Gully and cliff erosion feature detection in the Wairoa catchment in Hawke's Bay, New Zealand

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Introduction

- Gullies and cliff erosion are significant indicators of land degradation.
- Knowledge of their spatial distribution and dimensions is needed to effectively tackle erosion mitigation.
- Even if experts can delineate features at a local scale, mapping larger extents becomes time consuming.
- Object detection techniques based on aerial photographs and LiDAR digital elevation models (DEM) can improve their automated delineation.
- We aimed at using a data-driven deep learning (DL) approach to identify gully and cliff features in Hawke's Bay, New Zealand.

*Figure 1: Erosion features in New Zealand. **Top left:** Cliffs (and overgrown gully) along the Manawatū River near Palmerston North. **Top right:** Gully near Castlepoint. © D. Hölbling, 2020. **Bottom left:** Gullies (and shallow landslides) near Castlepoint. **Bottom right:** Gullies (and landslides) at Mount Ruapehu. © D. Hölbling, 2017.*

Methods

- Reference data consisted of expert-based delineations of gully and cliff features based on aerial photographs (2017-2020) and digitized on 5x5 km grid cells covering the study area.
- Several terrain derivatives from the LiDAR DEM, for instance, slope, curvature, slope length and steepness (LS) factor, mass balance, topographic wetness and terrain ruggedness indices, were computed.
- The derivatives and spectral bands (R-G-B-NIR) from aerial photographs were variously combined to train region-based convolutional neural network (Mask-RCNN) DL models.
- Other parameters tested during model training included the train/validation split, backbone and use of PointRend enhancement.

Data-driven approaches like deep learning can aid the mapping of potential gully and cliff erosion features

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Results

- Statistical analyses of the terrain derivatives revealed differences between gully and cliff features and random terrain units (Fig. 2).

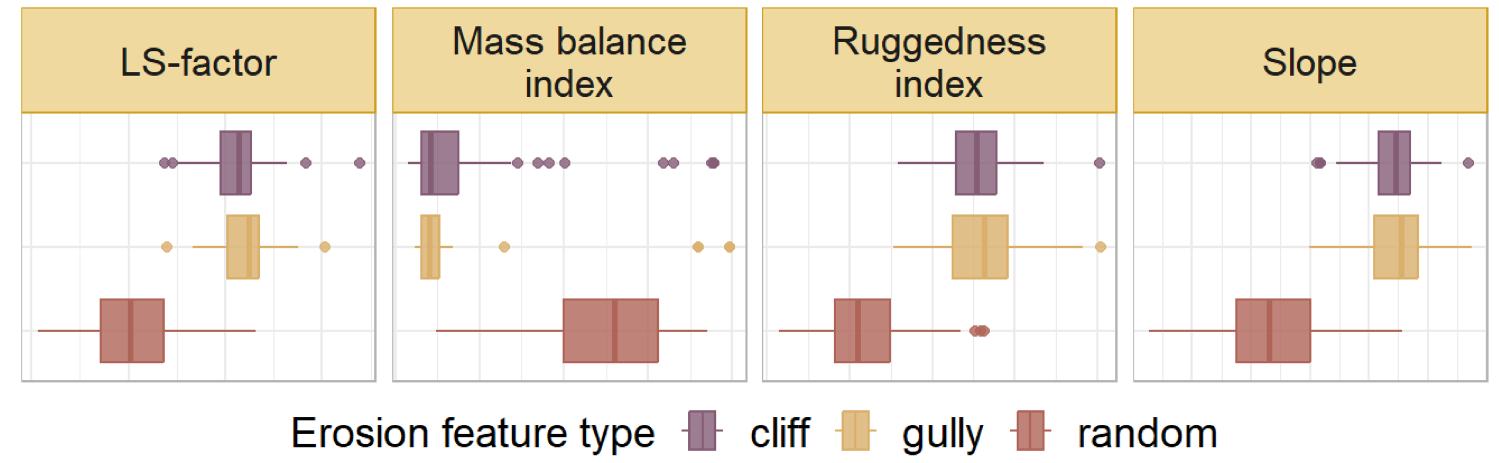

Figure 2: DEM derivatives for gully, cliff and random features in training areas.

- We tested several parameter iterations for model training, using different grids as training and validation regions. The results of the band combination R, G, NIR, slope, LS-factor are shown in the main figure.
- The correctly detected erosion features correspond well to the reference data delineations, fairly discriminating between gullies and cliffs (Fig. 3).
- A closer inspection of the false positive features suggests that the reference data could be incomplete.

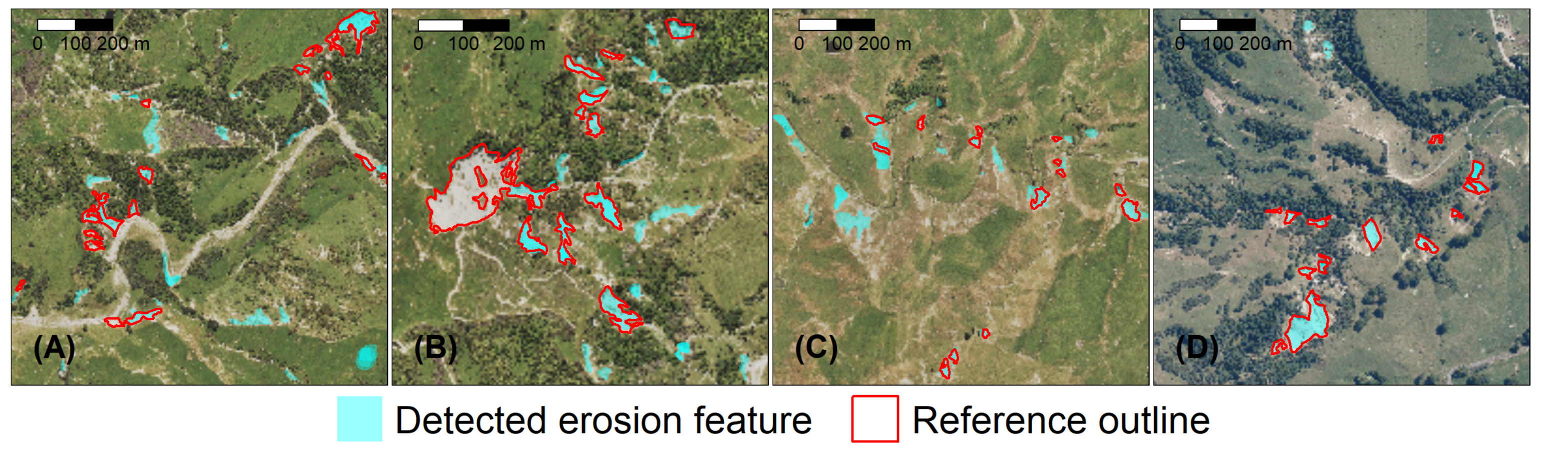

*Figure 3: Feature detection examples in zoom regions. **(A)** and **(B)** are subsets of training grid 119, while **(C)** and **(D)** are subsets of validation grids 64 and 113 resp. See Fig.2 for location within grid. Gully and cliff features are shown without distinction.*

- Transferring the models to validation areas resulted in relatively low detection rates, with a large number of false negatives (Table 1).

Table 1: Accuracy measures for erosion features in validation grids.

Detected features with:	Confidence > 50%		Confidence > 80%	
Accuracy measure	**Gully**	**Cliff**	**Gully**	**Cliff**
Precision (%)	50.0	38.6	70.0	52.5
Recall (%)	19.6	80.1	15.6	75.4
F1-score (%)	28.1	52.1	25.5	61.9

Conclusions

DL has a high potential for automated gully and cliff mapping, but improvement of the model transferability is needed. Using spectral information and terrain derivatives can improve detection, where band selection is guided by statistical and expert knowledge to avoid overfitting. A combination of automated and expert-based delineation would potentially result in reliable and efficient erosion feature mapping.

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