Manaaki Whenua
Landcare Research

Improving understanding and management of erosion with LiDAR

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Outline

1. Sub-project scope
2. Existing erosion models for the Hawke’s Bay region
3. Regional LiDAR coverage and digital stream network
4. Data collection for erosion modelling
5. Upgraded shallow landslide susceptibility model
6. LiDAR-based SedNetNZ model
7. Key messages

1. Erosion sub-project

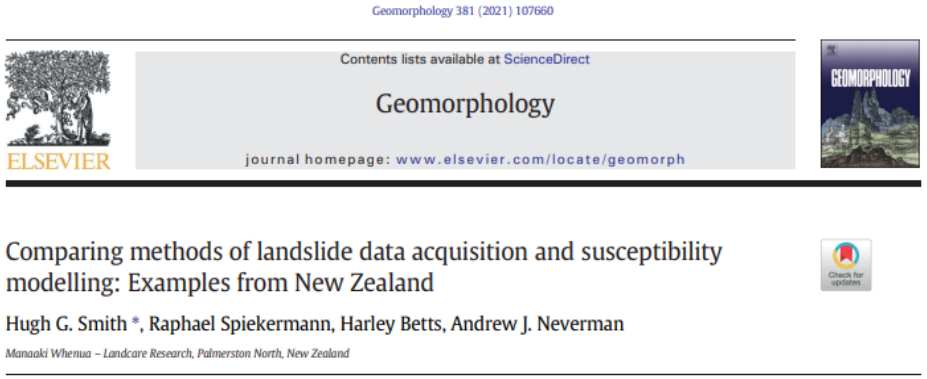
Scope

Upgrade regional erosion models to use higher resolution LiDAR topographic data alongside the targeted acquisition of new erosion data for modelling.

Objectives	Outputs
➢ upgrade SedNetNZ erosion and sediment load model ➢ improve the spatial representation of the stream network ➢ upgrade regional-scale shallow landslide susceptibility modelling	➢ suspended sediment loads for each erosion process for each segment in the new digital stream network ➢ improved digital stream network derived from regional LiDAR DEM ➢ upgraded landslide susceptibility maps

2.1 Existing models – Shallow landslide susceptibility

- **Landslide susceptibility:** the spatial probability of future landslide occurrence given local environmental conditions
- Landslide susceptibility models use a statistical approach to quantify future land instability
- Susceptibility models predict **where** and not **when** (i.e. how frequently) landslides may occur.
- Landslide susceptibility modelling requires data:
  - ➢ Landslide source locations
  - ➢ Non-landslide locations
  - ➢ Spatial co-variates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Comparing methods of landslide data acquisition and susceptibility modelling: Examples from New Zealand

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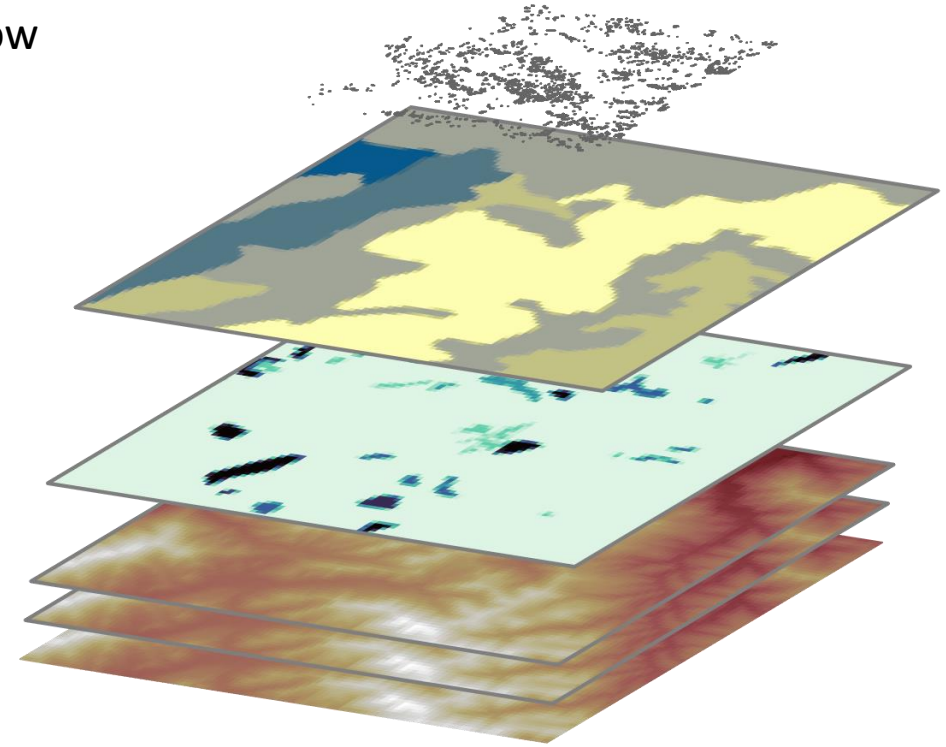


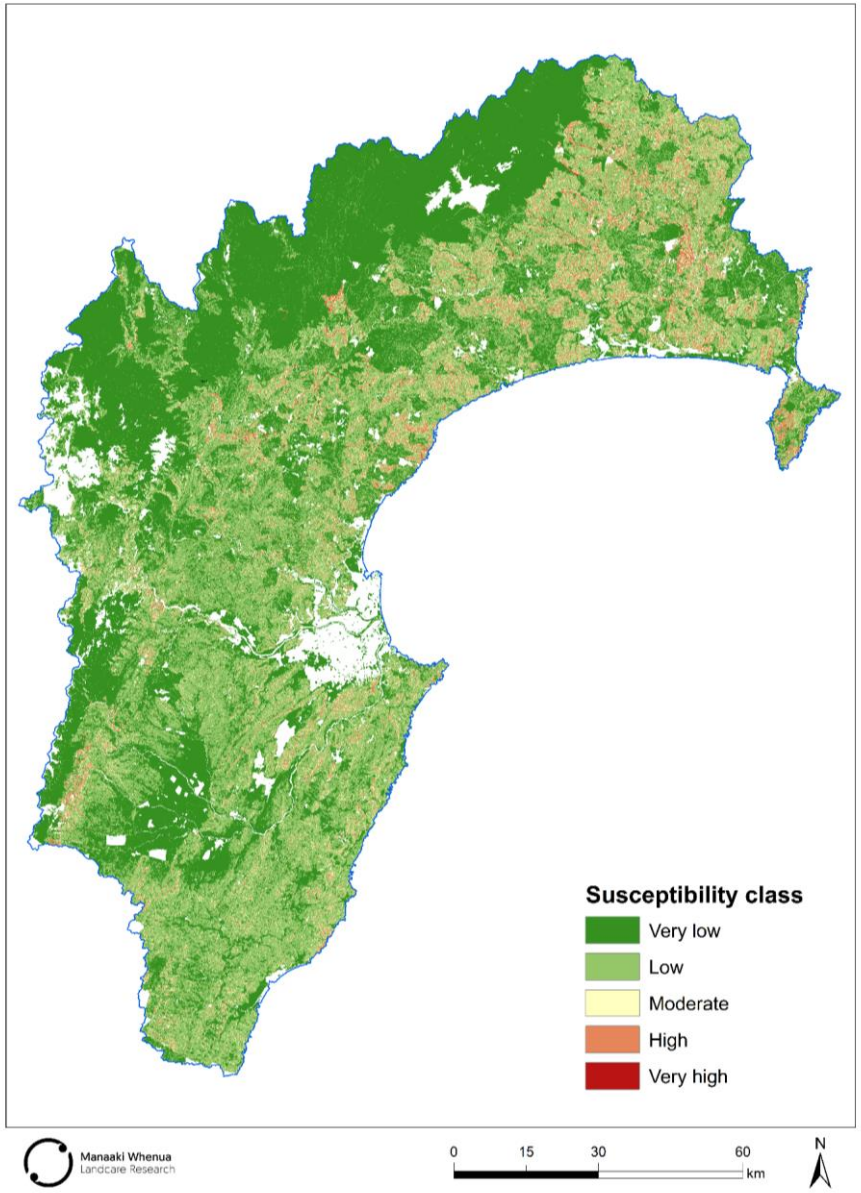
Landslide locations

Rock type
NZ LRI

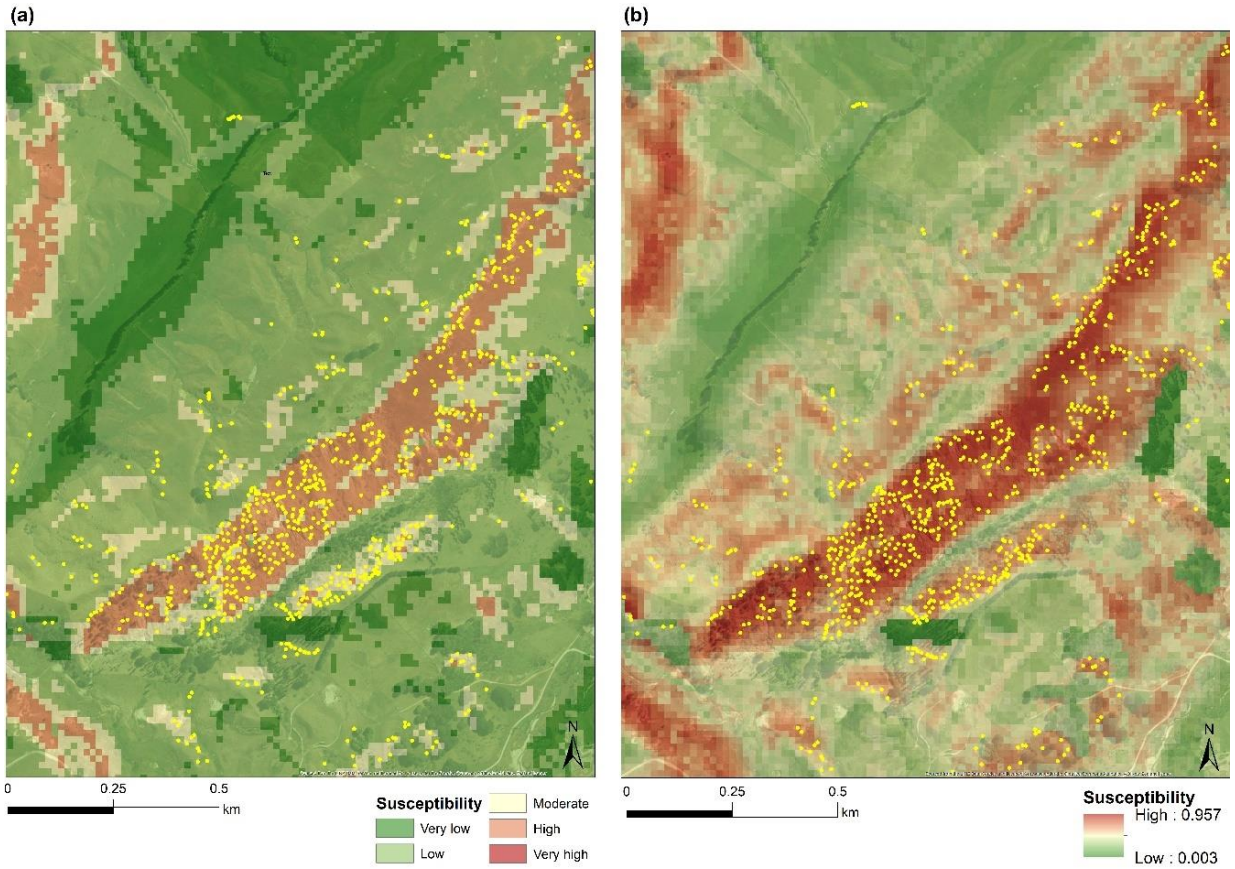
Land cover
NZ LCDB

Morphometry
Digital elevation model (DEM)

2.1 Existing models – Shallow landslide susceptibility



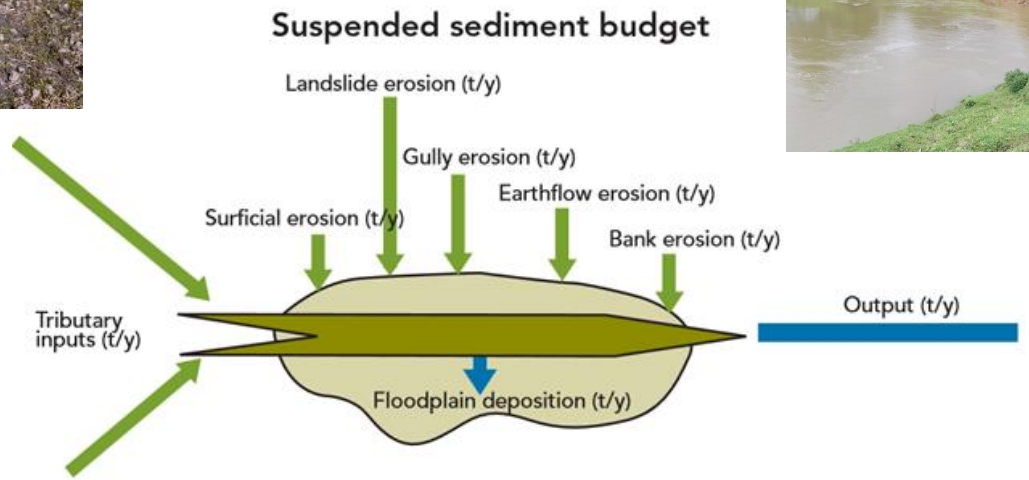
- Rainfall-induced shallow landslides
- Regional layer 15 m resolution
- Used probability and class-based scales

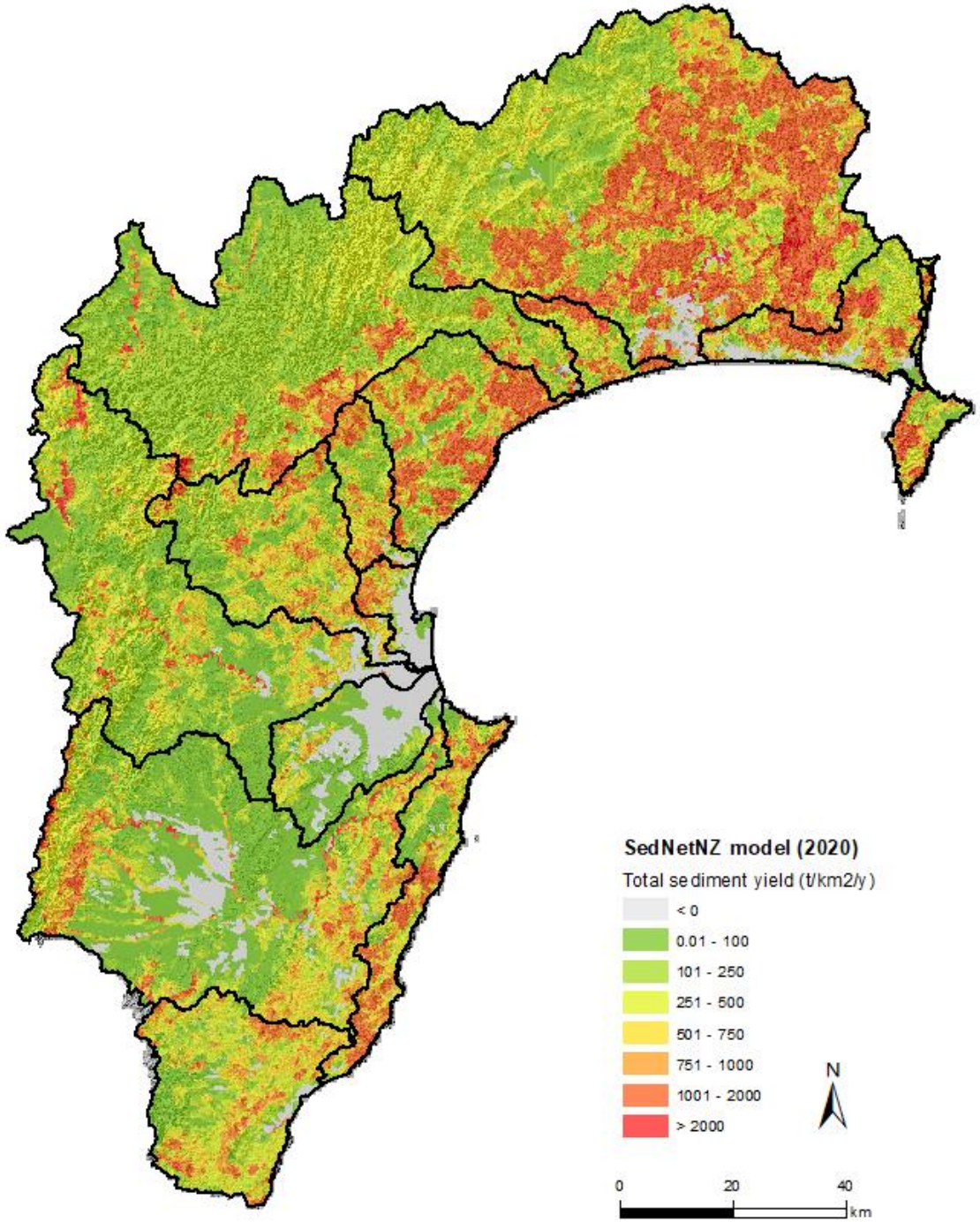


Smith HG (2020) A region-wide assessment of shallow landslide susceptibility in Hawke's Bay. Manaaki Whenua - Landcare Research Contract Report LC3720 for Hawke's Bay Regional Council.

2.2 Existing models – SedNetNZ

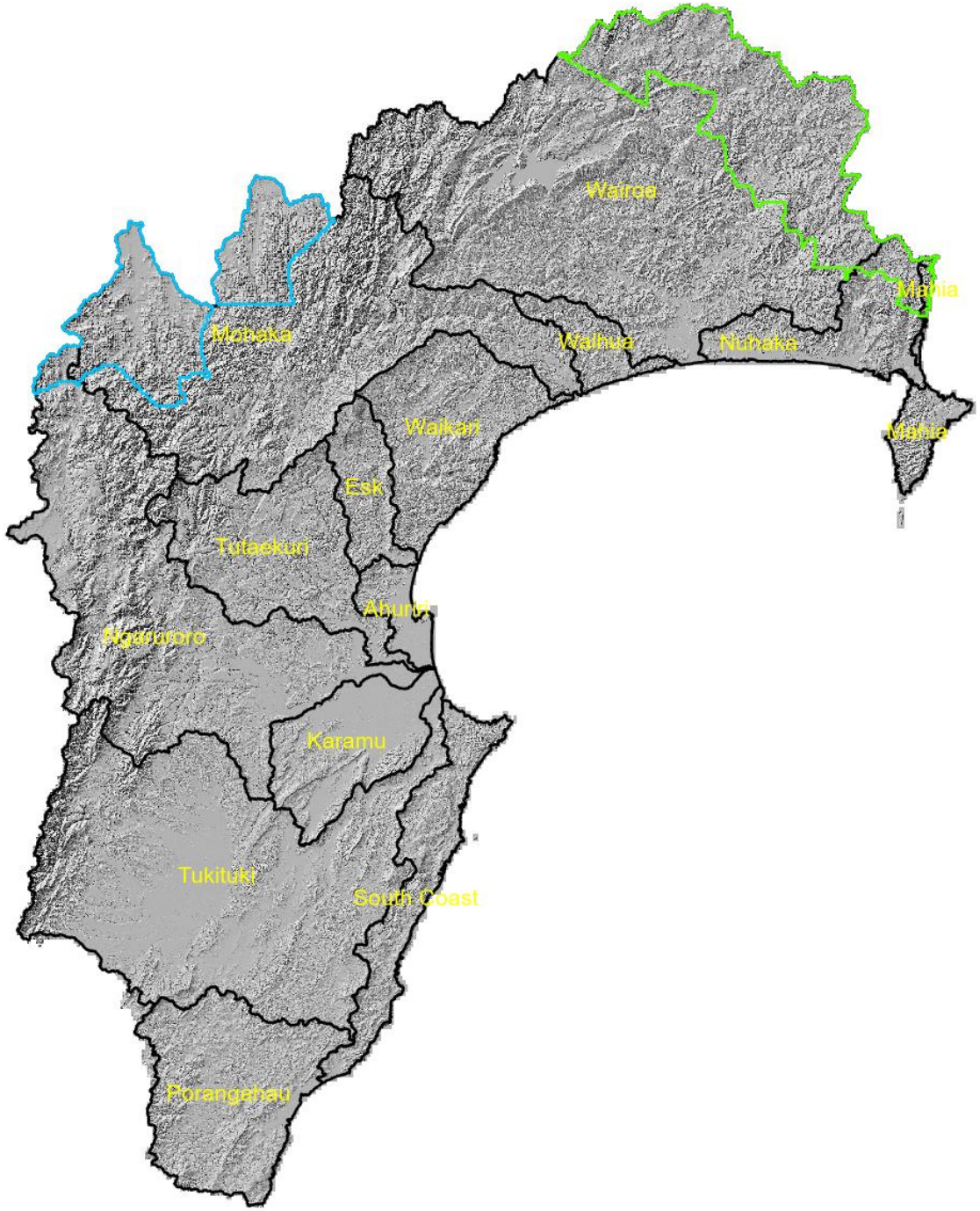
- **SedNetNZ** predicts average annual suspended sediment loads
- Model sediment contributions from different erosion processes
- Only erosion process-based sediment model designed for NZ





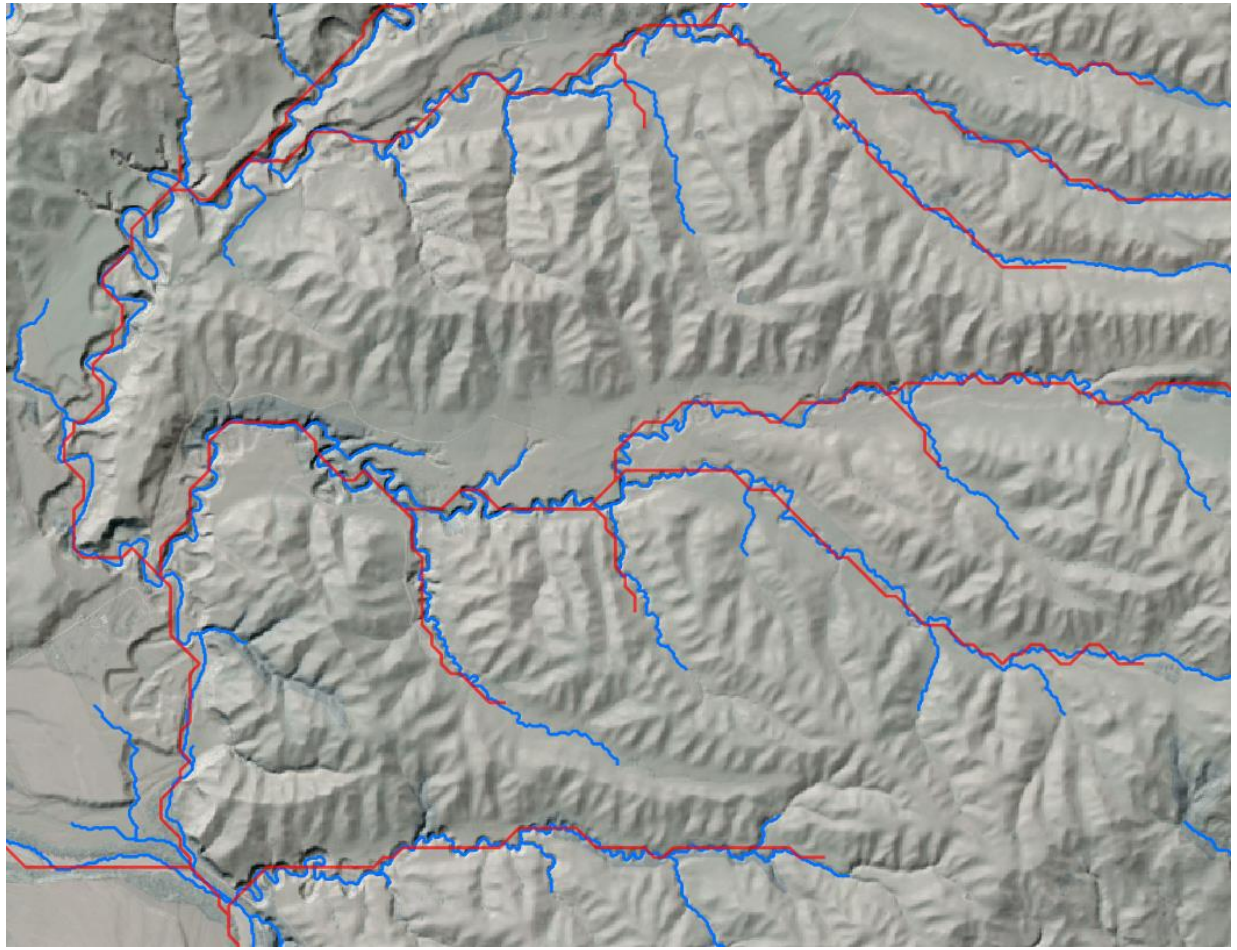
3.1 Regional LiDAR coverage

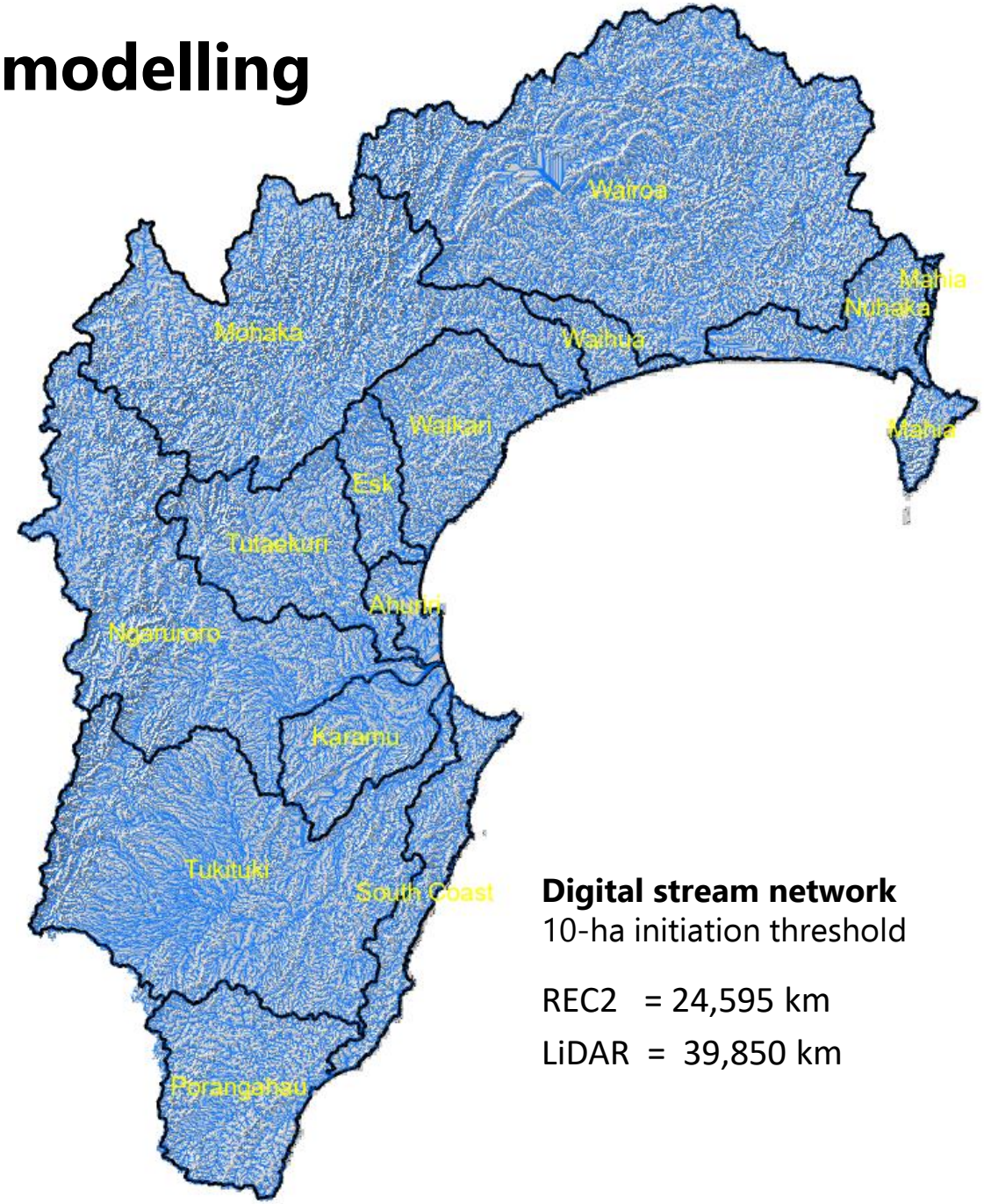
- HB LiDAR survey did not include headwaters of the Mohaka and Wairoa catchments
- Complete catchment coverage needed for erosion and sediment modelling
- Gaps filled using data from Gisborne and Waikato LiDAR surveys
- Erosion modelling based on a 5 m digital elevation model (DEM)



3.2 Digital stream network for erosion modelling

- Improved planform accuracy of channel network lines: LiDAR DEM (blue) vs. REC2 (red)



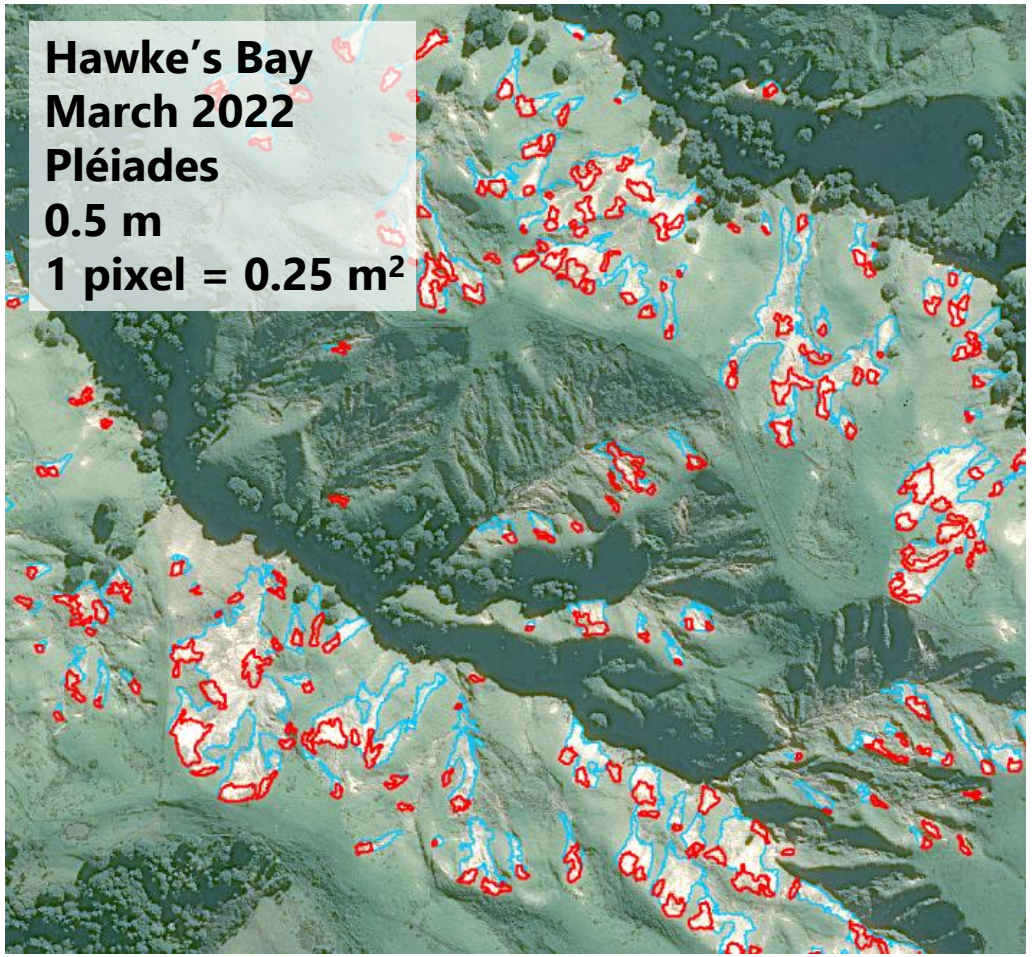


Digital stream network
10-ha initiation threshold

REC2 = 24,595 km

LiDAR = 39,850 km

4.1 Data collection for modelling – Shallow landslide mapping



- Landslide data are required for landslide susceptibility modelling
- Mapping data needs to overlap with available LiDAR coverages
- Require high-resolution aerial or satellite imagery (≤ 0.5 m) for accurate mapping

Study area	Location	Study area (km²)	Number of landslides
1	Southern Hawke's Bay	175	27,170
2	Northern Hawke's Bay	3,162	45,879
3	Wairarapa, Greater Wellington	843	43,069

4.2 Data collection for modelling – Channel change mapping

- Repeated aerial imagery used to map river channel change and estimate bank erosion rates for use in SedNetNZ
- Mapped channel change for >**420 km of channel** across Hawke's Bay for 2010-11 vs. 2019-20 interval
- Combine with data from 386 km of channel in Greater Wellington

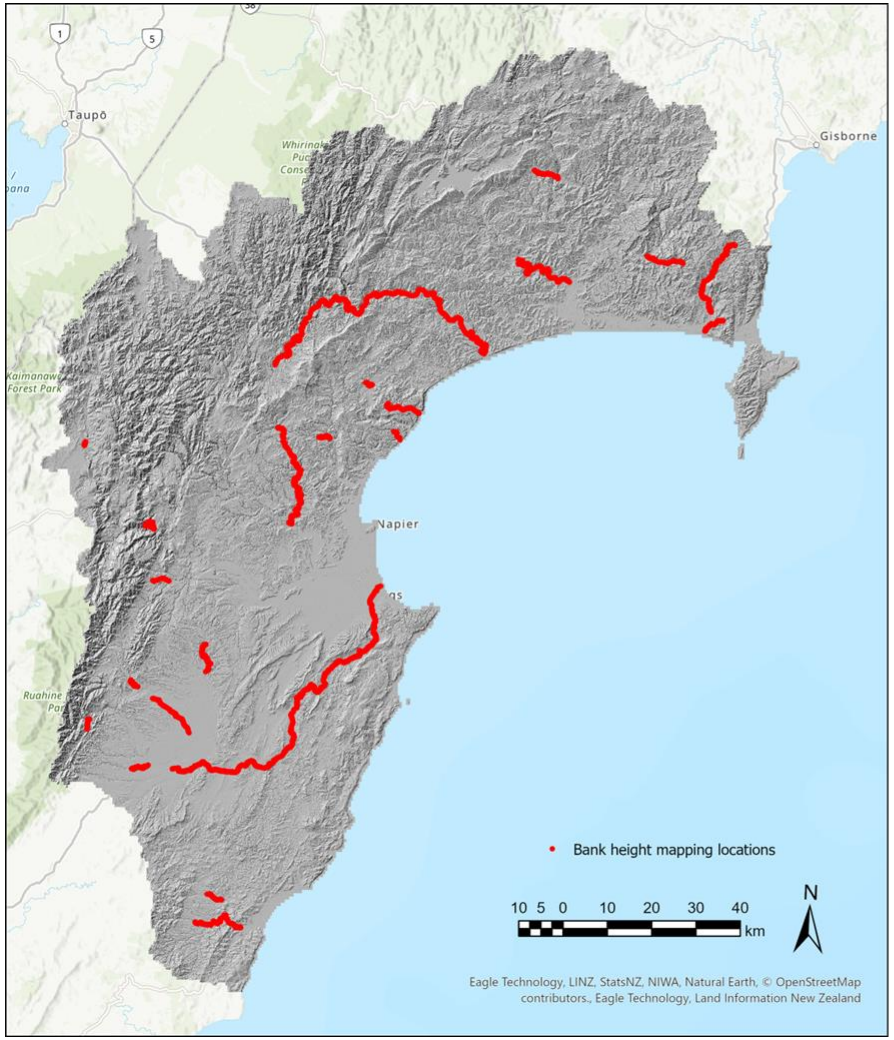
Channel planform changes between 2010-11 (yellow) vs. 2019-20 (red)

Shaded areas show zones of erosion

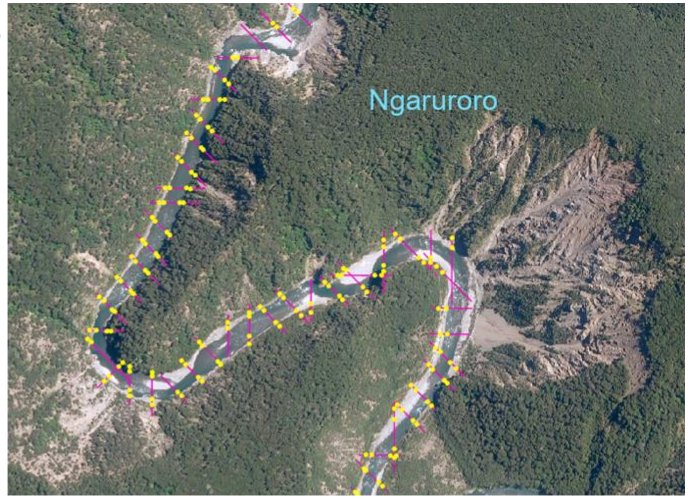
4.3 Data collection for modelling – Bank height mapping

- Require bank height information to model bank erosion
- Mapped bank heights along transects at 50 m intervals using 1 m DEM
- Mapped a total of **n = 10,519 banks**
- Summarise bank height by stream reach

a)



b)



c)

5. Upgraded shallow landslide susceptibility model

PREVIOUS MODEL

- National DEM based (15 m)
- 56,000 landslides
- Model performance:

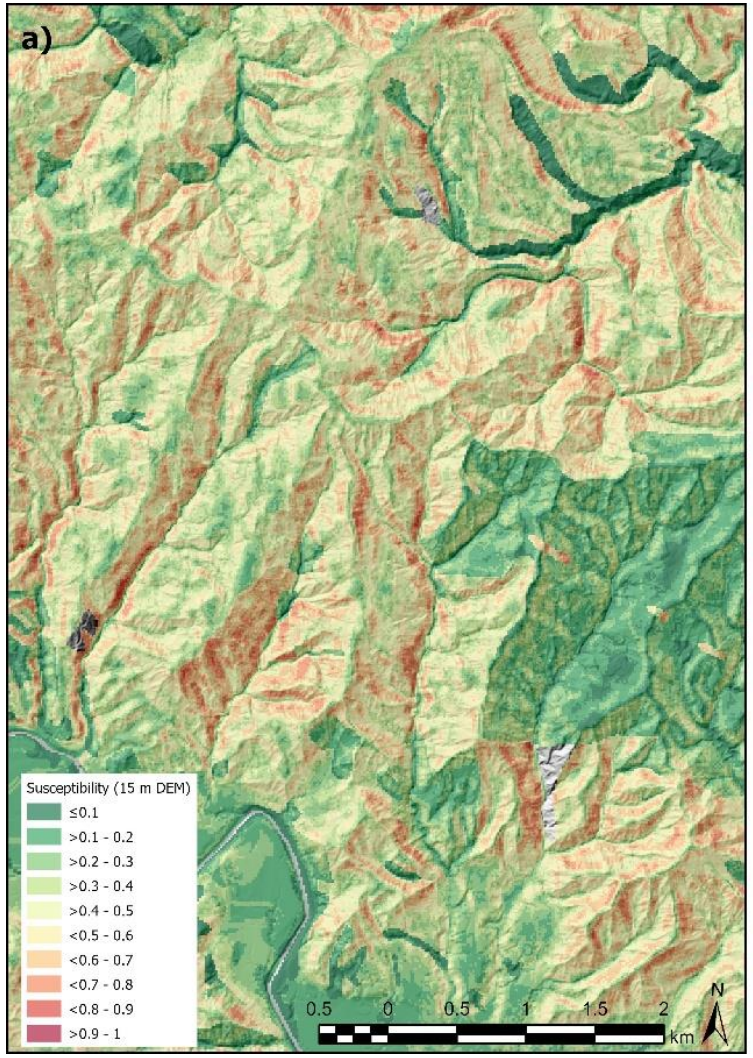
  AUC = 0.75 Accuracy = 68%

UPGRADED MODEL

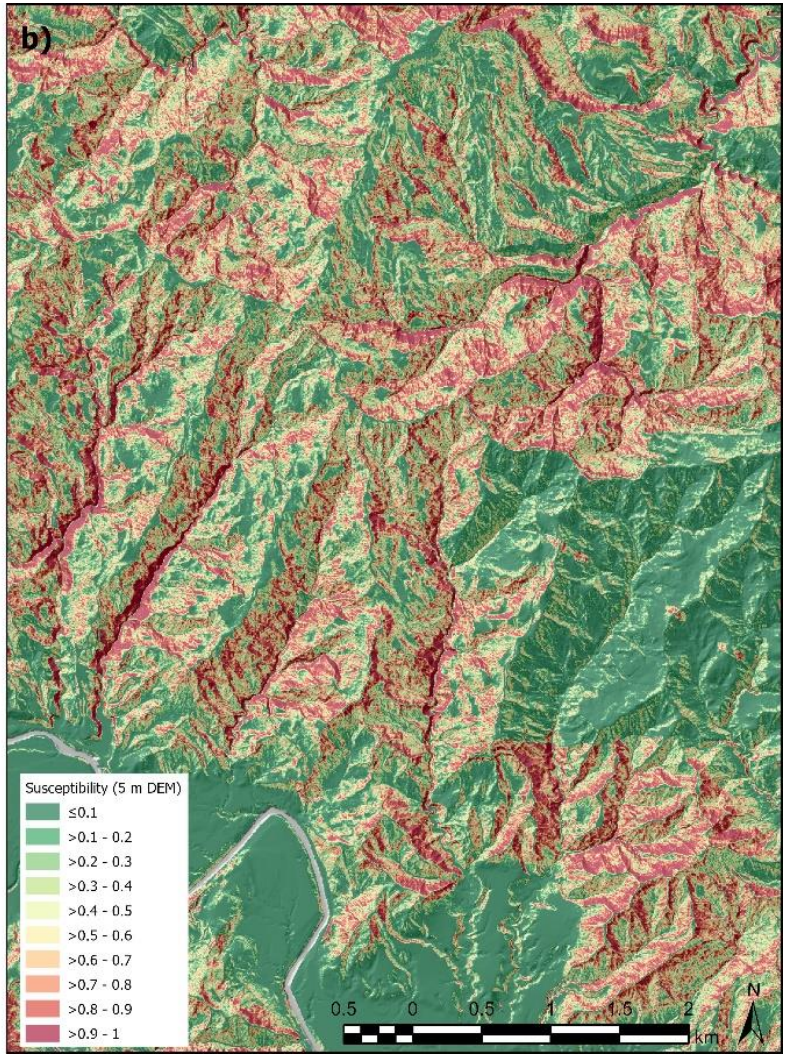
- LiDAR-based (5 m DEM)
- 116,000 landslides
- Model performance:

  AUC = 0.91 Accuracy = 84%

National 15 m DEM



LiDAR 5 m DEM



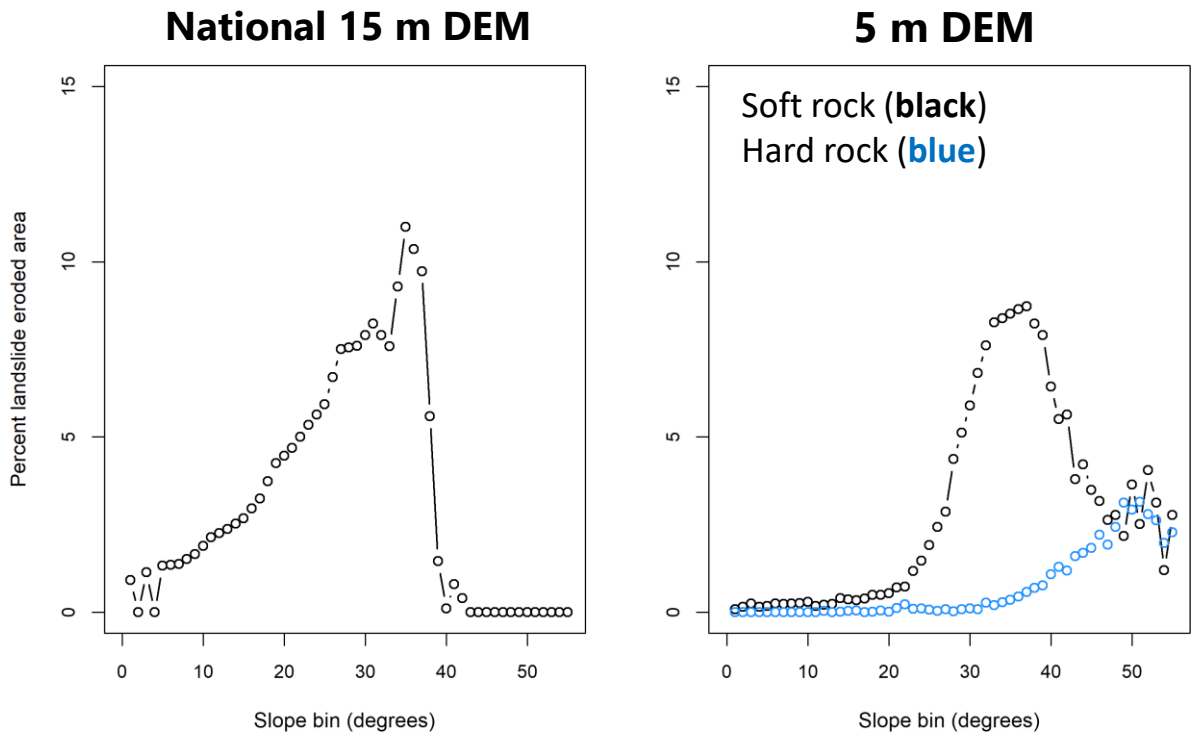
6.1 SedNetNZ – Model upgrade using LiDAR

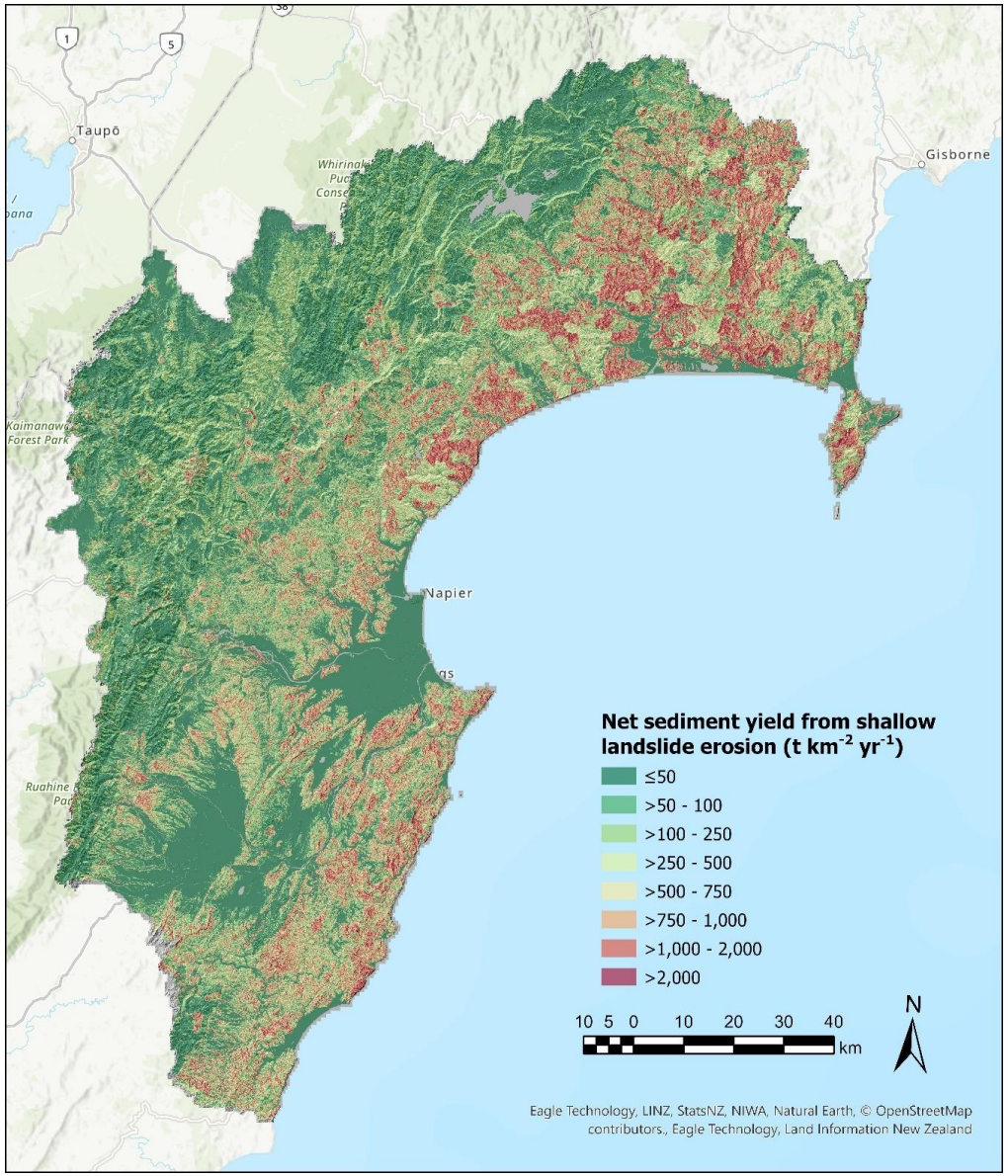
- Focus upgrade on shallow landslide, surface and riverbank erosion sub-models
- No change to the gully and earthflow sub-models – insufficient new data

Process sub-model	Modifications
Shallow landslide erosion	Integrated high-resolution landslide susceptibility with landslide erosion sub-model
Surface erosion	Implemented the Revised Universal Soil Loss Equation (RUSLE) to replace USLE
Riverbank erosion	Developed data-driven model for riverbank erosion using new data
Floodplain sedimentation	Use LiDAR 5 m DEM to identify areas adjacent channels where sediment may enter floodplain storage

6.2 LiDAR-based SedNetNZ – Shallow landslide erosion

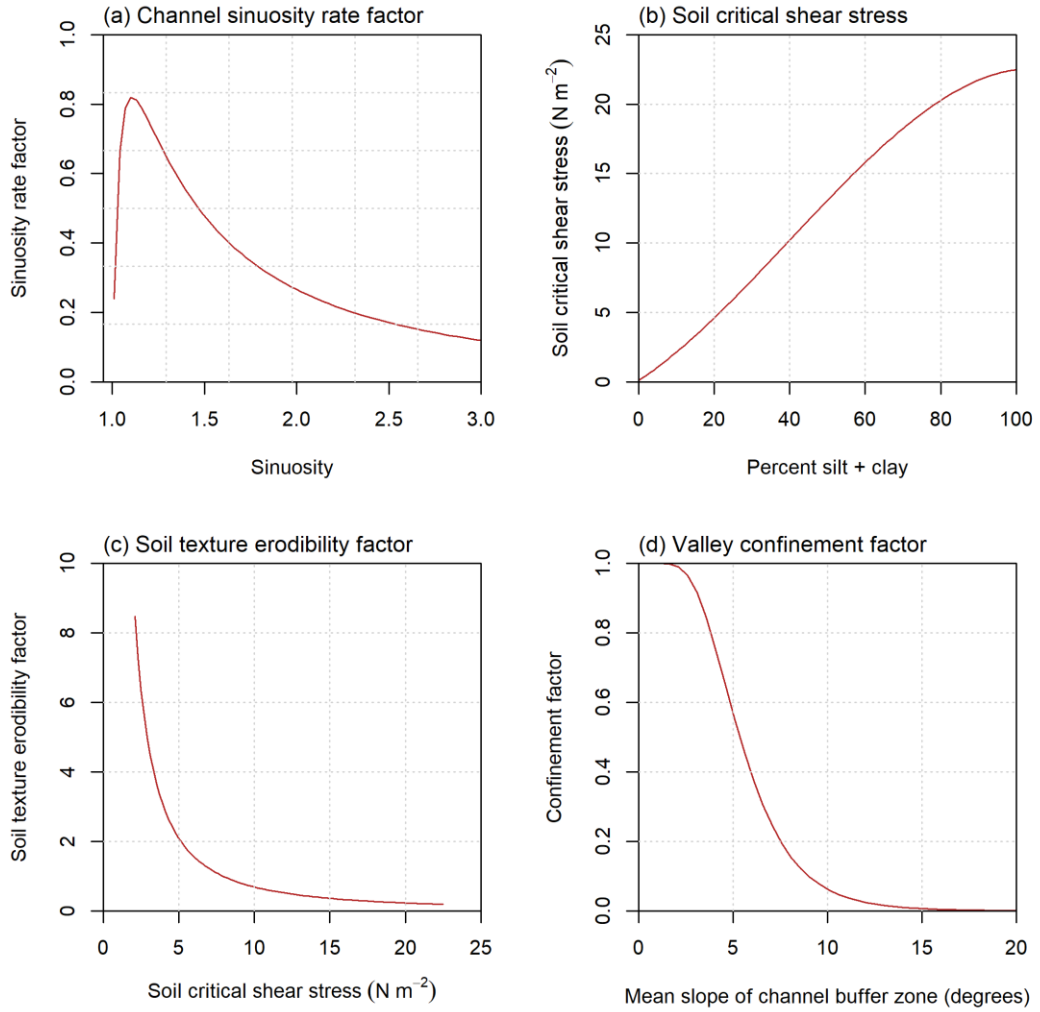
- Integrated new landslide susceptibility layer with landslide erosion sub-model
- Updated landslide-eroded area vs. slope relationship for soft and hard rock terrain using multi-decadal mapping data
- Estimate mean annual sediment load from landslide erosion





6.2 LiDAR-based SedNetNZ – Riverbank erosion

- Large increase in data → move to data-driven models
- Compared sub-models:
  - **Process – Original:** prior variable selection to represent process relationships; two variables fitted using original channel data (Smith et al. 2019)
  - **Process – Updated:** same as above**,** fitted with expanded channel change dataset
  - **General Additive Model (GAM)** with automated variable selection; allows non-linear relationships with constraints
  - **Random Forest (RF) model:** machine learning algorithm, automated variable selection, no constraints
- Used cross validation to compare model predictive performance (repeated 1000 times)



'Process – Original' sub-model (Smith et al. 2019)

6.2 LiDAR-based SedNetNZ – Riverbank erosion

1. Bank migration rate

- Model fitting (all data):

Error (m y^{-1})	Process-O	Process-U	GAM	RF
RMSE	0.78	0.38	0.36	0.15
MAE	0.65	0.14	0.17	0.06

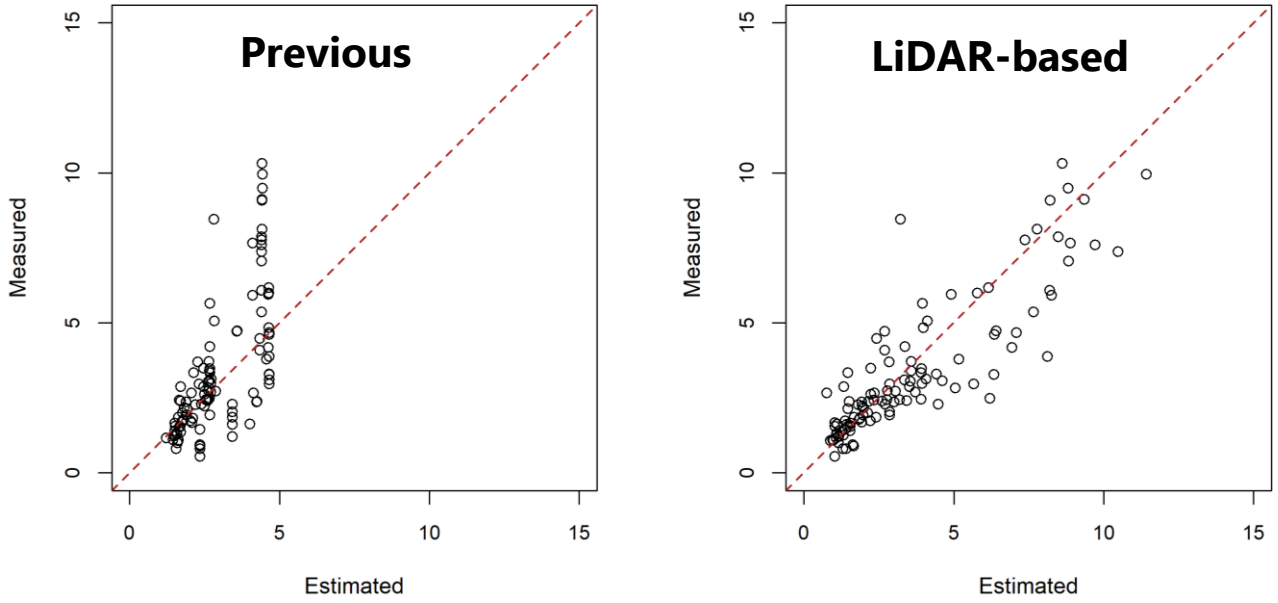
~40 km channel data

~800 km channel data

- Predictive performance (cross-validation):

Error (m y^{-1})	Process-O	Process-U	GAM	RF
RMSE	1.1	0.37	0.39	0.31
MAE	0.76	0.14	0.18	0.14

2. Estimate reach-scale bank height



3. Reach-scale net bank load

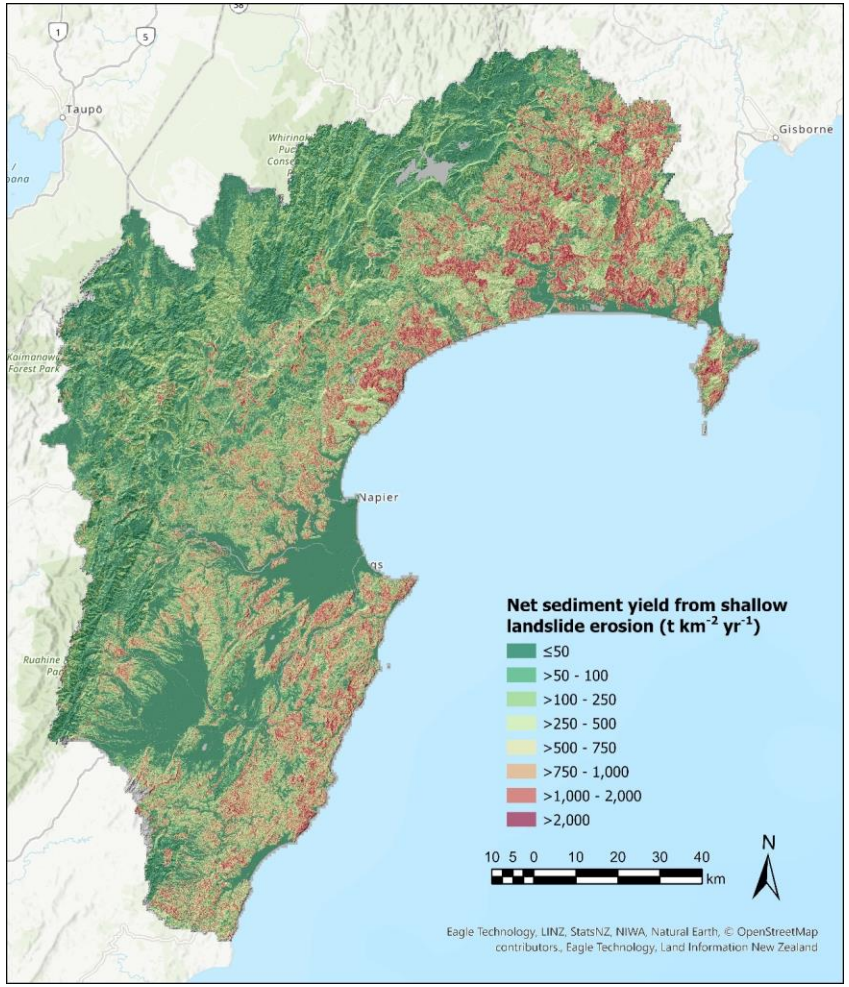
- RF model fitted using all data (R^2 = 0.87) and used to estimate suspended sediment load
- Estimated net load from bank erosion = 1.0 Mt yr^{-1}
- Previous model estimate = 0.7 Mt yr^{-1}

6.3 LiDAR-based SedNetNZ – Regional sediment budget

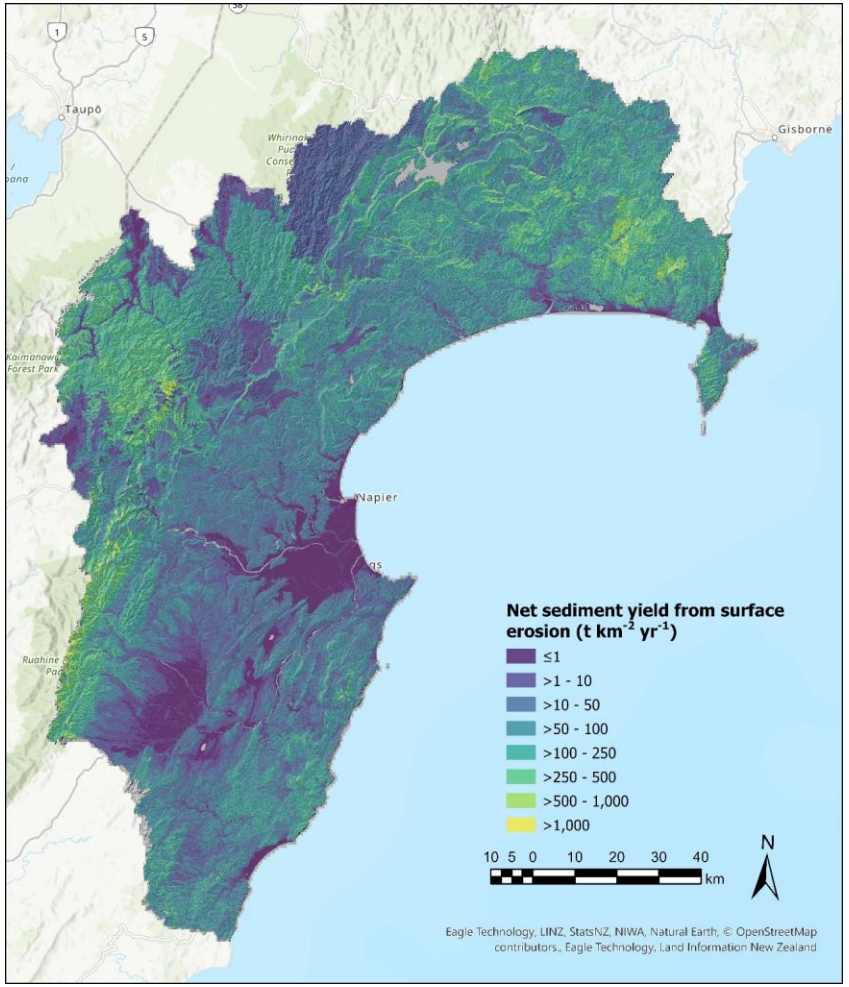
Estimated sediment loads delivered to the stream network	Previous SedNetNZ		LiDAR SedNetNZ	
	Suspended sediment load (Mt yr^{-1})	Percentage contribution to total load	Suspended sediment load (Mt yr^{-1})	Percentage contribution to total load
Shallow landslide erosion	4.9	66	5.4	64
Surface erosion	1.5	19	1.7	19
Riverbank erosion	0.70	9	1.0	12
Gully erosion	0.13	2	0.15	2
Earthflow erosion	0.27	4	0.27	3
Total load delivered to the stream network	**7.5**		**8.5**	
Total net load delivered to the coast	**7.2**		**8.0**	

6.4 LiDAR-based SedNetNZ – Model predictions

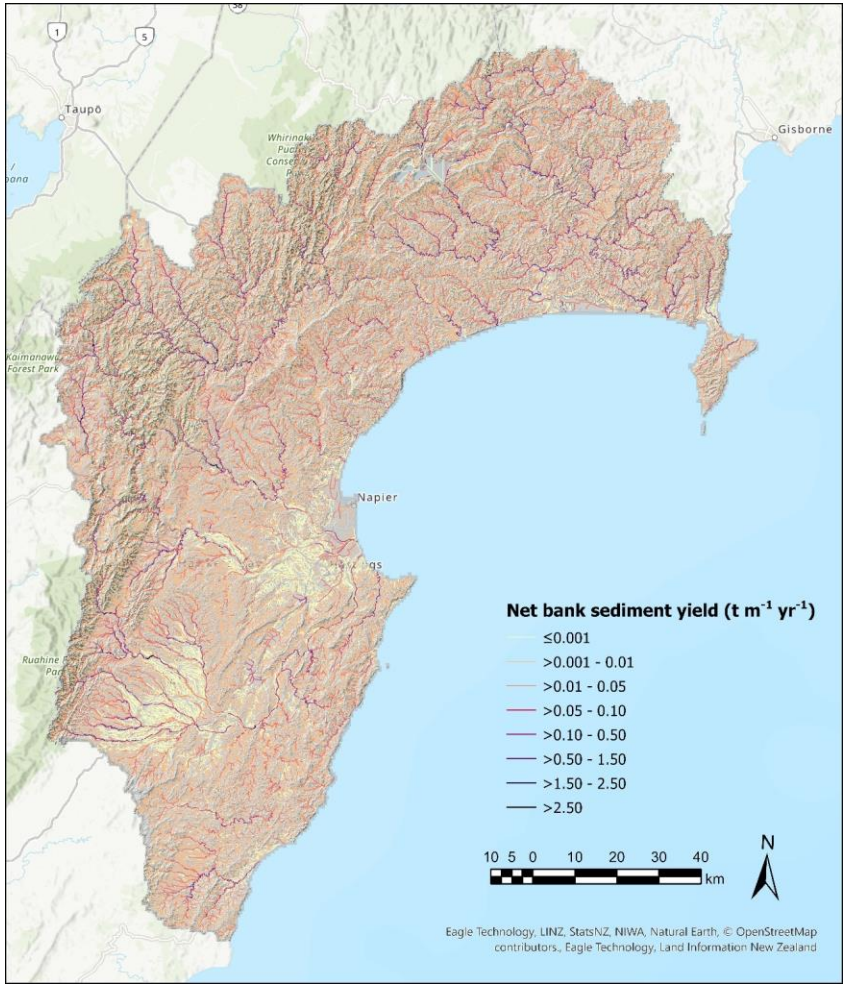
Shallow landslide erosion



Surface erosion

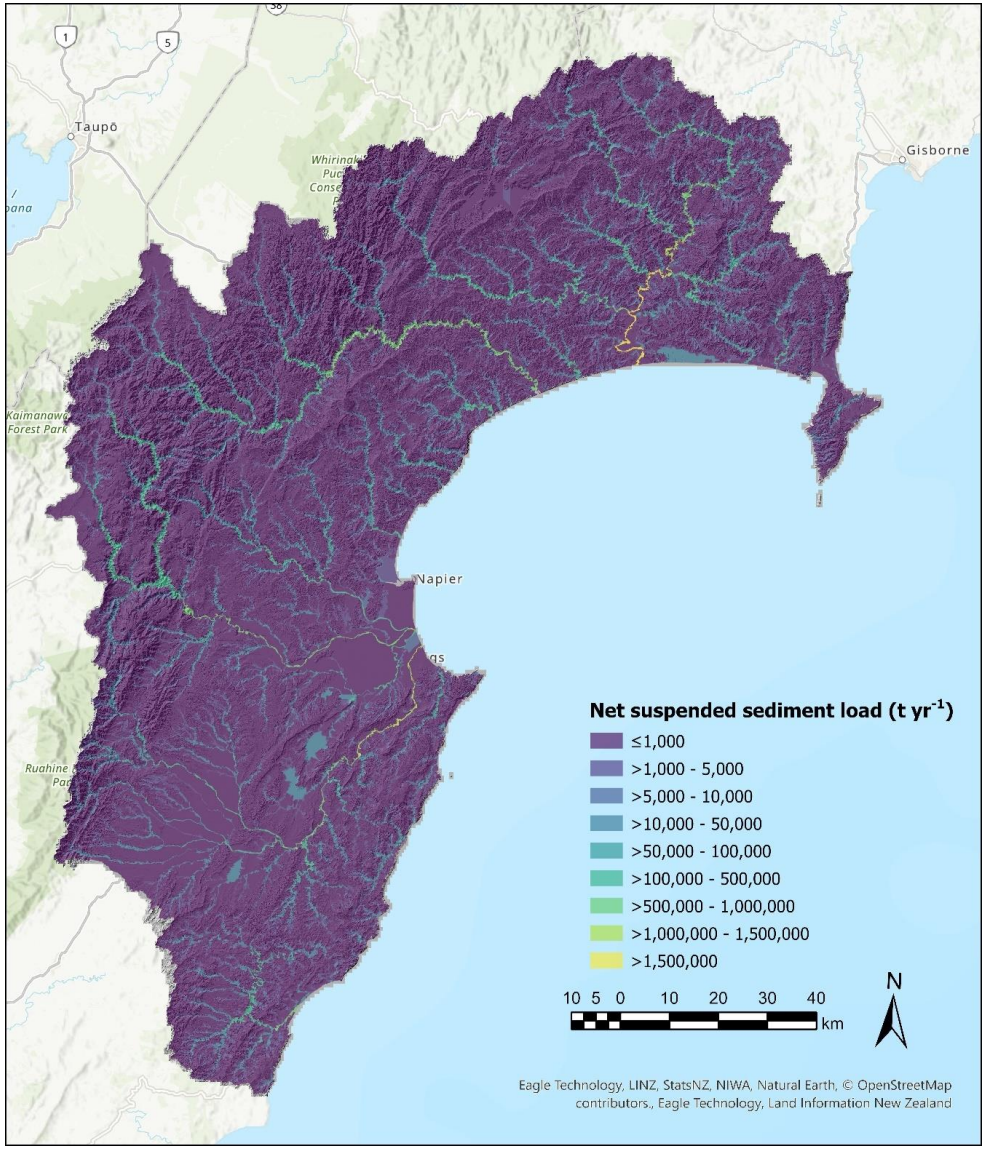


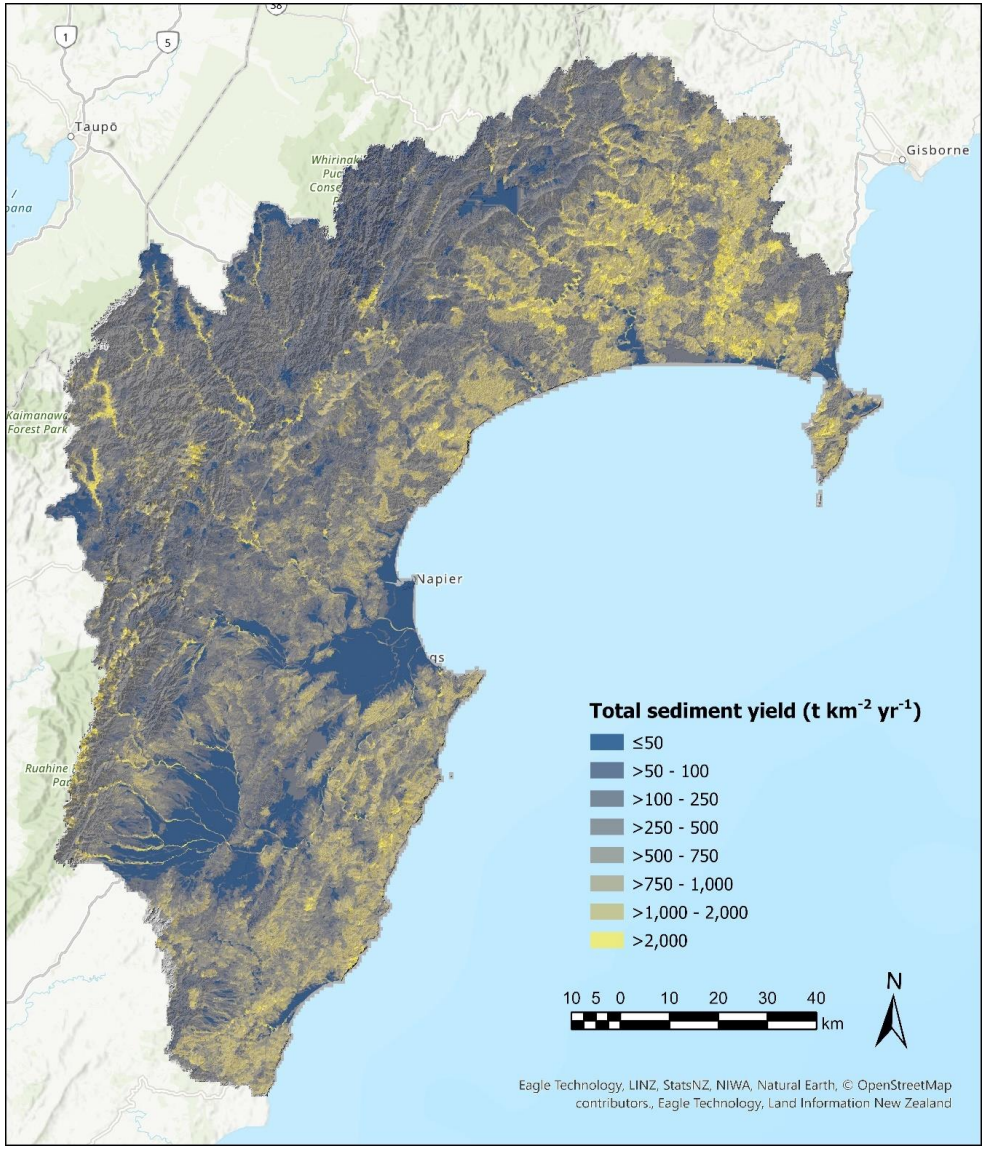
Riverbank erosion



6.5 LiDAR-based SedNetNZ – Model predictions

- Model predictions include
  - Net suspended sediment loads (t yr^{-1})
  - Subwatershed sediment yields (t km^{-2} yr^{-1})
- Compared modelled load vs. stream gauging estimates
- Correlation increased from R^2 = 0.55 to 0.67





7. Key messages

- Benefits of using higher resolution LiDAR-derived DEMs in erosion modelling:
    - improved model parameterisation and performance due to more accurate topographic data
    - better representation of the stream network – e.g., channel sinuosity, channel slope
    - higher resolution raster layers
- Shallow landslide susceptibility modelling produces higher resolution layers to support better targeting of tree planting to those areas most susceptible to land instability
- LiDAR-based SedNetNZ provides improved predictions of erosion process contributions to suspended sediment loads and higher resolution layers to support land and water planning
- Future work using SedNetNZ could focus on modelling erosion mitigation and climate change scenarios to assess impacts on suspended sediment loads