N ha^{-1} yr^{-1}

If medium/low or low/medium
&
If N loss > 20 kg N ha^{-1} yr^{-1} → 15 kg N ha^{-1} yr^{-1}

Intensify landuse (S2)

- Landuse intensity was increased on flat (<15 degree slope) hydrogeologic units that have high/high (soils/rocks), and high/medium or medium/high capacity to attenuate nitrogen

If high/high
&
Slope < 15 degree
&
N loss < 30 kg N ha^{-1} yr^{-1} → 45 kg N ha^{-1} yr^{-1}

If high/medium or medium/high
&
Slope < 15 degree
&
N loss < 20 kg N ha^{-1} yr^{-1} → 30 kg N ha^{-1} yr^{-1}

THE ENGINE OF THE NEW NEW ZEALAND

Intensify landuse in some areas and de-intensifying in other areas (S3)

- The two scenarios described above were combined here i.e. N leaching from the low attenuation areas was re-assigned to the high attenuation areas.

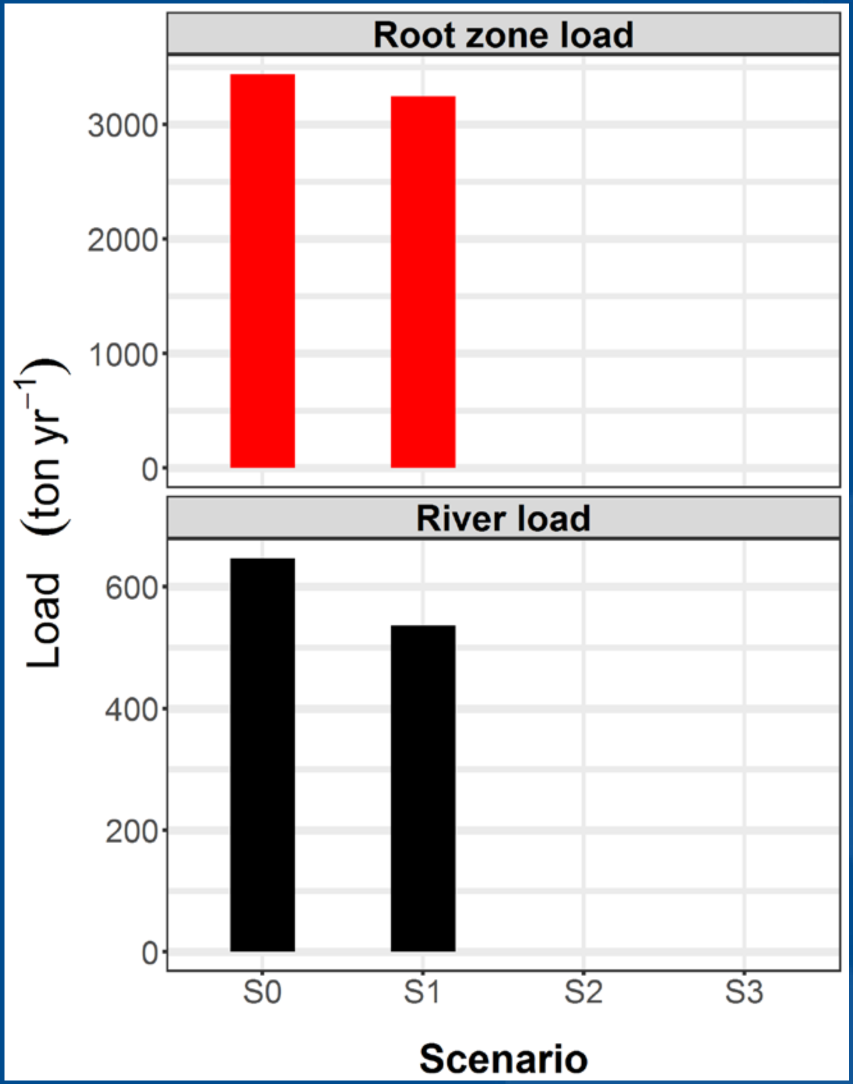
Areas involved

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

- Landuse intensity was reduced on approximately 9,800 ha in the Rangitikei catchment.

- Landuse intensity was increased on approximately 83,000 ha in the Rangitikei catchment.

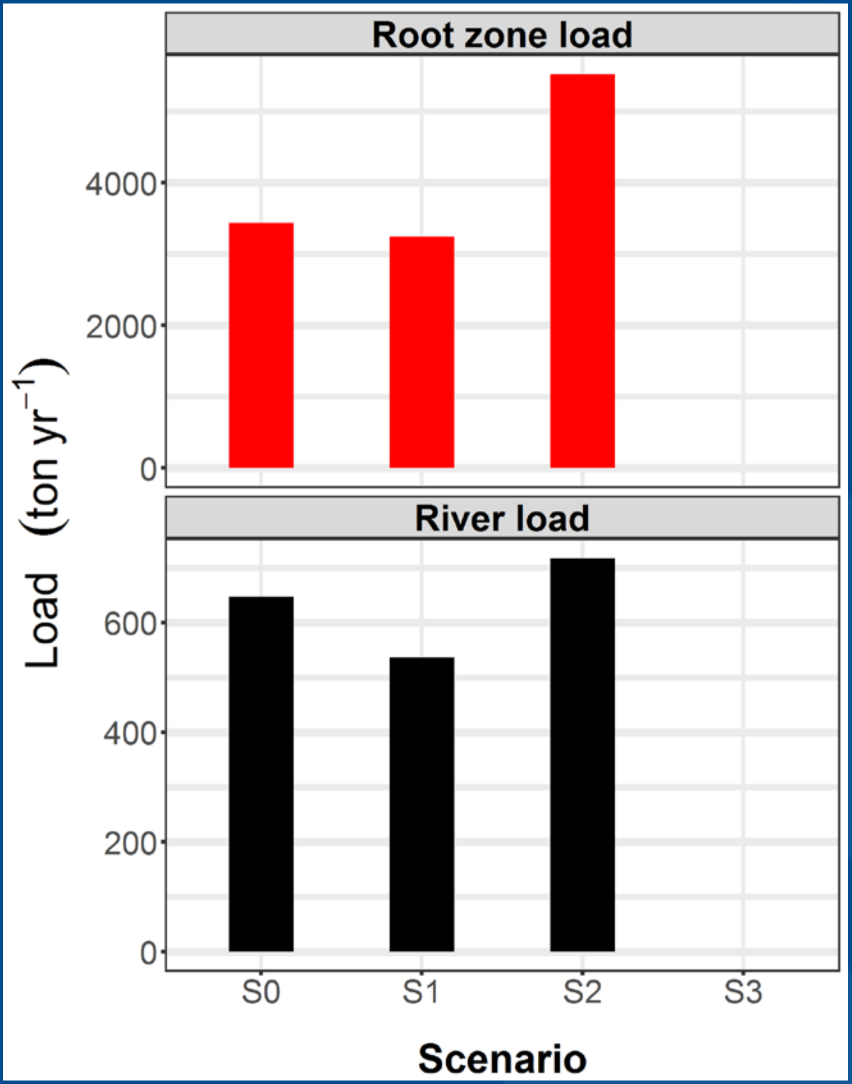
De-intensify landuse (S1)



Root zone losses decrease by 6%

N load in river decreases by 17%

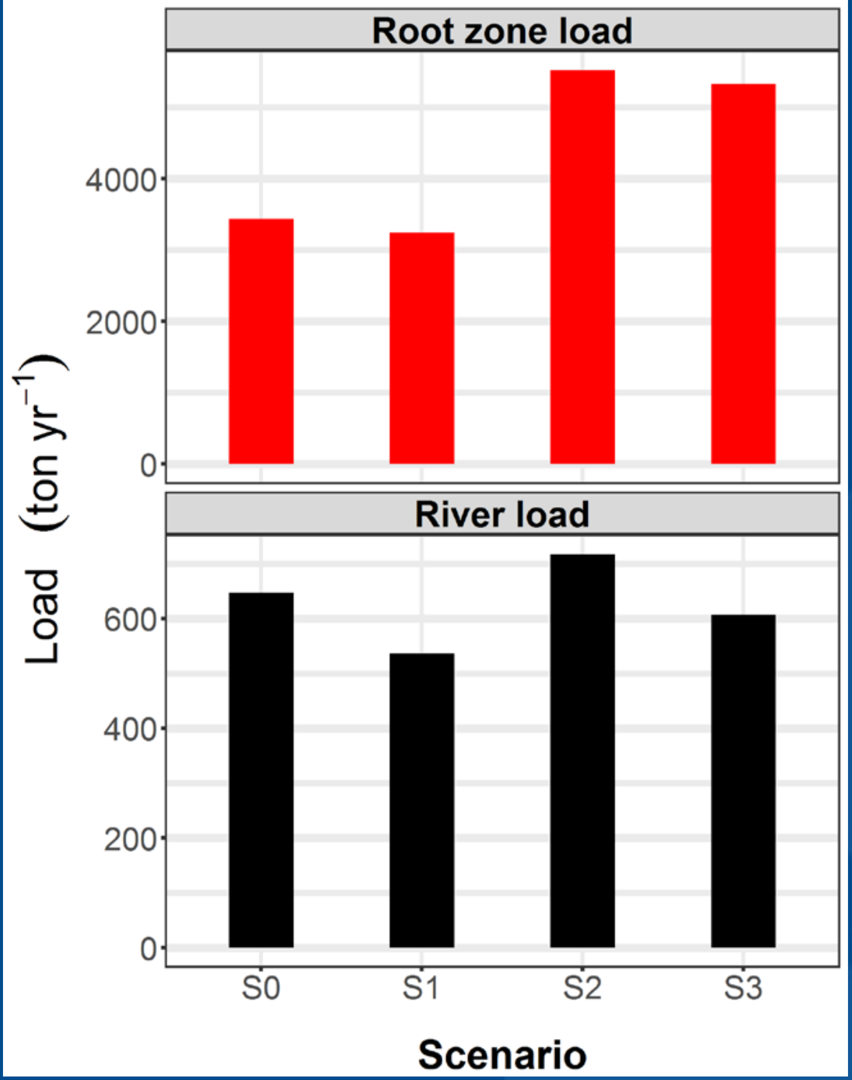
Intensify landuse (S2)



Root zone losses increase by 61%

N load in river decreases by 11%

De-intensify and Intensify landuse (S3)



Root zone losses increase by 55%

N load in river decreases by 6%

THE ENGINE OF THE NEW NEW ZEALAND

Concluding remarks

Models like the one explored here help to:

- identify the most critical areas for targeting our investment and efforts to reduce nitrogen loads to our rivers;
- redesign land use practices in a coordinated fashion by spatially aligning intensive land use practices with high nitrogen attenuation pathways, i.e. ‘matching landuse with land suitability’, to increase agricultural production while reducing environmental impacts.

However, further understanding and mapping of subsurface nitrogen attenuation capacity in NZ agricultural catchments is required and work-in-progress.