Erosion and sediment 101

101st LINK Seminar

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Outline

1. Erosion and sediment research – drivers
2. Erosion and sediment research – methods and tools
3. STEC – programme overview
4. Research highlights – STEC and beyond
5. Future research – Improving landslide and slash risk management
6. Summary

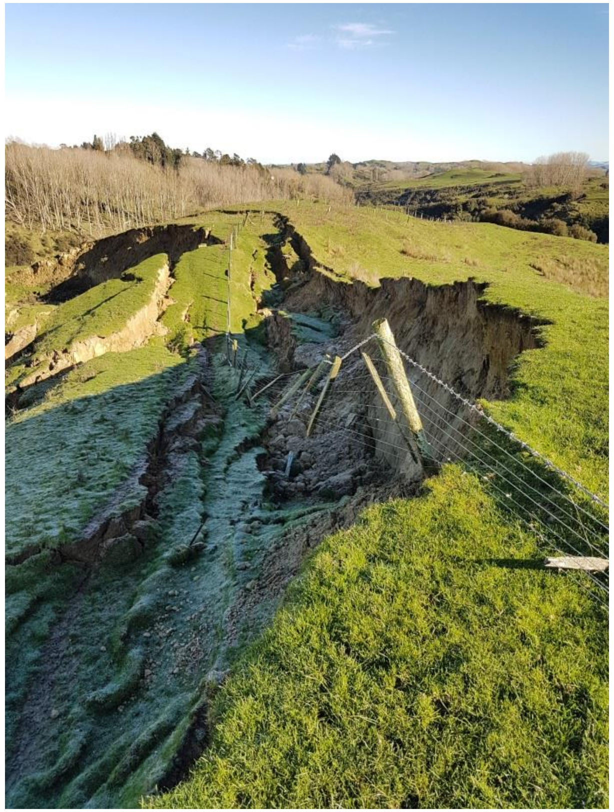
1. Erosion and sediment research - drivers

Environment Aotearoa 2019:

- Estimated 192 million tonnes of soil enters waterways each year with 44% coming from pastoral land.
- Fine sediment impacts water quality, ecosystem health and recreational amenity.
- Economic cost of soil erosion and landslides at least $250-300 M per year.

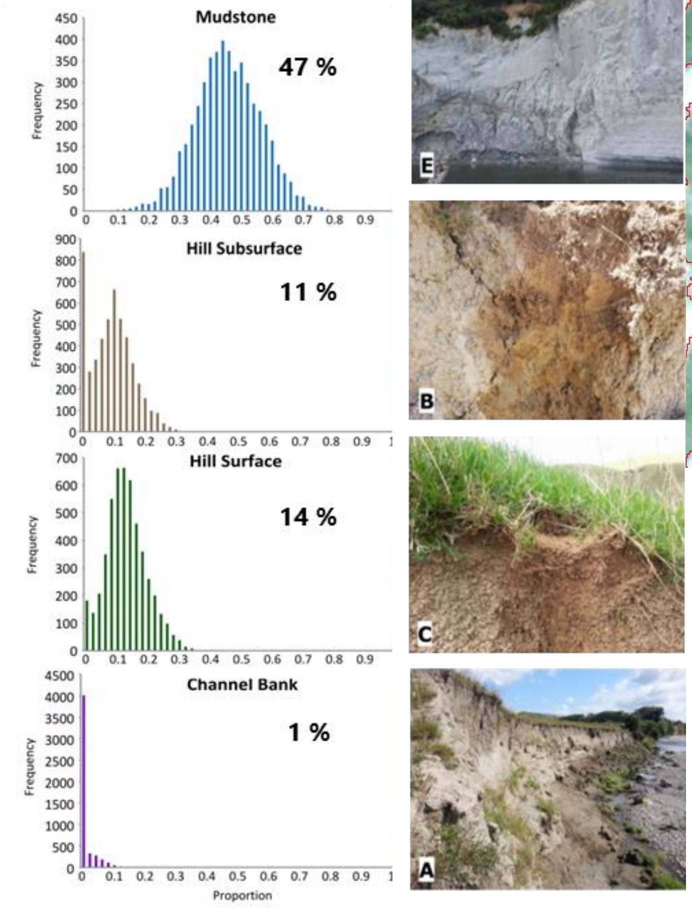
Our research aims to:

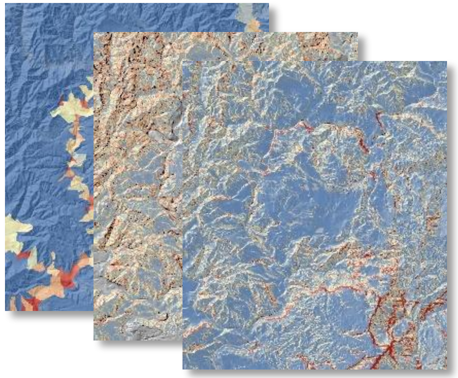
- Better link upstream land-based erosion sources to downstream sediment loads and sediment-related water quality impacts.
- Enable higher-resolution targeting of effective and efficient erosion mitigation measures to:
  - reduce costs of erosion control
  - improve water quality and reduce ecological impacts (NPS FM & NOF)
  - reduce storm damage and improve land productivity.
- Meet the needs of land managers, regional councils and central government for:
  - higher-resolution data on erosion and sediment delivery to streams.
  - new tools and models that provide information at appropriate scales.



2. Our methods and tools

- High-resolution measurements of erosion and land surface change
- Remote sensing and automated erosion feature detection (e.g. OBIA)
- Rain radar processing and analysis
- Sediment source fingerprinting and mixing models
- Catchment erosion process and sediment modelling
- Erosion and sediment mitigation optimisation (LUMASS)





LUMASS
modelling & optimisation

3. Smarter Targeting of Erosion Control (STEC) – Research programme overview

Aim: *inform design and implementation of cost-effective, targeted erosion control measures to meet national water quality targets.*

Data and models to:

- quantify links between erosion sources and sediment-related water quality.
- determine the performance of erosion control measures across multiple spatial scales.
- framework for national-scale assessment of economic impacts of erosion.

3. STEC structure

RA1.1 **Measurement** - Hugh Smith	RA1.2 **Mitigation** - Chris Phillips	RA1.3 **Modelling** - John Dymond	RA1.4 **Economic impact** - Patrick Walsh
High spatial and temporal resolution understanding of sediment generation and sediment quality characteristics are required to link farm-scale erosion mitigation to catchment-scale sediment dynamics and underpin model development.	*Discrimination of critical source areas within farms combined with information on mitigation efficiency across a wide range of sediment quality characteristics will improve erosion mitigation measures.*	*Development of an event-scale spatially-explicit erosion model will enable improved targeting of erosion mitigation measures to meet catchment limits.*	*Economic analysis of erosion mitigation can be used to quantify the benefits and support implementation of interventions leading to reduced soil loss and degradation of New Zealand waters.*

3. STEC catchments

- We are committed to working in certain catchments.
- We will also collect data from outside these catchments:
  - measure storm impacts (incl. Waikato, Hawke's Bay etc)
  - test erosion mitigation effectiveness (e.g. Te Whanga, Ruamāhanga)

- **Manawatu** – new and continuing data collection, testbed for model development.
- **Whanganui** – storm event impacts, legacy sediments.
- **Oreti (Southland)** – bank erosion, sediment fingerprinting.
- **Wairoa (Auckland)** – MWLR & NIWA collaboration on sediment fingerprinting methods.

4. Research highlights – STEC and beyond

4.1 Predicting storm-generated landslide erosion

4.2 Establishing an experimental research catchment

4.3 Characterising erosion source and sediment quality

4.4 Sediment source fingerprinting – an introduction

4.5 SedNetNZ and bank erosion modelling

4.1 Shallow landslide erosion: analysis and prediction

- **Aim:** quantify factors influencing the location of storm-generated landslides and predict erosion susceptibility.
- **Case study:** March 2018 storm triggered many landslides in the Whanganui catchment.
- Acquired high-resolution satellite imagery.
- Applied automated procedure for mapping and analysing landslide scars.

Storm impact area - Blue Duck station

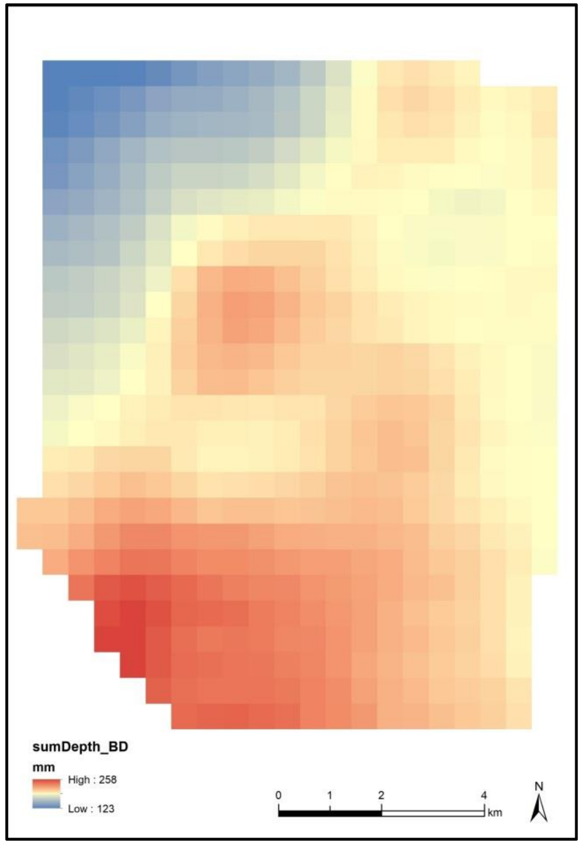
Video: Blue Duck station

Photo: Blue Duck station by Frances Ferguson/Stuff

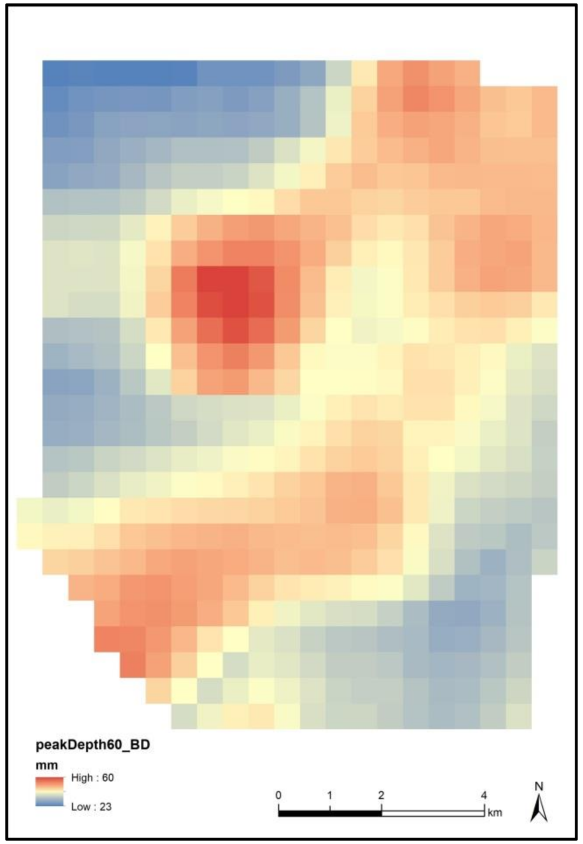
4.1 Case study: spatial patterns in storm rainfall

- Storm rainfall total across target area = 120 – 260 mm (calibrated rain radar).
- Nearest rain gauge = 172 mm.

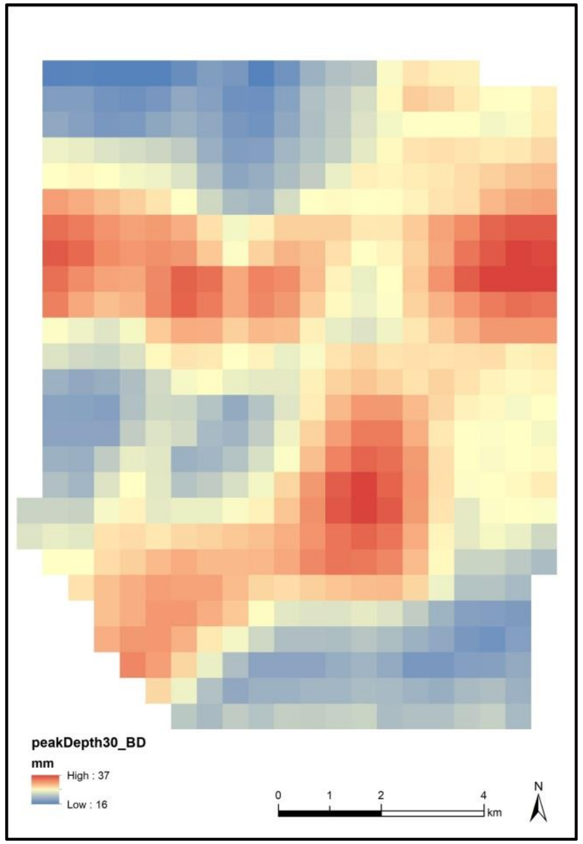
Total storm rainfall



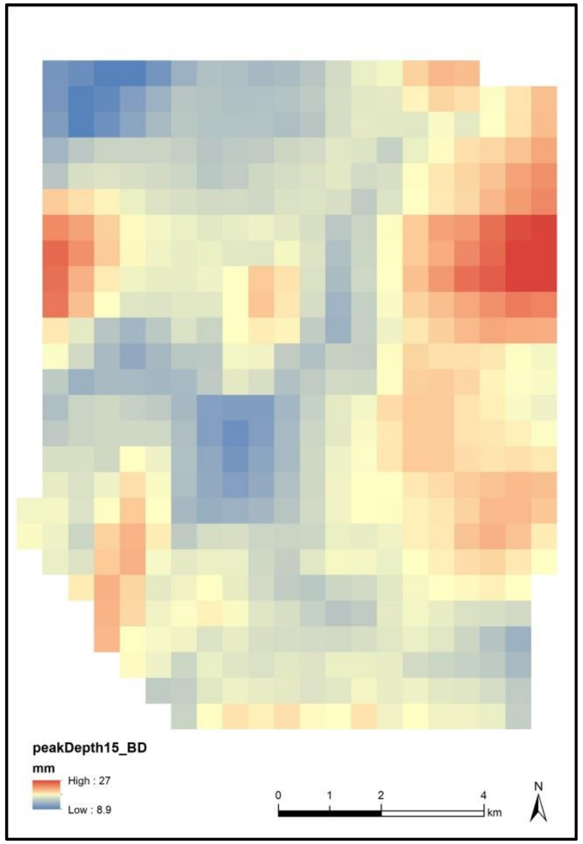
Max. rainfall 60 min



Max. rainfall 30 min



Max. rainfall 15 min



4.1 Case study: model training for landslide prediction

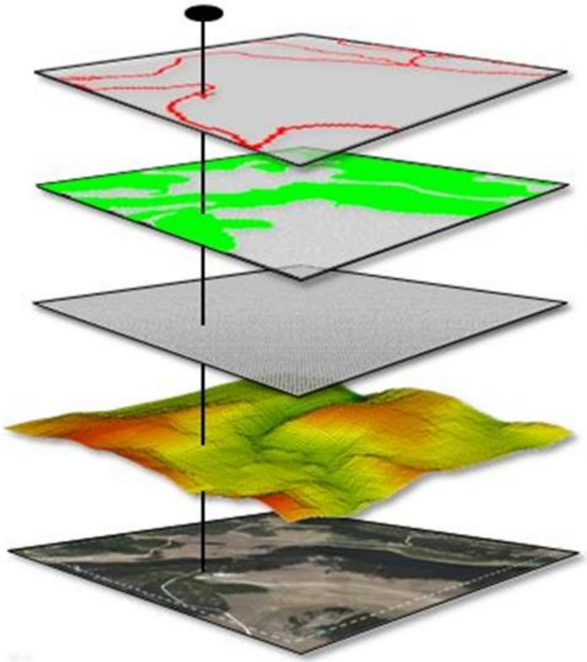
- Initial procedure to predict presence or absence of shallow landslides:

1. Extract intersecting spatial data for mapped landslide scars [e.g. slope, aspect, land cover, soil, geology, rainfall...] - **Presence**

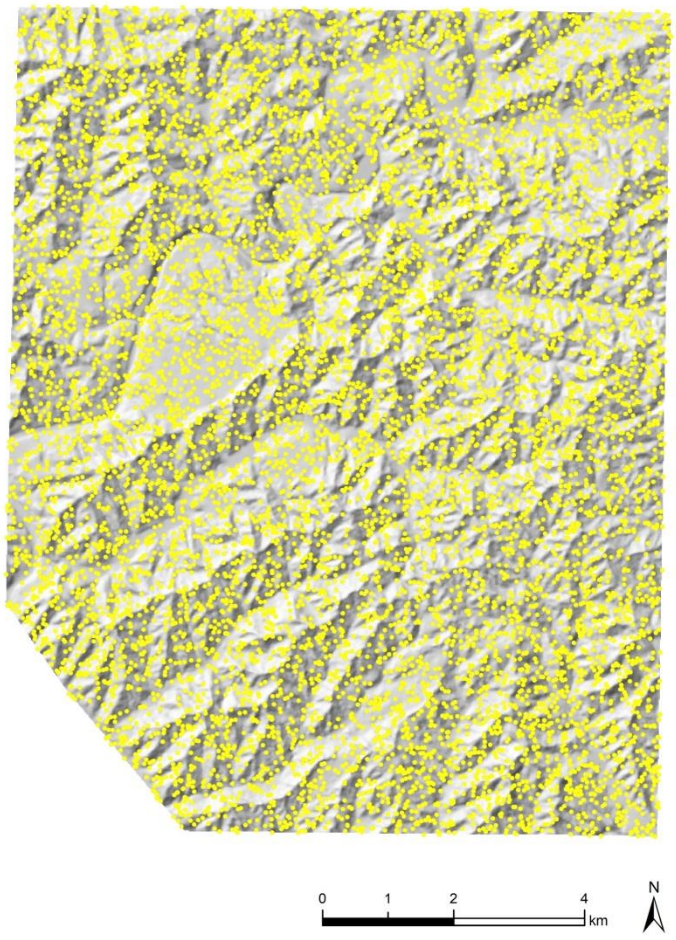
2. Extract above data for random ‘non-landslide’ locations - **Absence**

3. Apply logistic regression with cross-validation: random split into ‘train’ and ‘test’ datasets.

4. Evaluate model predictive performance: ROC curves and AUC



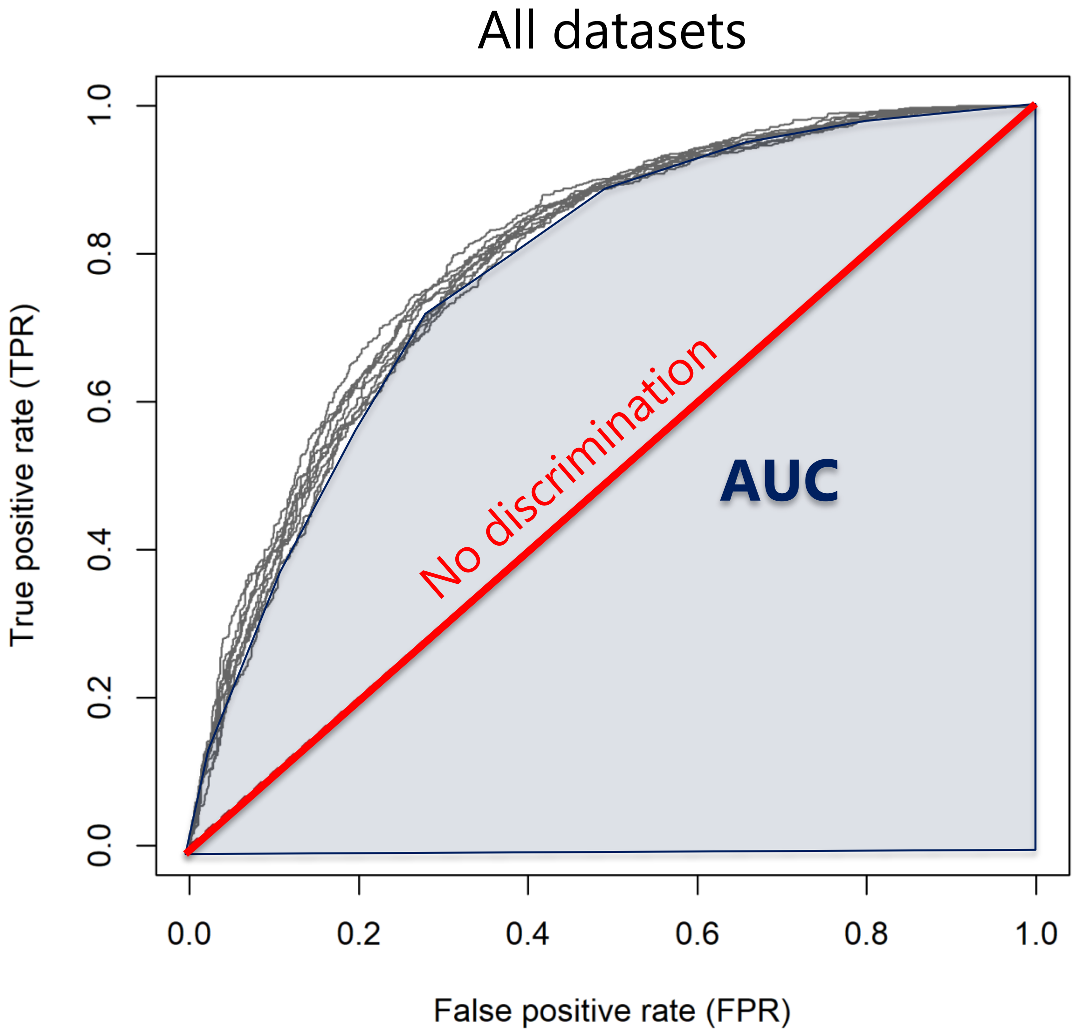
Absence



4.1 Case study: model prediction performance

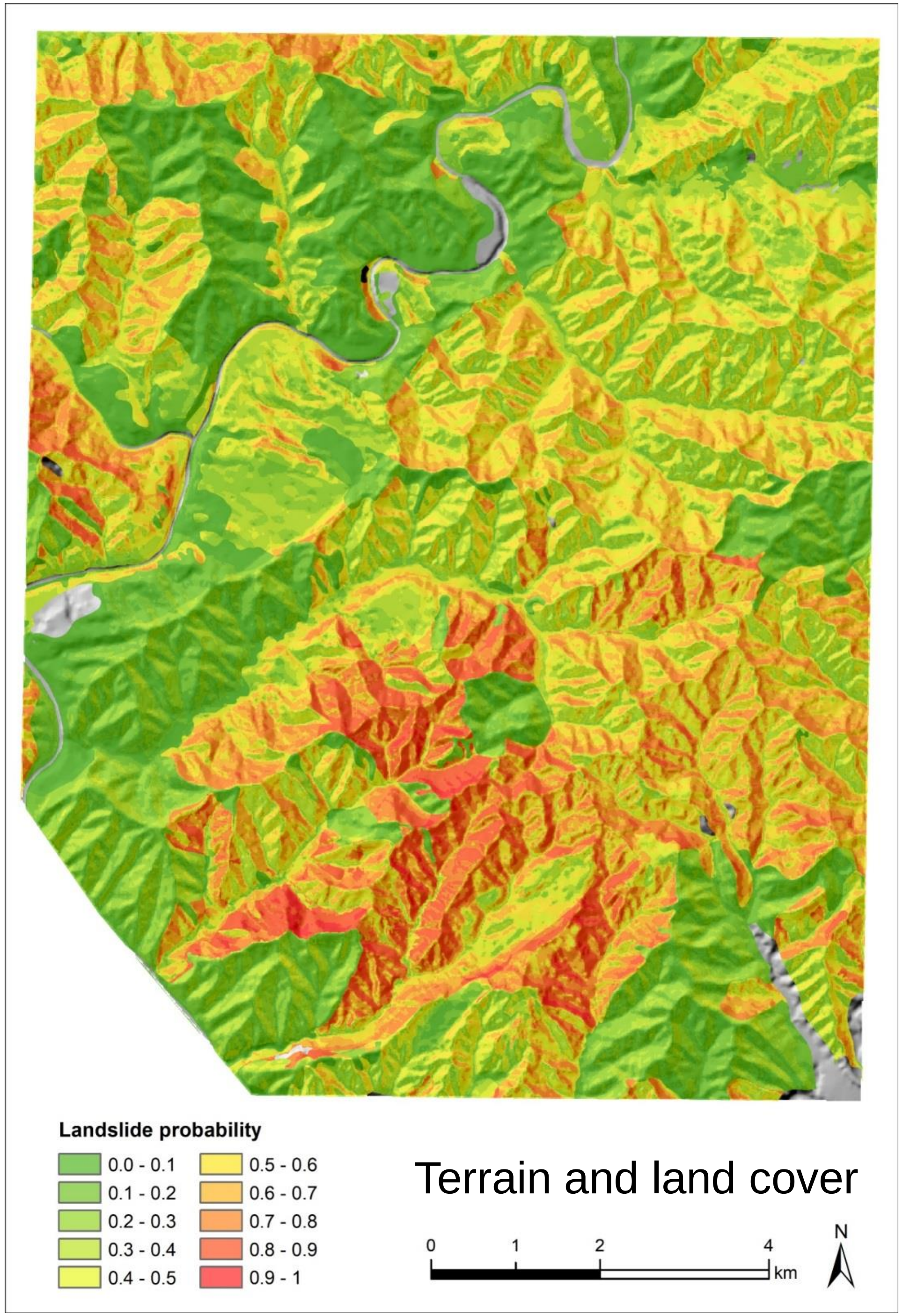
Input data	AUC
Rainfall (radar)	0.65
Terrain (slope, aspect, soil, rock)	0.69
Land cover (LCDB 2012)	0.69
Terrain & land cover	0.78
All datasets	0.79

$$TPR = \frac{TP}{TP + FN} \qquad FPR = \frac{FP}{TN + FP}$$



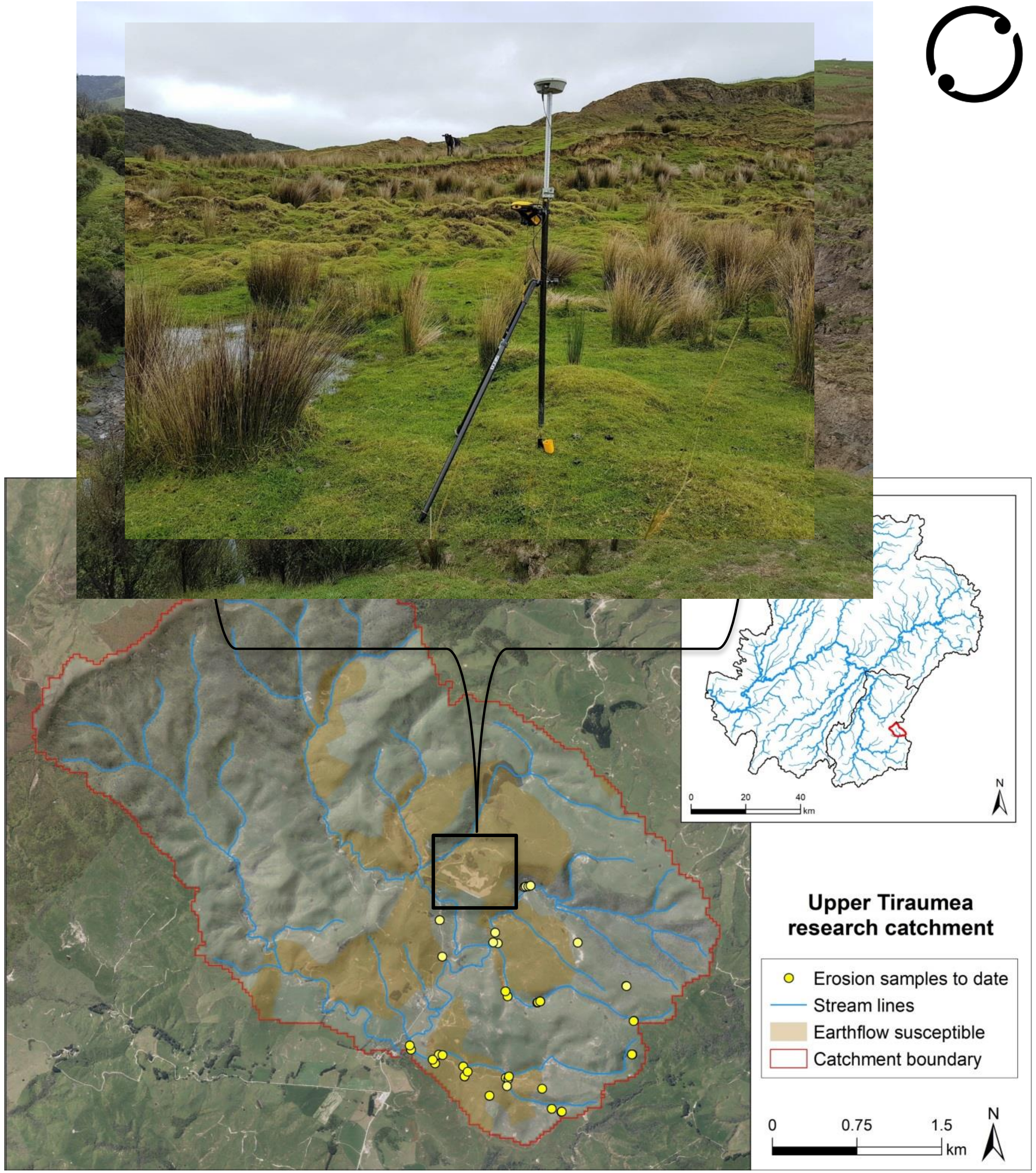
4.1 Case study: predicting landslide susceptibility

- Compare *Terrain only* vs. *Terrain + land cover*.
- Further work:
    1. Trial more spatial predictors, e.g. antecedent soil moisture.
    2. Apply to more storm-impacted areas
    3. Build database for model training and testing
    4. Compare predictions for individual and combined storms.
- Machine learning algorithms offer a **quantitative** and **consistent** basis for predicting erosion susceptibility.



4.2 STEC experimental research catchment

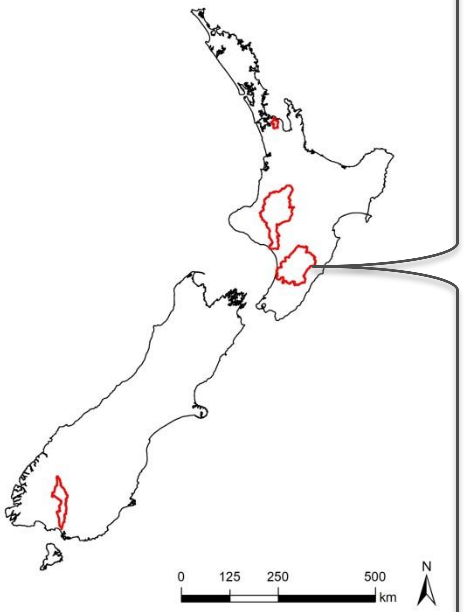
- Aim to better link land-based erosion processes to instream sediment effects.
- Nested measurements in headwater catchment (1 – 20 km^2) in the Manawatu.
- Measurements comprise:
  - Repeated earthflow movement surveys
  - Sediment source fingerprinting
  - Instream flow, turbidity and suspended sediment sampling
  - Erosion source & sediment quality measurements

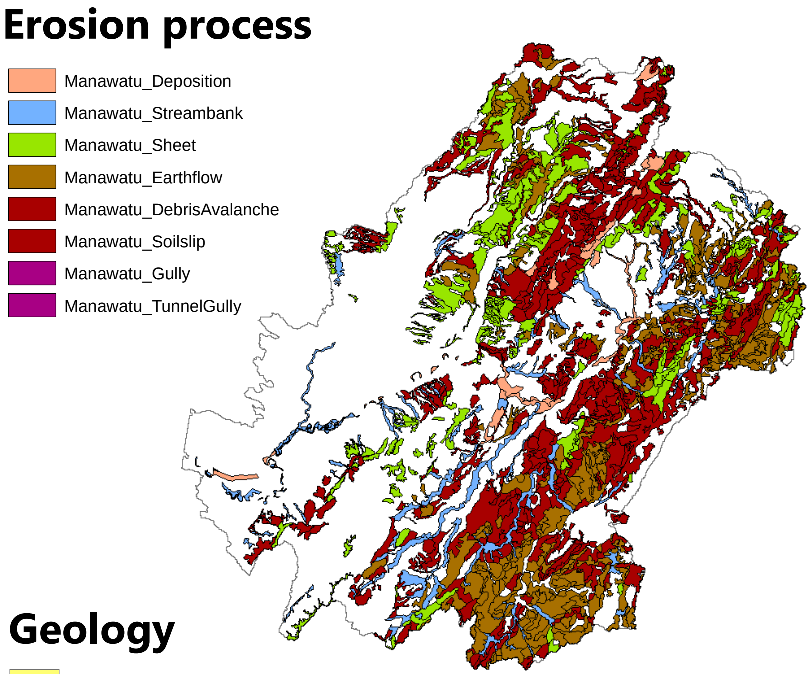


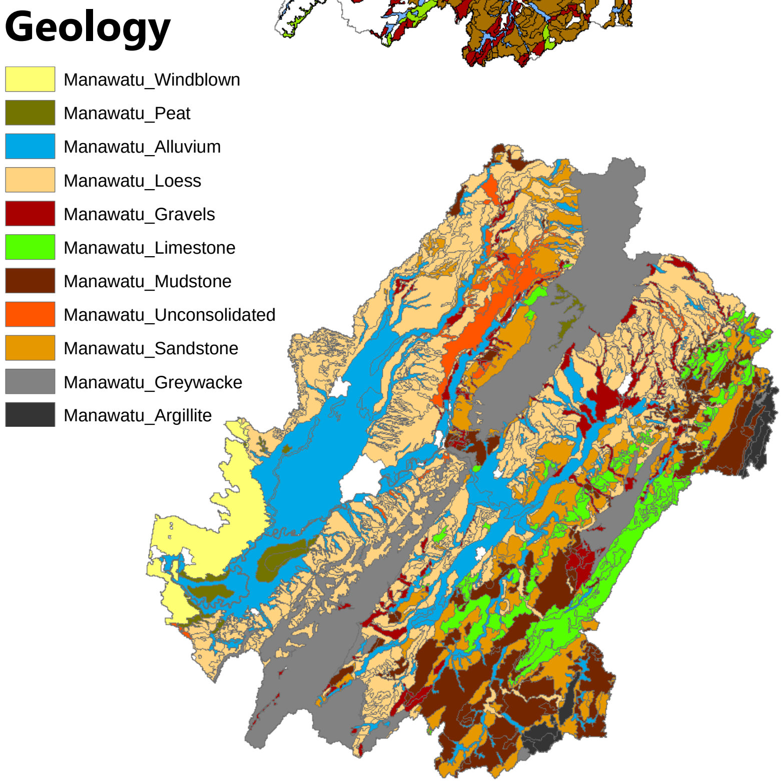
4.3 Characterising erosion source & sediment quality

- Aim: characterise suspended sediment properties and relate to erosion sources
- Build database for modelling (>500 samples)
- Measure properties affecting instream visual clarity

  - particle size, shape and organic matter content
- Stratify sources by erosion processes and geological units
- Instream auto-sampling of suspended sediment







4.4 Sediment source fingerprinting – Q & A

- **What is sediment source fingerprinting?**

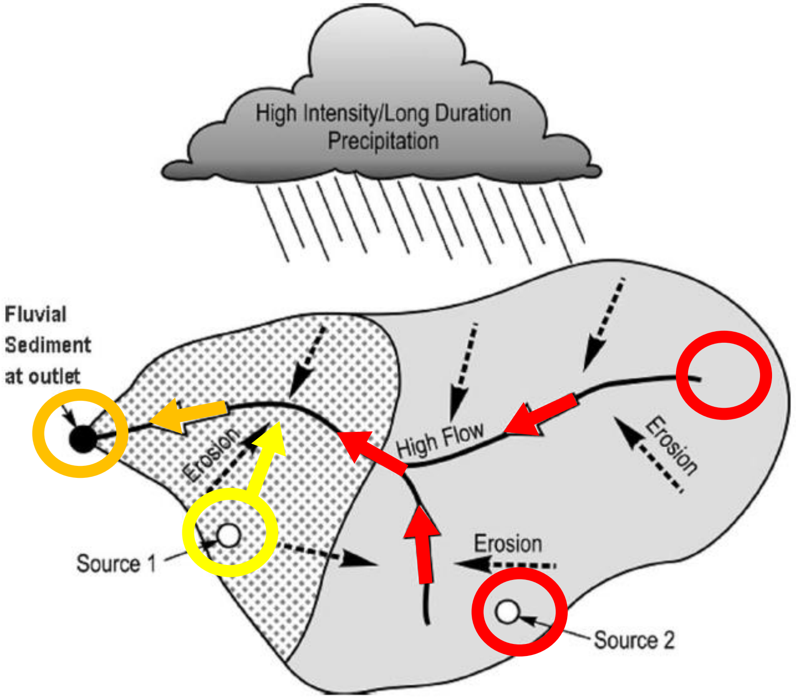
We select "tracers" to 1) discriminate sediment sources and 2) statistically "un-mix" contributions from those sources to fine sediment transported downstream.

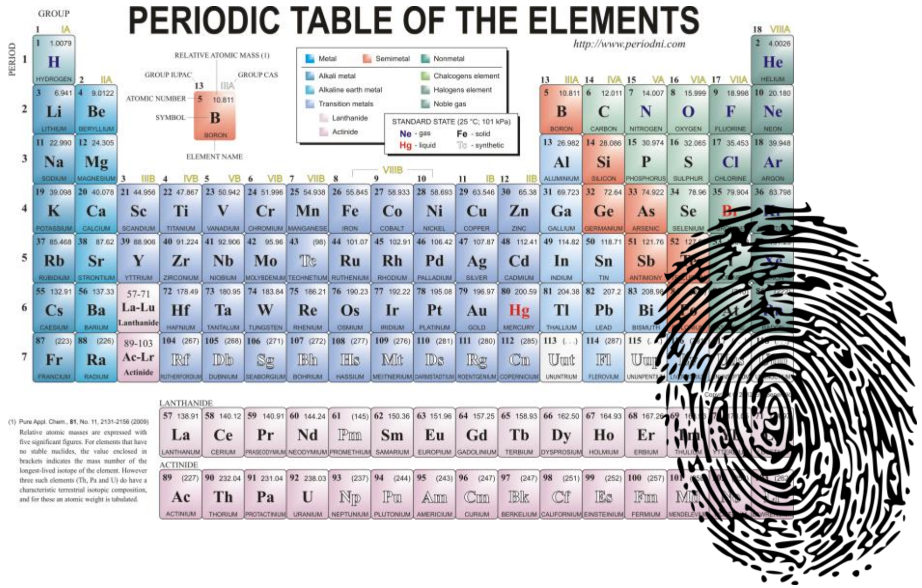
- **What soil and sediment properties are used as "tracers"?**

Tracers may include geochemical, radionuclide, magnetic, Compound Specific Stable Isotope (CSSI) properties.

- **What is the basis for source soil discrimination?**

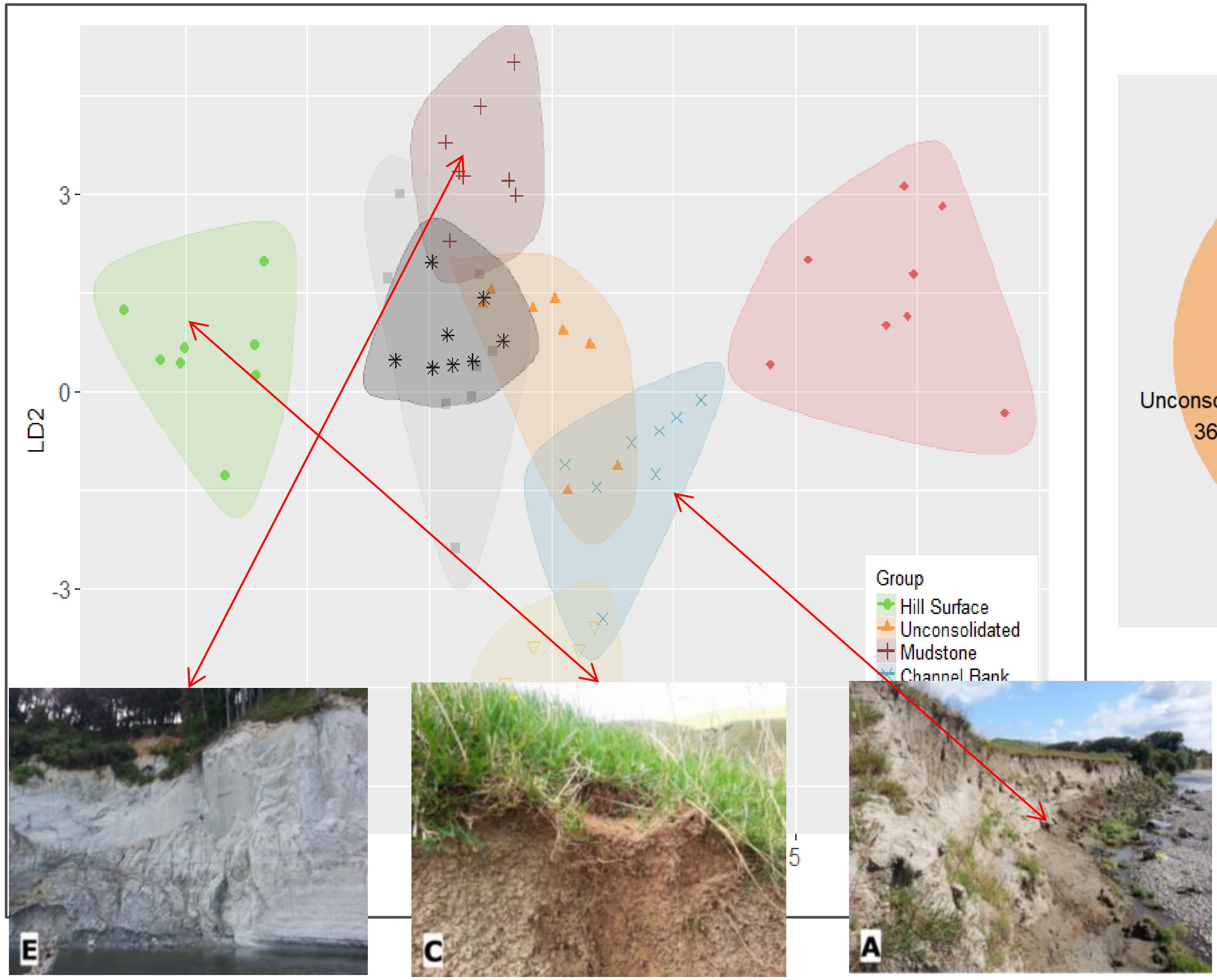
Tracers may discriminate sources based on 1) vertical soil controls (soil development, pollution) or 2) spatial controls (geological parent material, vegetation type).

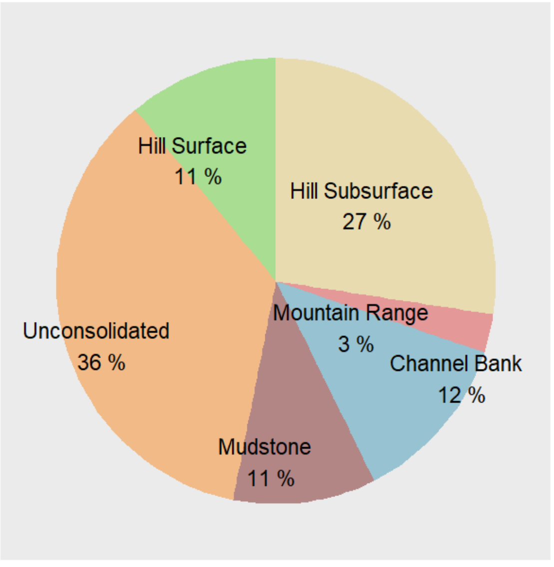


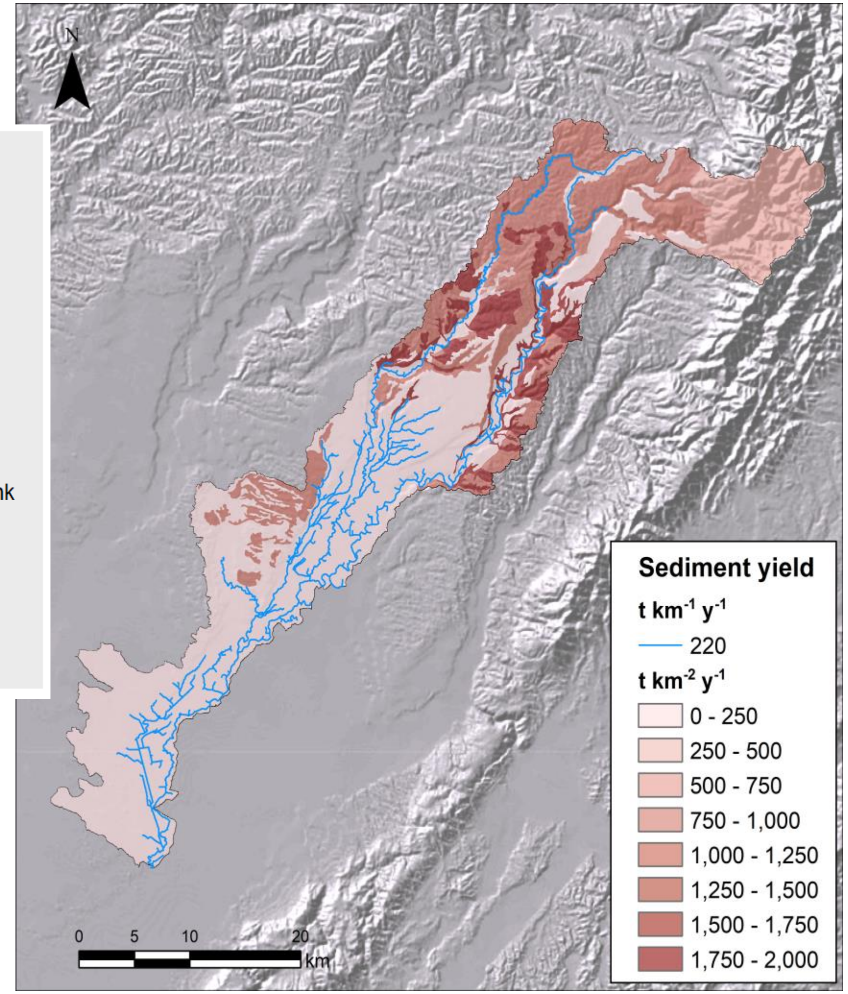


4.4 Sediment source fingerprinting – example

- Case study: Oroua catchment, Manawatu
- Quantify sediment source contributions to sediment deposits.







4.5 SedNetNZ model and STEC

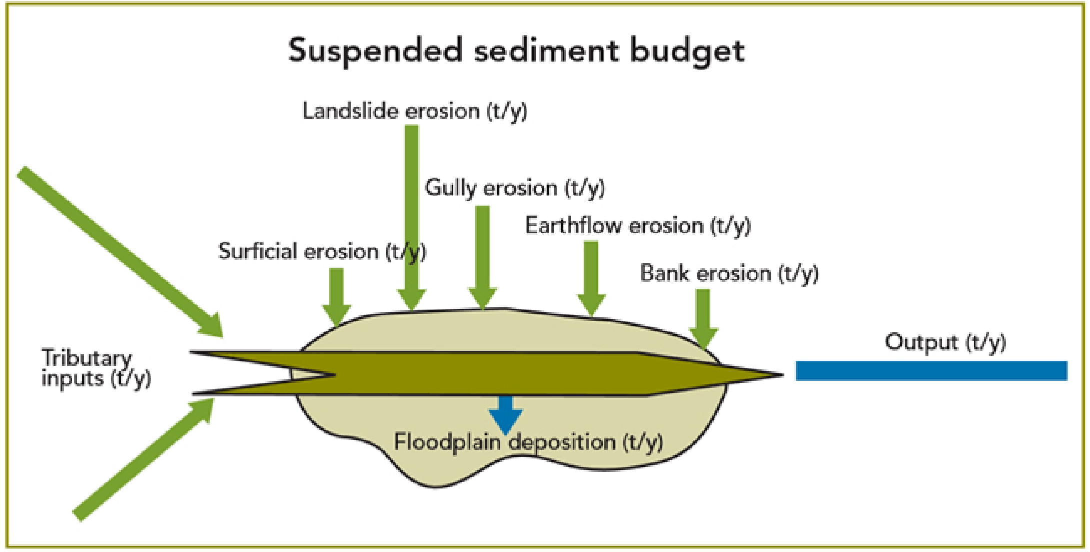
SedNetNZ sediment budget model

- catchment-to-regional scale patterns in mean annual erosion and suspended sediment loads.
- uptake by regional councils for catchment planning.
- continuing development - e.g. new bank erosion model.

STEC event-scale model

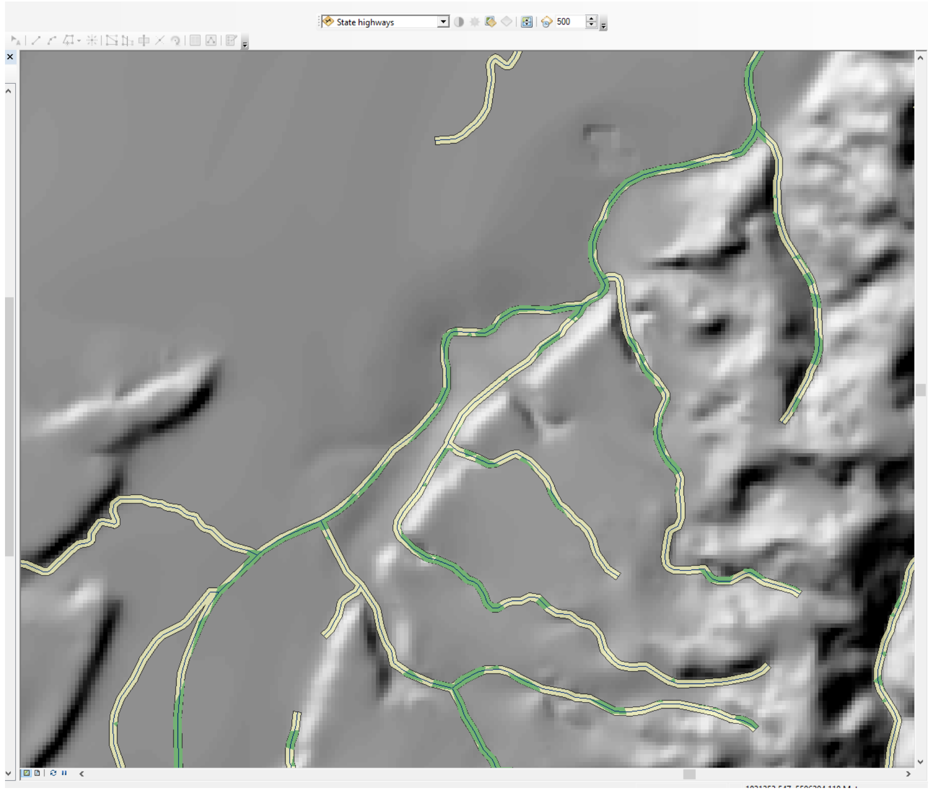
- link catchment erosion to sediment-related water quality impacts.
- represents temporal variability
- climate change impacts - projected increase in storminess.

SedNetNZ model



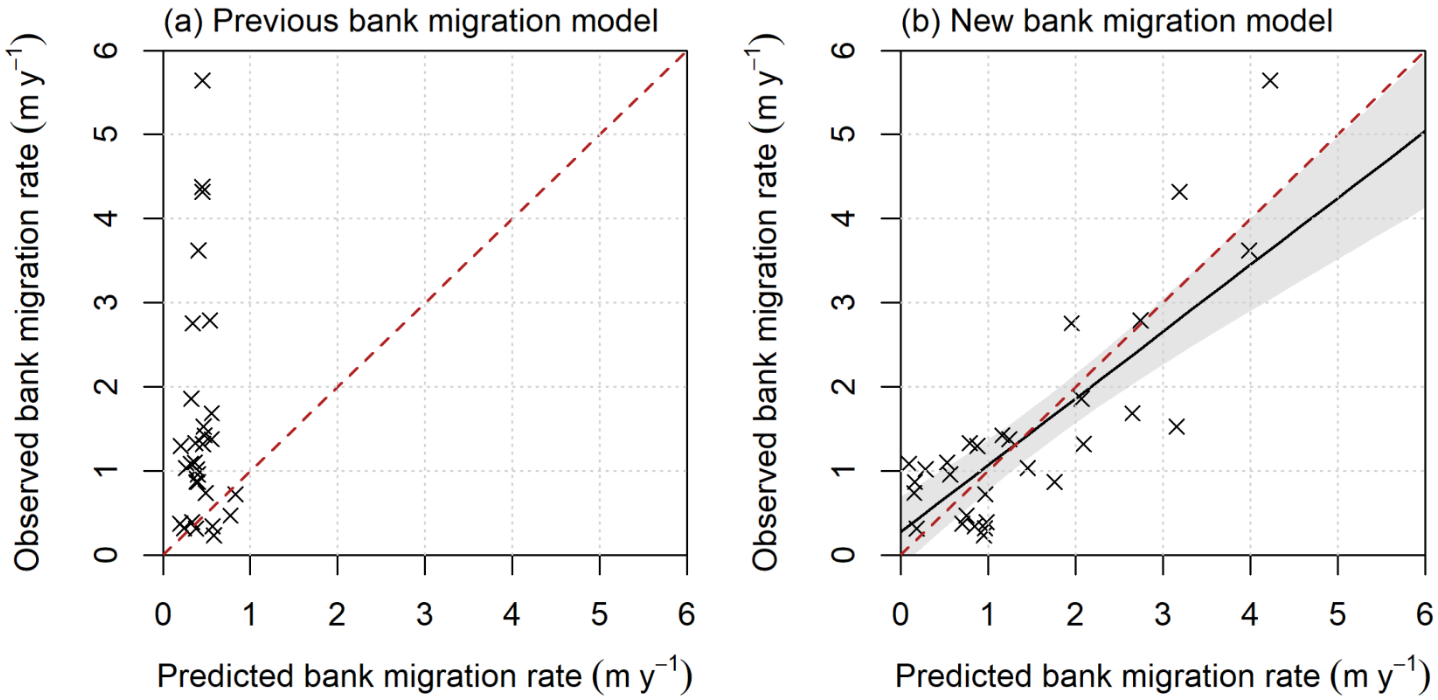
4.5 New riverbank erosion model for SedNetNZ

- Previous bank erosion model based on mean annual flood only.
- This does not take into account the effects of factors such as:
  - riparian woody vegetation
  - soil texture
  - channel slope
  - erosion mitigation works
- We now include these spatially-varying factors in a new model of bank erosion.



4.5 Evaluating model performance

- Model calibrated and tested using measured channel change from repeated aerial photography.
- Improved predictive performance over previous model.
- Applications to date – Horizons, Southland, Northland.



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RESEARCH ARTICLE

Check for updates

Predicting spatial patterns in riverbank erosion for catchment sediment budgets

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ABSTRACT

Riverbank erosion is an important component of catchment sediment budget models but remains one of the least well-understood processes, particularly at large spatial scales. Here, we develop and test a new bank migration model in New Zealand for large catchment applications that (1) better represents spatial variability in factors influencing bank erosion and (2) improves predictive performance. We represent bank migration rates as a function of reach-scale stream power, channel sinuosity, soil texture, valley confinement, riparian woody vegetation and channel protection works. The new model significantly improves prediction compared to the SedNetNZ model. Comparison of measured bank migration rates with individual variables shows percent silt + clay derived from soil maps exhibited the strongest correlation, whereas other variables were non-significant. The model results demonstrate that improved prediction can be achieved by combining spatial representation of multiple factors over large areas, despite low correlation between individual variables and bank migration rates.

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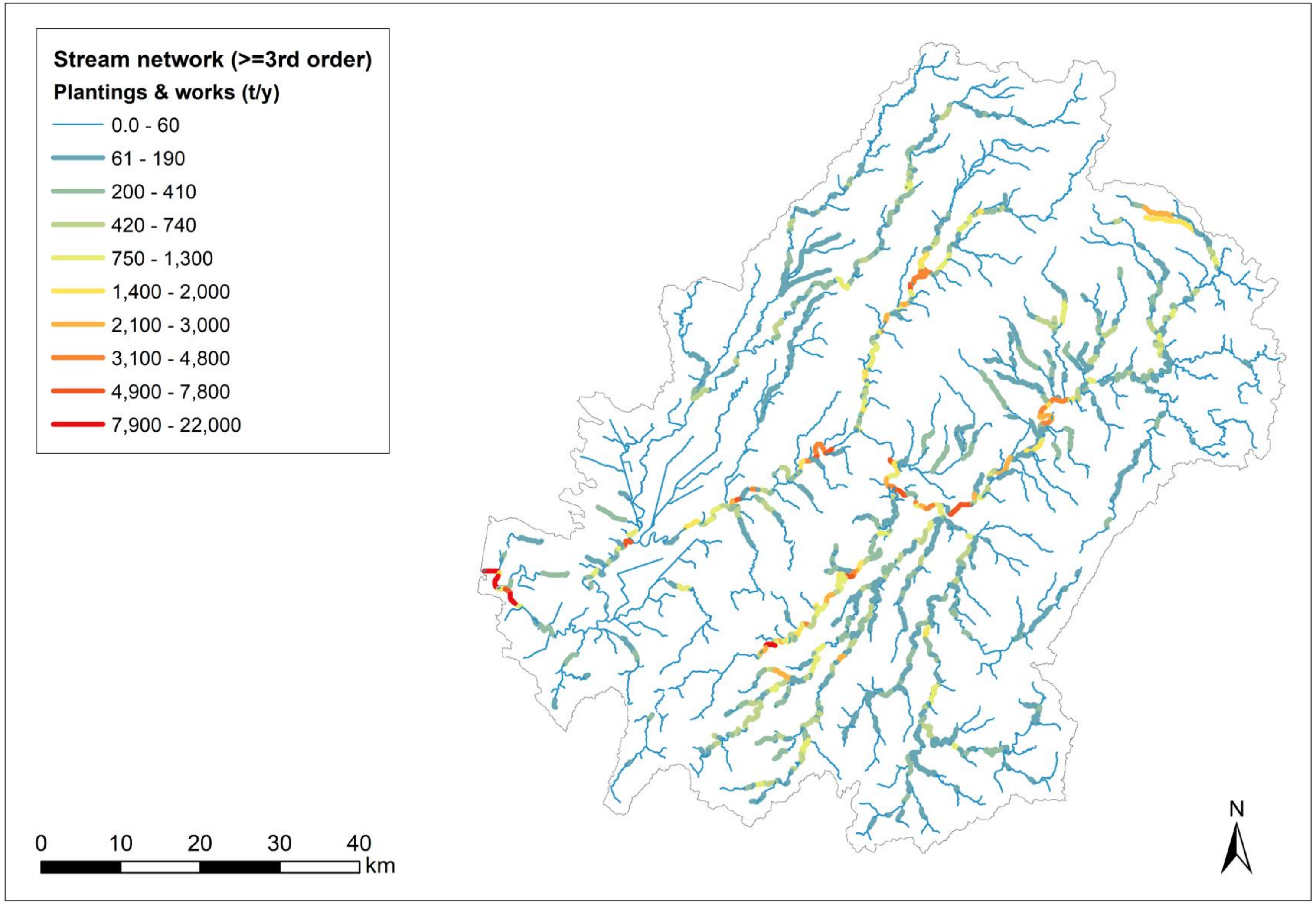
Riverbank erosion; bank migration rate; stream bank erosion; catchment sediment budgets; riparian management

4.5 Bank erosion scenarios – Manawatu example



Net bank sediment load (x 10^3 t y^{-1})

762		**Baseline**
684	**(-10%)**	**HRC plantings**
602	**(-21%)**	**HRC bank works**
556	**(-27%)**	**Plantings & works**

5 Future research

Improving landslide and slash risk management for plantation forestry

- Managing forestry slash a significant and ongoing challenge.
- Need a consistent and defendable basis for decision-making to reduce slash risk.
- Require quantitative analysis of post-harvest landslide and debris flow risk for steepland plantation forest estate.

Landslide & debris flow susceptibility, hazard & risk

What are the sources of wood?

Landslide-debris flow-slash event risk assessment and management

What are the feasible solutions to reduce slash event risk?

What is socially acceptable and how will climate change impact on this?

6. Summary

- Our research aims to support smarter targeting of investment in land-based erosion control for onsite and offsite (downstream) benefits.
- STEC investment driving new higher-resolution data collection, application of data science techniques, and event-scale model development.
- Combining techniques allows us to assess model results (e.g. sediment fingerprinting with catchment erosion modelling).
- Further research need - landslide and slash risk management.

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