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MANAAKI WHENUA – LANDCARE RESEARCH

Models of erosion processes and suspended sediment loads in New Zealand

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The purpose of this brief guidance is to outline options for accessing modelled information on erosion processes and suspended sediment loads in New Zealand.

EROSION PROCESSES

Erosion comprises multiple processes, including shallow landslide, surface (sheet/rill/wind), earthflow and deep landslide, gully, and riverbank processes. Large spatial variations in the distribution and severity of these erosion processes in New Zealand arise from differences in topography, lithology, climate, land cover and grazing intensity. While erosion rates in New Zealand are naturally elevated by global standards, deforestation has further increased erosion (Basher, 2013). Landslide erosion is a particularly important process given the extent of hilly and mountainous terrain and widespread deforestation contributing to slope instability (Basher, 2013; Smith et al. 2021).

Models that aim to represent erosion contributing sediment to rivers on regional or national scales need to consider this array of processes. Most international models focus on surface (sheet/rill) erosion and may include streambank erosion, whereas few represent landslide processes. The episodic nature of landslide events triggered by large storm events requires representation of intervals that capture the longer-term (i.e., multi decadal) contribution of these events to sediment loads.

Assessing changes in erosion and the resulting sediment loads entering river networks over these timescales relies on models in the absence of equivalent long-term data. Models allow simulation of erosion mitigation scenarios to assess the effect of different land management actions in reducing downstream sediment loads. Models can also be used to assess potential impacts on erosion and sediment loads from projected climate change.

NATIONAL & REGIONAL MODELLING

Modelling at national scale involves a trade-off between model complexity and the availability of nationally consistent information and data for model parameterisation. National scale models tend to focus on either a single erosion process, such as surface erosion or bank erosion, or estimate suspended sediment loads without explicit representation of the erosion processes contributing sediment.

At regional scales, more data is often available for use in modelling that is not consistently available at the national scale. Regional differences in how and what data are collected by councils mean that regional-scale modelling can be better customised to address specific regional needs and make better use of available data, such as spatial information on soil conservation works or long-term hydrological data for model calibration and validation.

The following guidance briefly summarises models grouped into those that represent multiple erosion processes versus models that consider only a single process or estimate total suspended sediment loads without explicit representation of erosion processes.

MULTI-PROCESS MODELS

SedNetNZ

SedNetNZ is a sediment budget model that represents the range of erosion processes that occur in New Zealand and their contribution to suspended sediment loads. SedNetNZ includes surface (sheet/rill), shallow landslide, earthflow, gully, and riverbank erosion processes (Betts et al. 2017; Dymond et al. 2016; Smith et al. 2019). Hillslope erosion processes are computed on a 15 m grid while bank erosion is estimated for each segment of the digital stream network developed for the River Environment Classification (RECv2). The sediment loads from these processes are combined and routed through the digital stream network while accounting for losses due to floodplain deposition and trapping in lakes to estimate the mean annual suspended sediment load for each RECv2 subcatchment across a region.

SedNetNZ has been used to assess a) the effectiveness of erosion mitigations (e.g., tree planting, scrub reversion, stock-exclusion fencing etc) for reducing suspended sediment loads and b) the impacts of climate change scenarios on erosion and sediment loads. SedNetNZ has also been coupled with a national-scale empirical model relating improvement in visual clarity to reductions in suspended sediment load (Hicks et al. 2019a) to assess how land management interventions and climate change affect achievement of the National Policy Statement – Freshwater Management (NPS-FM, 2020) suspended fine sediment attribute bands.

Data	Not available online
Extent	Regional
Contact	Manaaki Whenua – Landcare Research (Hugh Smith)
References	*Peer-reviewed journal publications* Basher L, Spiekermann R, Dymond J, Herzig A, Hayman E, Ausseil A-G. 2020. Modelling the effect of land management interventions and climate change on sediment loads in the Manawatū-Whanganui region. New Zealand Journal of Marine and Freshwater Research 54: 490-511. Betts H, Basher L, Dymond J, Herzig A, Marden M, Phillips C. 2017. Development of a landslide component for a sediment budget model. Environmental Modelling & Software 92: 28–30. Dymond JR, Herzig A, Basher L, Betts HD, Marden M, Phillips CJ, Ausseil AE, Palmer DJ, Clark M, Roygard J. 2016. Development of a New Zealand SedNet model for assessment of catchment-wide soil-conservation works. Geomorphology 257: 85-93. Smith HG, Spiekermann R, Dymond J, Basher L. 2019. Predicting spatial patterns in riverbank erosion for catchment sediment budgets. New Zealand Journal of Marine and Freshwater Research 53: 338-362. *Contract reports* Neverman A, Smith HG, Herzig A, Basher L. 2020. Modelling baseline suspended sediment loads and load reductions required to achieve Draft Freshwater Objectives for Southland. Manaaki Whenua - Landcare Research Contract Report LC3749 prepared for Environment Southland. Neverman A, Smith HG, Herzig A. 2021. Planning soil conservation for sediment load reduction in Taranaki. Manaaki Whenua - Landcare Research Contract Report LC3942 prepared for Taranaki Regional Council Neverman A, Smith HG. 2022. SedNetNZ modelling for freshwater planning in Otago. Manaaki Whenua - Landcare Research Contract Report LC 5016 prepared for Otago Regional Council. Neverman A, Smith HG. 2023. SedNetNZ modelling to assess sediment contributions from natural land cover areas and impacts of climate change in Taranaki. Manaaki Whenua - Landcare Research Contract Report LC4258 prepared for Taranaki Regional Council.

	Smith HG, Herzig A, Dymond J, Basher L. 2019. Application of a revised SedNetNZ model to the Oreti and Aparima catchments, Southland. Manaaki Whenua-Landcare Research Contract Report LC3507 prepared for Our Land and Water National Science Challenge. Smith HG, Spiekermann R, Herzig A, Dymond J. 2020. Application of a revised bank erosion model to update SedNetNZ results for Hawke's Bay. Manaaki Whenua - Landcare Research Contract Report LC3740 prepared for Hawke's Bay Regional Council. Smith HG, Vale S, Neverman A, Robson-Williams M, Harris L. 2022. Climate change impacts on suspended sediment loads in the Wairoa catchment, Hawke's Bay. Manaaki Whenua - Landcare Research Contract Report LC4121 prepared for the Our Land & Water National Science Challenge. Vale S, Smith HG, Neverman A, Herzig A. 2021. Application of SedNetNZ with erosion mitigation and climate change scenarios and temporal disaggregation in the Bay of Plenty Region. Manaaki Whenua - Landcare Research Contract Report LC4002 prepared for Bay of Plenty Regional Council. Vale S, Smith HG, Neverman A, Herzig A. 2022. Application of SedNetNZ with SLUI erosion mitigation and climate change scenarios in the Horizons region to support NPS-FM 2020 implementation. Manaaki Whenua - Landcare Research Contract Report LC5033 prepared for Horizons Regional Council. Vale S, Smith HG, Robson-Williams M, Harris L. 2023. Effects of climate change and erosion mitigation on suspended sediment loads and visual clarity in the Wairoa catchment, Hawke's Bay. Manaaki Whenua - Landcare Research Contract Report LC4274 prepared for the Our Land & Water National Science Challenge.

Hybrid model for assessing climate change impacts

A recent hybrid approach has been developed for modelling mean annual erosion and suspended sediment loads under climate change at national scale (Neverman et al. 2023). This comprises a model framework combining use of spatial erosion domains with models representing surface erosion (RUSLE) and total suspended sediment load (NZeem®). This approach approximates contributions from mass movement, surficial and bank erosion by differencing surface erosion and total load within their respective spatial erosion domains, then routing sediment loads to the coast while accounting for sediment storage in lakes. The framework applies changes to erosion processes based on the estimated change in their hydroclimatic drivers for each climate scenario.

Data	https://wwo.landcareresearch.co.nz/dataset/climate-change-impacts-on-suspended-sediment-loads-in-new-zealand
Extent	National
Contact	Manaaki Whenua – Landcare Research (Andrew Neverman)
References	Neverman AJ, Donovan M, Smith HG, Ausseil A-G, Zammit C. 2023. Climate change impacts on erosion and suspended sediment loads in New Zealand. Geomorphology 427, 108607.

SINGLE PROCESS OR TOTAL LOAD MODELS

NZeem®

The New Zealand empirical erosion model (NZeem®) estimates total suspended sediment yields (t km-2 yr-1) nationally on a 15 m grid (Dymond et al. 2010). The model relates net sediment yield to mean annual rainfall, land cover and a coefficient based on an erosion terrain classification. The original NZeem® model does not account for sediment storage in lakes.

Data	https://lris.scinfo.org.nz/layer/48178-nzeem-erosion-rates-north-island/ and https://lris.scinfo.org.nz/layer/48176-nzeem-erosion-rates-south-island/
Extent	National
Contact	Manaaki Whenua – Landcare Research (Andrew Neverman)
References	Dymond JR, Betts HD, Schierlitz CS. 2010. An erosion model for evaluating regional land-use scenarios. Environmental Modelling & Software 25, 289–298.

Updated sediment load estimator

The updated sediment load estimator is an empirical model relating mean annual suspended sediment load to the average slope, mean annual rainfall, land cover and erosion terrain present within a 1 ha grid cell (Hicks et al. 2019b). River suspended sediment loads are computed based on upstream grid cells and routed through the RECv2 digital stream network while accounting for sediment storage in lakes.

Data	https://data.mfe.govt.nz/layer/103686-updated-suspended-sediment-yield-estimator-and-estuarine-trap-efficiency-model-results-2019/
Extent	National
Contact	NIWA
References	Hicks M, Semadeni-Davies A, Haddadchi A, Shankar U, Plew D. 2019b. Updated sediment load estimator for New Zealand. NIWA Client Report No. 2018341CH. Prepared for Ministry for the Environment.

Surface erosion - RUSLE

The Revised Universal Soil Loss Equation (RUSLE) has been widely used internationally to represent surface (sheet/rill) erosion rates (t ha-1 yr-1). RUSLE has been applied in New Zealand using a 15 m DEM and incorporates the impacts of grazing on ground cover and soil erodibility (Donovan 2022). RUSLE does not represent the contribution from other erosion processes such as landslides, nor does it account for deposition of eroded sediment before it reaches a stream.

Data	Not available online
Extent	National
Contact	AgResearch
References	Donovan M. 2022. Modelling soil loss from surface erosion at high-resolution to better understand sources and drivers across land uses and catchments; a national-scale assessment of Aotearoa, New Zealand. Environmental Modelling & Software 147, 105228.

Streambank erosion susceptibility

Susceptibility to streambank erosion has been modelled nationally based on the RECv2 digital stream network (Smith & Betts, 2021). Susceptibility is expressed as a dimensionless index value (range 0-100) per stream segment. The index does not estimate the contribution of bank erosion to sediment loads but instead provides a relative measure of the spatial variation in reach-average susceptibility to streambank erosion.

Data	https://data.mfe.govt.nz/layer/105771-streambank-erosion-susceptibility-index/
Extent	National
Contact	Manaaki Whenua – Landcare Research (Hugh Smith)
References	Smith HG, Betts H. 2021. Memorandum on implementing a national index for susceptibility to streambank erosion. Manaaki Whenua - Landcare Research Contract Report LC3998 prepared for the Ministry for the Environment.

Shallow landslide susceptibility

Landslide susceptibility models use statistical or machine learning techniques to predict the spatial probability (range 0-1) of landslide occurrence based on geo-environmental factors (Smith et al 2021). These models predict where and not when landslides are likely to occur. Susceptibility to rainfall-triggered shallow landslides has been modelled (15 m resolution) in the Hawke's Bay and Horizons regions. This modelling draws on a database comprising tens of thousands of shallow landslides. The resulting high-resolution maps of shallow landslide susceptibility may be used to prioritise farms and sub-catchments for erosion control and to better target tree planting to reduce landslide erosion and downstream sedimentation.

Data	Not available online
Extent	Regional
Contact	Manaaki Whenua – Landcare Research (Hugh Smith)
References	Smith HG, Spiekermann R, Betts H, Neverman AJ. 2021. Comparing methods of landslide data acquisition and susceptibility modelling: Examples from New Zealand. Geomorphology 381: 107660. Smith HG. 2020. A region-wide assessment of shallow landslide susceptibility in Hawke's Bay. Landcare Research Contract Report LC3720 for Hawke's Bay Regional Council.

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Basher LR. 2013. Erosion processes and their control in New Zealand. In Dymond JR ed. Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand; p. 363-374.

Hicks DM, Haddadchi A, Whitehead A, Shankar U. 2019a. Sediment load reductions to meet suspended and deposited sediment thresholds. NIWA Client Report 2019100CH. Prepared for the Ministry for the Environment.

Smith HG, Spiekermann R, Betts H, Neverman AJ. 2021. Comparing methods of landslide data acquisition and susceptibility modelling: Examples from New Zealand. Geomorphology 381: 107660.