Geospatial landslide modelling for targeted erosion control

The following questions were asked during our live webinar with Raphael Spiekermann but due to time restrictions, we were unable to answer these in the session.

How to validate the desktop study and how to evaluate the success of the classification?

In terms of the classification of tree canopies, the general approach to evaluating the classification accuracy was as follows:

- Tree mapping was carried out in the field at two farms to identify the tree species to be used as samples in the tree species classification.
- Inputs derived from LiDAR data and optical imagery were then used to characterise the individual tree crowns delineated with a 1-m canopy height model.
- The model was then trained using a support vector machine classifier using 10-fold cross-validation. This method randomly partitions the data into ten equal sized subsamples of tree crowns, and each subsample is used to test the remaining nine subsamples assigned to training. This provides a robust estimate of the average overall classification accuracy.

A similar procedure was used to test the performance of the landslide susceptibility and connectivity models that are based on logistic regression. Again, k-fold cross-validation was the approach used for quantifying model fit and predictive ability.

Since logistic regression predicts probabilities of class association (e.g., stable (1) vs unstable (0) for landslide susceptibility), the area under the receiver operator curves (AUROC) is commonly used to estimate model performance as it is a threshold-independent performance measure. An AUROC score of 1 would mean the model can perfectly discriminate between connected and unconnected landslides in its predictions; a value of 0.5 corresponds to no discriminatory power and is equal to that achieved by pure chance. A good AUROC score is considered to lie between 0.8 and 0.9; an excellent score > 0.9. The landslide susceptibility model at 1-m resolution including individual trees, had a median AUROC of 0.95 in the final model used for predictions, which equates to an accuracy of 88.7% using a probability cut-off of 0.5.

Please refer to Spiekermann et al. (2021) and Spiekermann et al. (2022a) for further detail.

How is the effect of individual trees on stability quantified, is it based on root depth etc?

The combined hydrological and mechanical influence of trees on slopes was inferred through the spatial relationship between individual tree locations and landslide erosion (43,000 landslide scars across an 840 km2 study area). The method determines whether landslide scars occur preferentially close to or remote from trees. The idea is that by using spatial relationships observed at landscape scale, the influence of trees on landslide erosion may be inferred. These spatial distribution models for individual trees of different vegetation types represent the average contribution to slope stability as a function of distance from tree at 1-m spatial resolution (normalized to 0-1).

For further detail, please refer to Spiekermann et al. (2021).

Re the susceptibility hotspots at farm scale- steep spots - thoughts re practical options for stabilising?

Yes. Several studies in NZJAR. Many of these older ones are now freely available at: Slope gradient is an important determinant for shallow landslides, which is why we often find landslides being triggered on steep slopes. Other important factors include rock type and land cover. Slope aspect was also identified as an important determinant.

In terms of practical options for stabilising steep slopes, it is generally thought that pole-planting on steep slopes will be less viable compared to lower slopes or valley bottoms. Steep slopes, shallow soils with reduced soil moisture availability, greater exposure to wind gusts, are all factors that are unfavourable for tree establishment and survival. Due to the lack of data on survival, we are currently undertaking a planting trial on three farms (Taumaranui, Hawke's Bay, Wairarapa) to provide a scientific basis for supporting planting decisions in erosion-susceptible hill country terrain in New Zealand. The trial includes three varieties of poplar material (3-m poles, rooted and unrooted wands, as well as kānuka seedlings). The kānuka component of the trial is led by Thomas Mackay-Smith, who undertook PhD research on kānuka silvopastoral systems. Managing naturally reverting native vegetation can also be a good option for stabilizing steep slopes.

Further information can be found here:

https://www.massey.ac.nz/~flrc/workshops/22/Manuscripts/Davison_Poster.pdf
https://www.massey.ac.nz/~flrc/workshops/22/Manuscripts/Mackay-Smith_Session10.pdf

5% of area accounts for two-thirds of land sliding? or sediment to water?

This refers to the modelled landslide-derived sediment delivered to streams. More specifically, our modelling results from across 50 farms (with a median farm size of 600 ha) suggest that, in total, only 6.5% of the pastoral land (2400 ha of 36,600 ha) is both highly susceptible to shallow land sliding and has high potential for sediment delivery to the stream network under a tree-less baseline scenario. However, due to the existing tree cover (as at 2013), this class now represents just 5% of the total land area. The change from a pasture only scenario to tree cover as of 2013 led to an estimated reduction in sediment delivery of 24% across the 50 farms.

For further information, please refer to Spiekermann et al. 2022b.

As well as a STEC newsletter item:
https://www.landcareresearch.co.nz/discover-our-research/land/erosion-and-sediment/smarter-targeting-of-erosion-control/stec-news/lidar-data-enables-modelling-of-slope-stability-at-the-scale-of-individual-trees/

Is rainfall data a weak link in wider rollout?

Rainfall data is not required to predict landslide susceptibility over wider areas. Landslide susceptibility maps show the spatial variation in the likelihood of slope instability based on landscape factors. Such maps do not tell us when landslides may occur (which is dependent on rainfall data to assess potential triggering thresholds). Instead, these maps provide a spatial representation of the areas that are more likely to experience instability should a rainfall event of sufficient magnitude to trigger a landslide response occur.

Rainfall data can be used to better understand the occurrence of shallow landslides in response to high-magnitude storm events. We are currently using rain radar data for this purpose, which can help fill the gaps between sparsely located rain gauges in hill country areas. While we do not know when a particular landslide is triggered during a storm event, we can instead examine how the pattern of landslides varies spatially in relation to rainfall. A STEC newsletter item describes how rainfall data can be used in the models to build a more comprehensive quantitative understanding of both the storm and landscape conditions that trigger shallow landslides and predict potential landslide responses to storm rainfall scenarios: https://www.landcareresearch.co.nz/discover-our-research/land/erosion-and-sediment/smarter-targeting-of-erosion-control/stec-news/rain-radar-improves-understanding-of-shallow-landslide-occurrence/

Apart from satellite data, to which extend to you use ground-based sensors intermixed, dynamically and centrally processed?

We do not use ground-based sensors for shallow-landslide modelling. However, we do have work underway using ground-based sensors to monitor earthflows in the Tiraumea sub-catchment of the Manawatū. We have established continuously operating sensors to record meteorological and stream flow data. Continuous GNSS (Global Navigation Satellite System) receivers have been installed on the earthflows to obtain sub-daily movement rates to better understand when the earthflows are active and contributing sediment to the stream network, which can help link earthflow movement to meteorological conditions. More recently, we installed piezometers to monitor temporal variation in the water table to increase understanding of the drivers of earthflow movement.

More information can be found here: https://www.landcareresearch.co.nz/discover-our-research/land/erosion-and-sediment/smarter-targeting-of-erosion-control/stec-news/introducing-the-haunui-erosion-and-sediment-research-catchment/