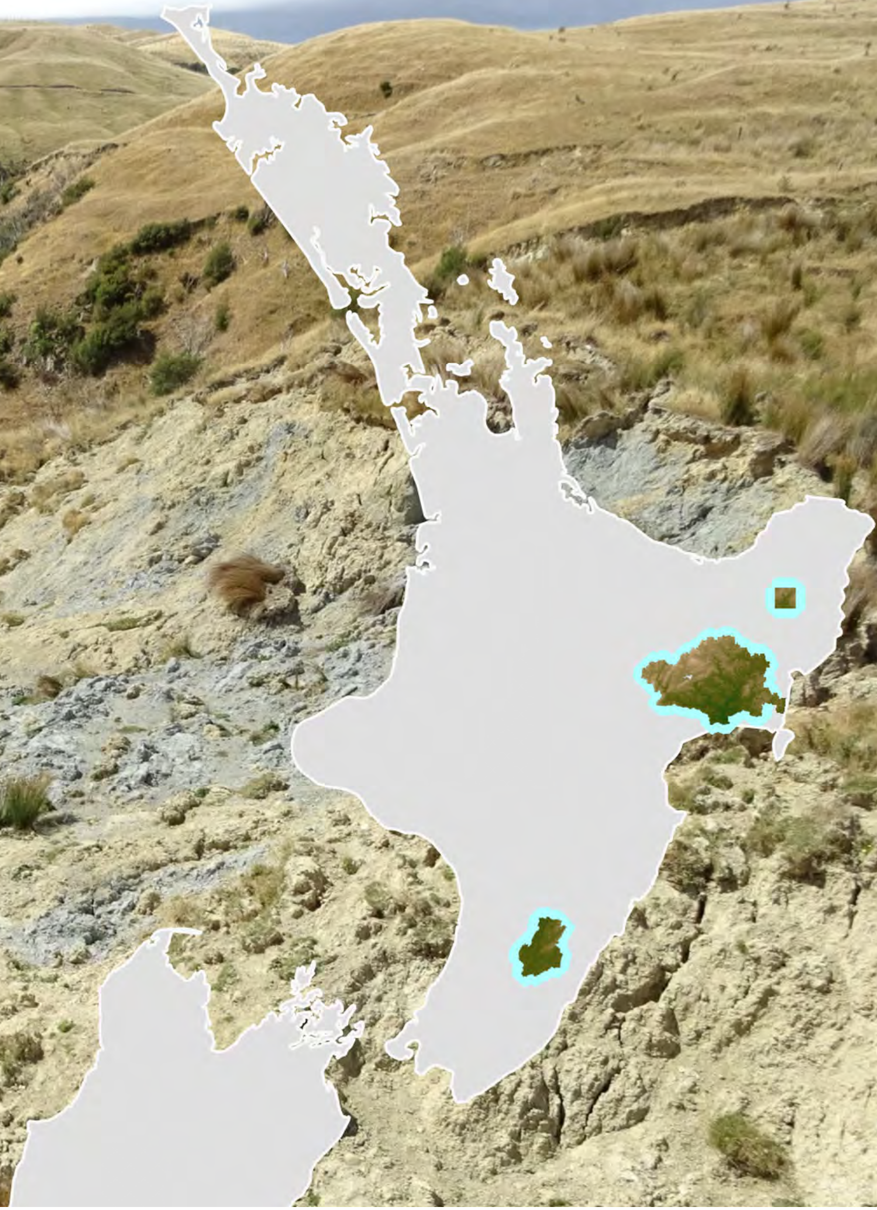
# KNOWLEDGE-BASED AND DATA-DRIVEN EROSION FEATURE MAPPING



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*STEC Meeting, 13/09/2023, Palmerston North*

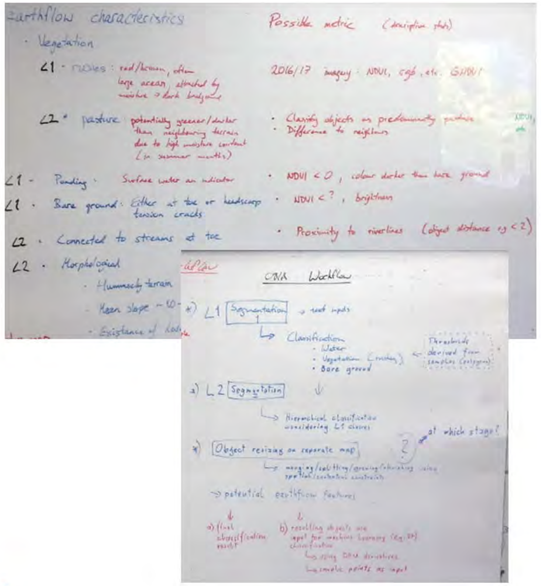
# Knowledge-based earthflow mapping in the Tiraumea catchment

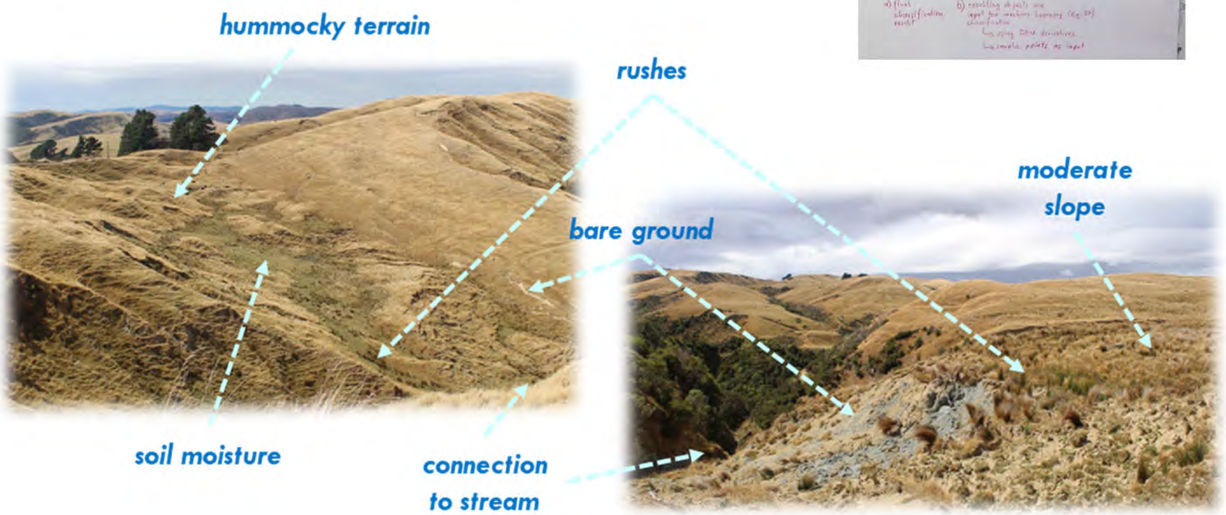
- Semi-automated detection of potential earthflows
- Object-based image analysis (OBIA) approach
- Based on LiDAR digital elevation model (DEM) and aerial photographs


- *Hölbling et al., in preparation. Detection and delination of earthflows in Tiraumea, New Zealand, using object-based image analysis.*
- *Hölbling, D., Abad, L., Spiekermann, R., Smith, H., Neverman, A., 2023. Semi-automated detection and delineation of earthflows in New Zealand using remote sensing - challenges and opportunities. EGU General Assembly 2023, Vienna, Austria, 24–28 April, EGU23-1670. https://doi.org/10.5194/egusphere-egu23-1670*
- *Hölbling, D., Abad, L., Spiekermann, R., Smith, H., Neverman, A., Betts, H., 2022. Exploring knowledge-based and data-driven approaches to map earthflow and gully erosion features in New Zealand. EGU General Assembly 2022, Vienna, Austria, 23-27 May, EGU22-1013. https://doi.org/10.5194/egusphere-egu22-1013*

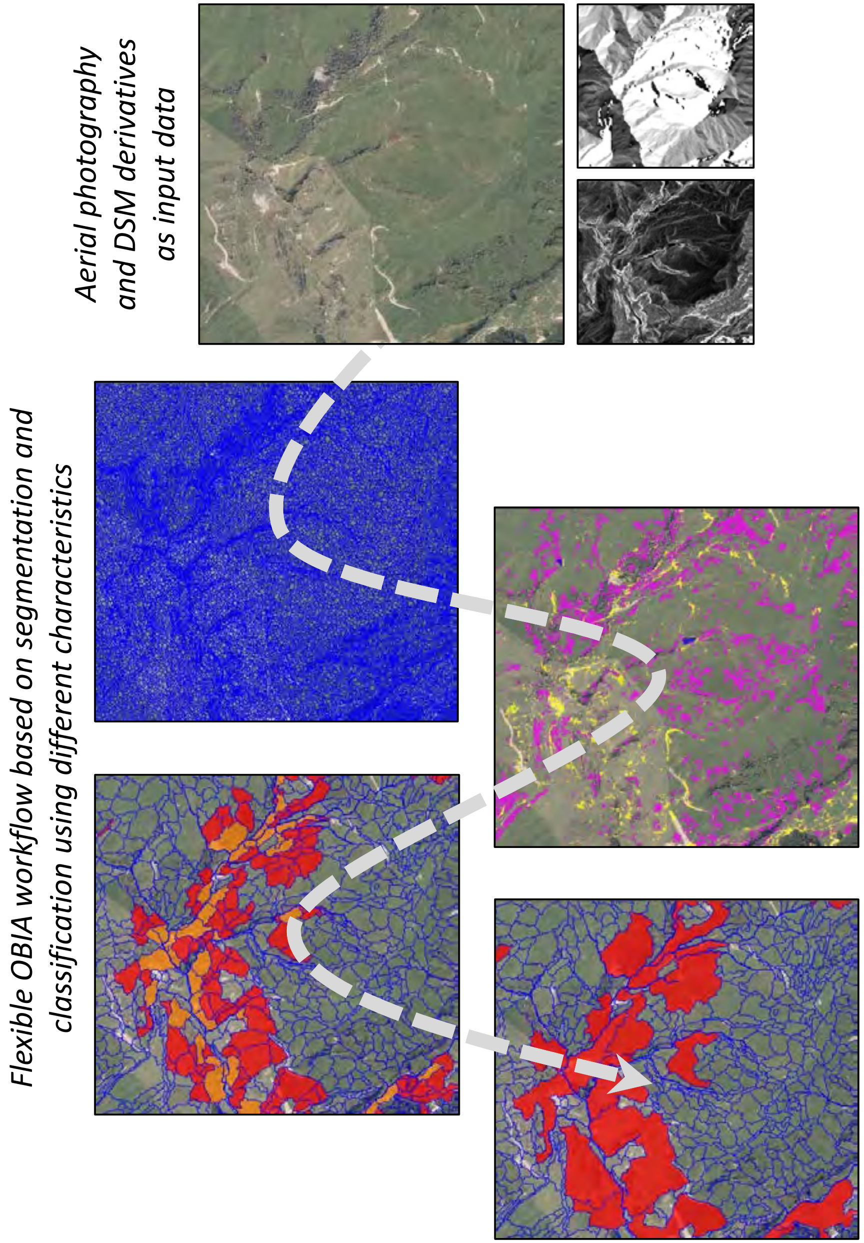
# Detection of potential earthflows

- Identifying earthflow characteristics that can be derived from aerial photography and DEM data
- Knowledge-based classification workflow



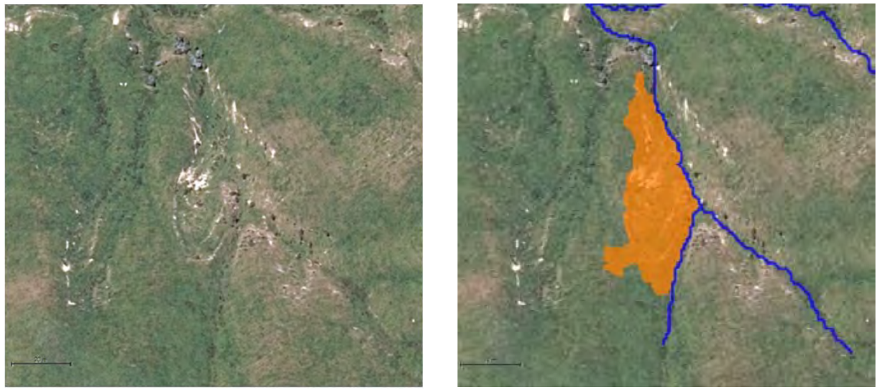




Photographs © L. Abad

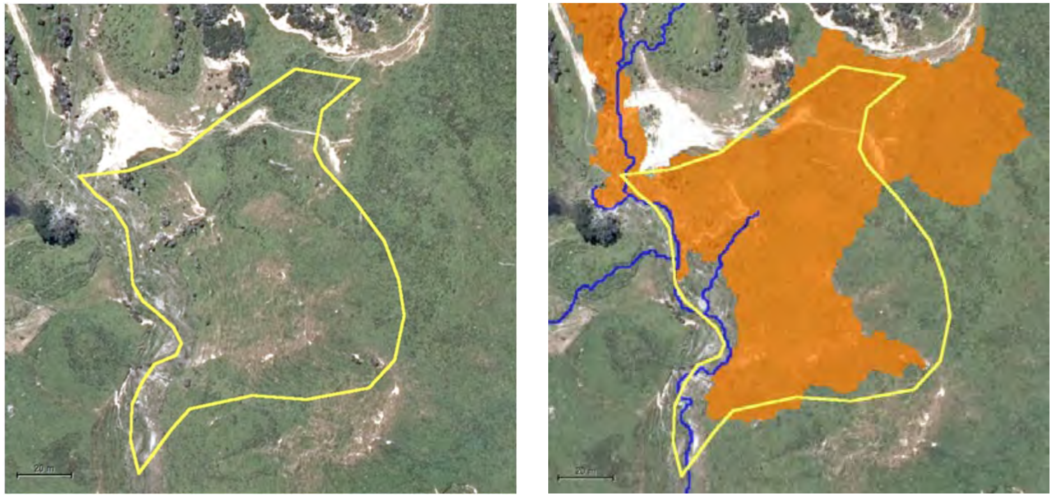


# Results & Validation

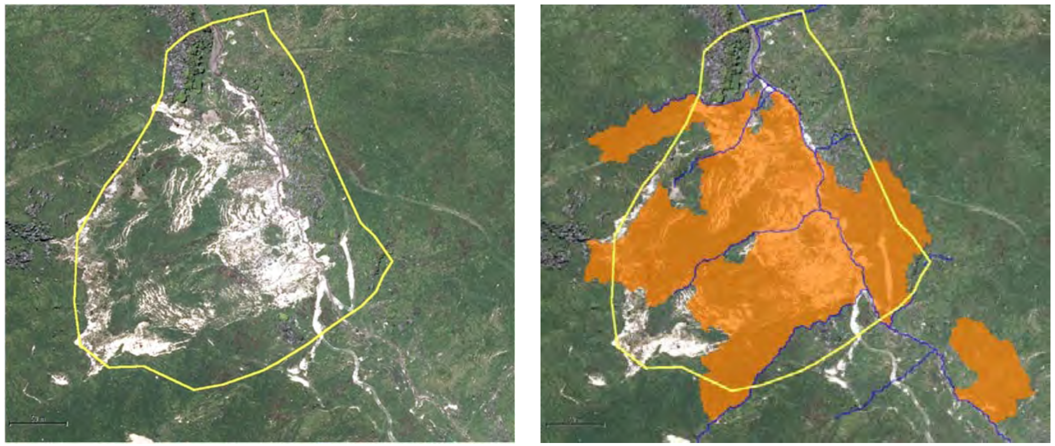
- Comparison of potential earthflows to manual mapping
  - Approx. 87% of the reference earthflow polygons were detected
  - Delineations can differ significantly
- Many additional potential earthflows were detected → further verification is needed



*Newly discovered earthflow (orange).*



*Earthflow mapping examples. OBIA mapping (orange) in comparison to reference data (yellow outline). Channel network is shown as blue lines.*

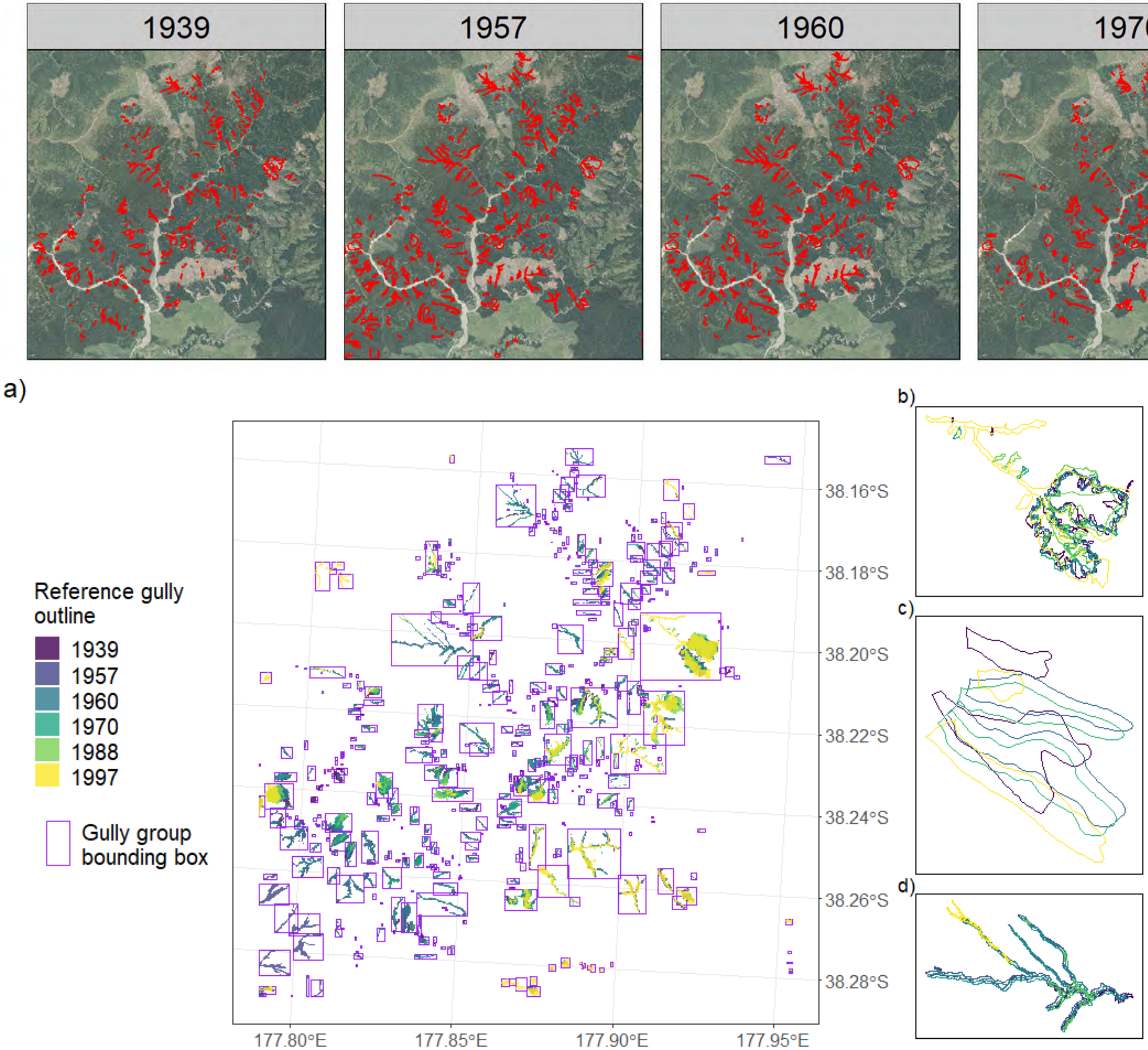


# Gully characterisation and detection with historical reference data in the Mangatu forest

- Deep learning approach
  - Based on LiDAR DEM from 2019
- Gully data from 1939 to 1997 for six different years



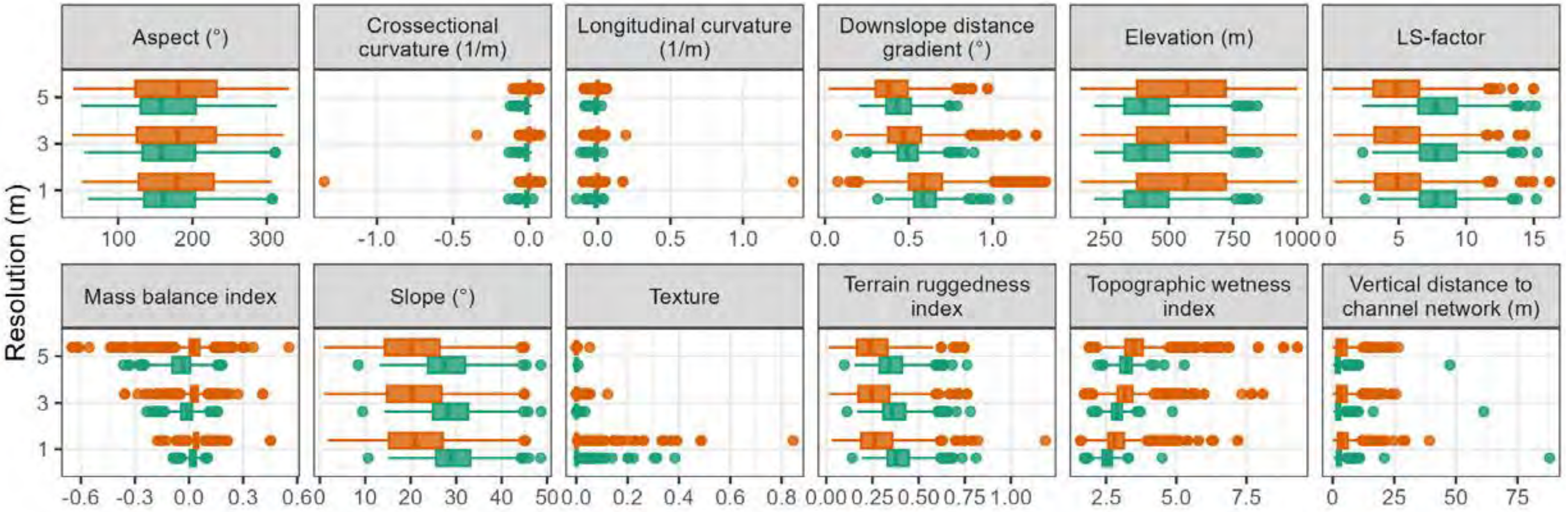

- *Abad et al., in preparation. Gully characterisation and mapping based on LiDAR data using deep learning and historical training data.*
- *Hölbling, D., Abad, L., Spiekermann, R., Smith, H., Neverman, A., Betts, H., 2022. Exploring knowledge-based and data-driven approaches to map earthflow and gully erosion features in New Zealand. EGU General Assembly 2022, Vienna, Austria, 23-27 May, EGU22-1013.* *https://doi.org/10.5194/egusphere-egu22-1013*

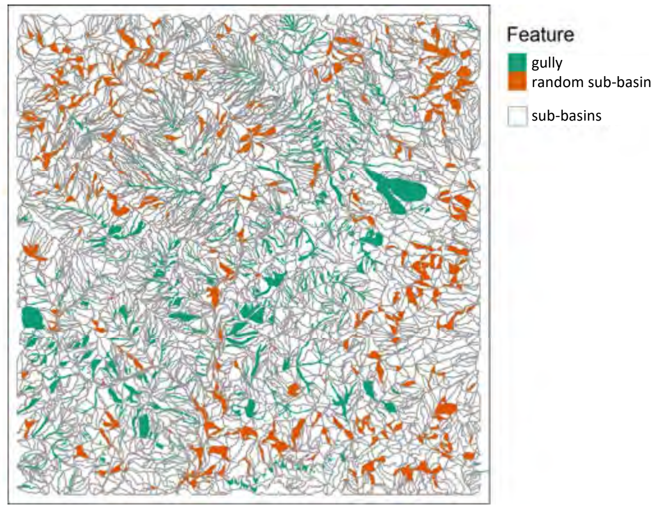


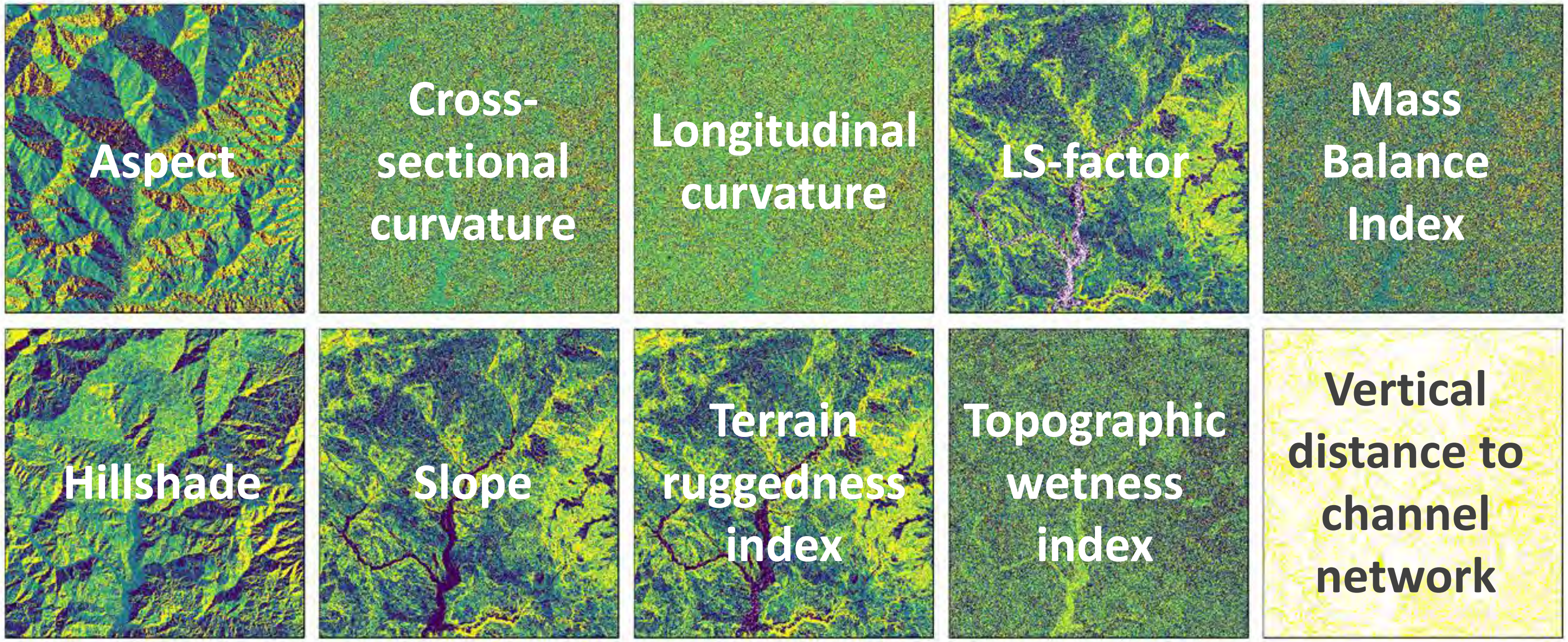

- Historical data from Marden et al. (2012 & 2014)
- Co-registration errors were partially fixed
- Most errors come from the manual delineation using oblique aerial imagery
- Grouping based on topological relation of the historical data can help understand the evolution of gullies

***a)** Spatio-temporal grouping of reference gully features. **b)** Example of gully complex evolution over time. **c)** and **d)** Examples of co-registration mismatch of reference data for different years.*


*Marden, M., Arnold, G., Seymour, A., & Hambling, R. (2012). History and distribution of steepland gullies in response to land use change, East Coast Region, North Island, New Zealand. Geomorphology, 153–154, 81–90.*
*Marden, M., Herzig, A., & Basher, L. (2014). Erosion process contribution to sediment yield before and after the establishment of exotic forest: Waipaoa catchment, New Zealand. Geomorphology, 226, 162–174.*

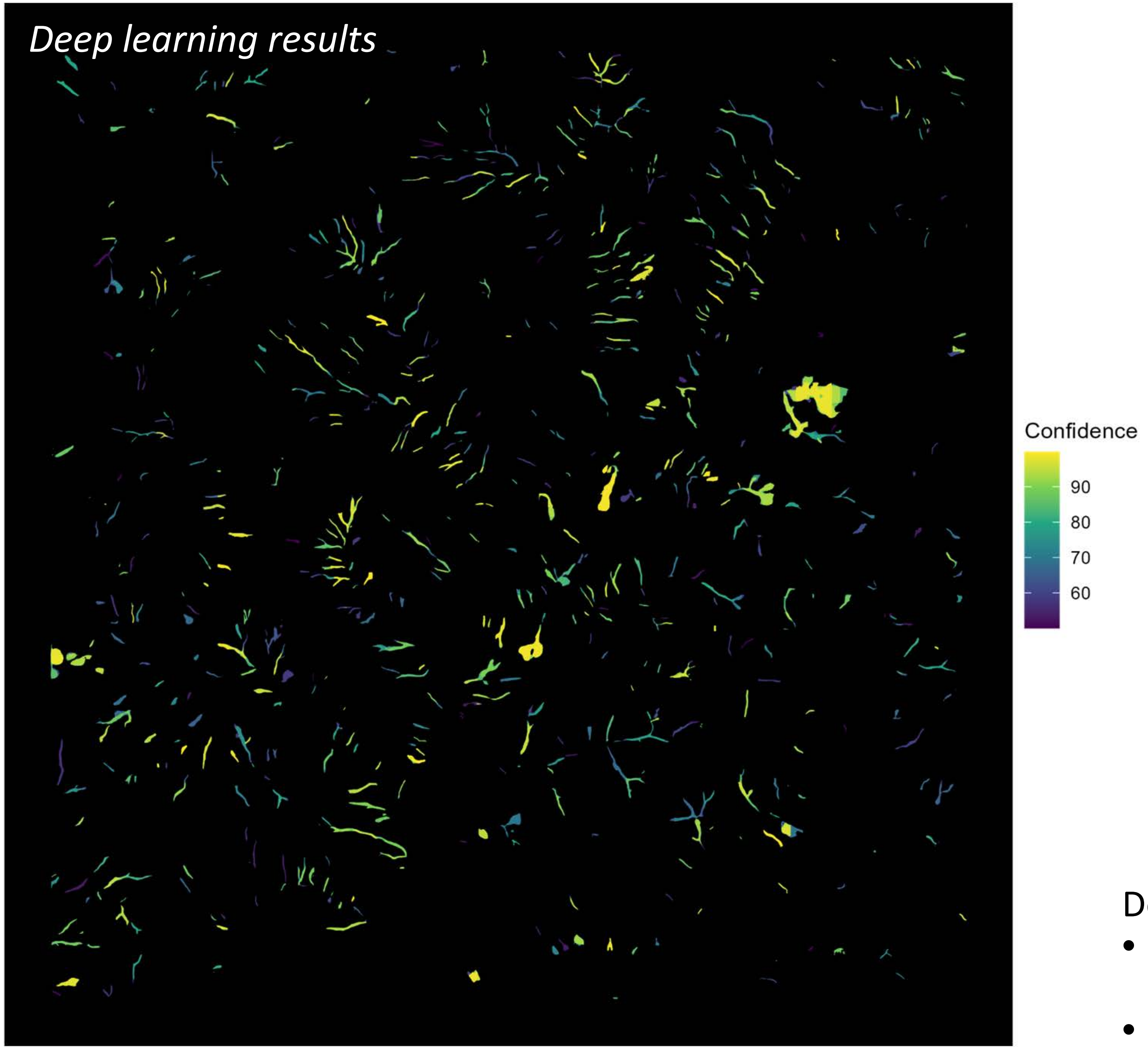


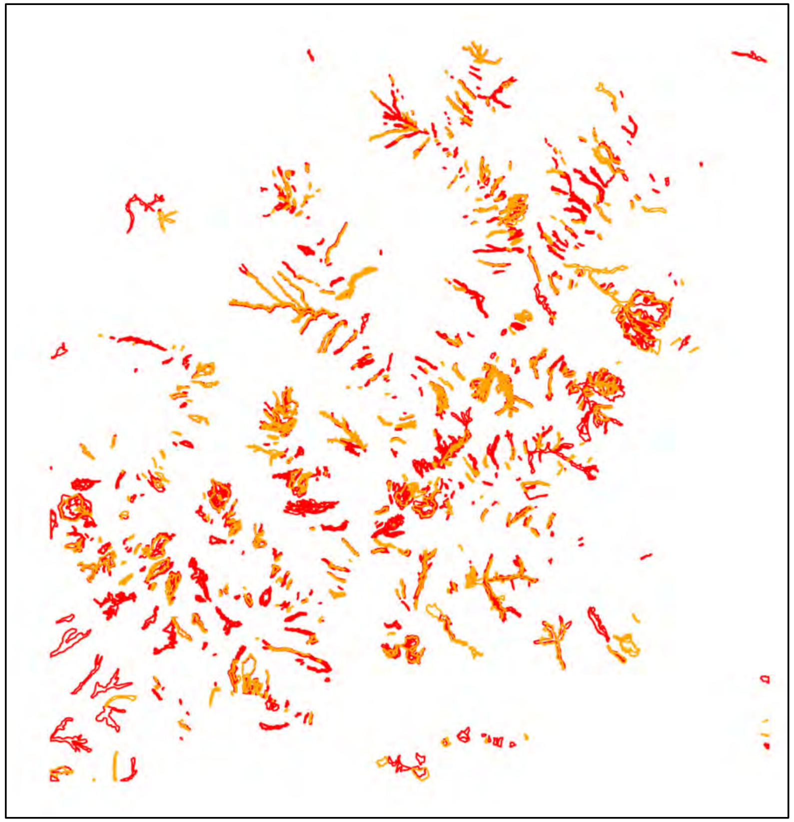




- Several terrain derivatives were computed and compared for sub-basins with and without gullies
- The most distinctive derivatives were used for training deep learning models

# Detected Gully Features




*Reference features. Training in red and testing in orange.*



Deep learning results are partially inconclusive

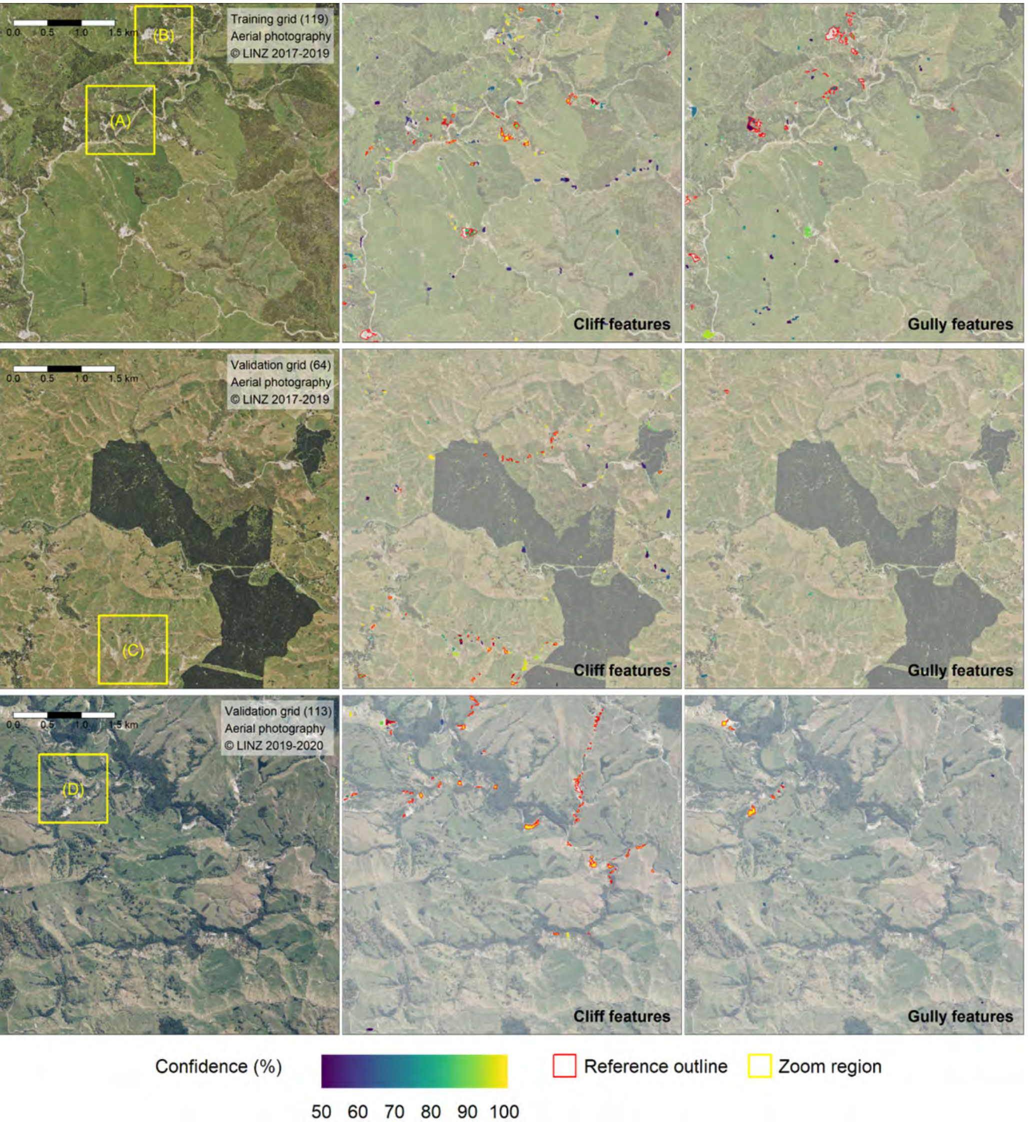
- Time difference between historical reference data and LiDAR data
- Delineations differ

# Gully and cliff detection in the Wairoa catchment

- Data-driven approach: deep learning Mask R-CNN
- Knowledge-based OBIA approach
- Based on LiDAR DEM and aerial photographs

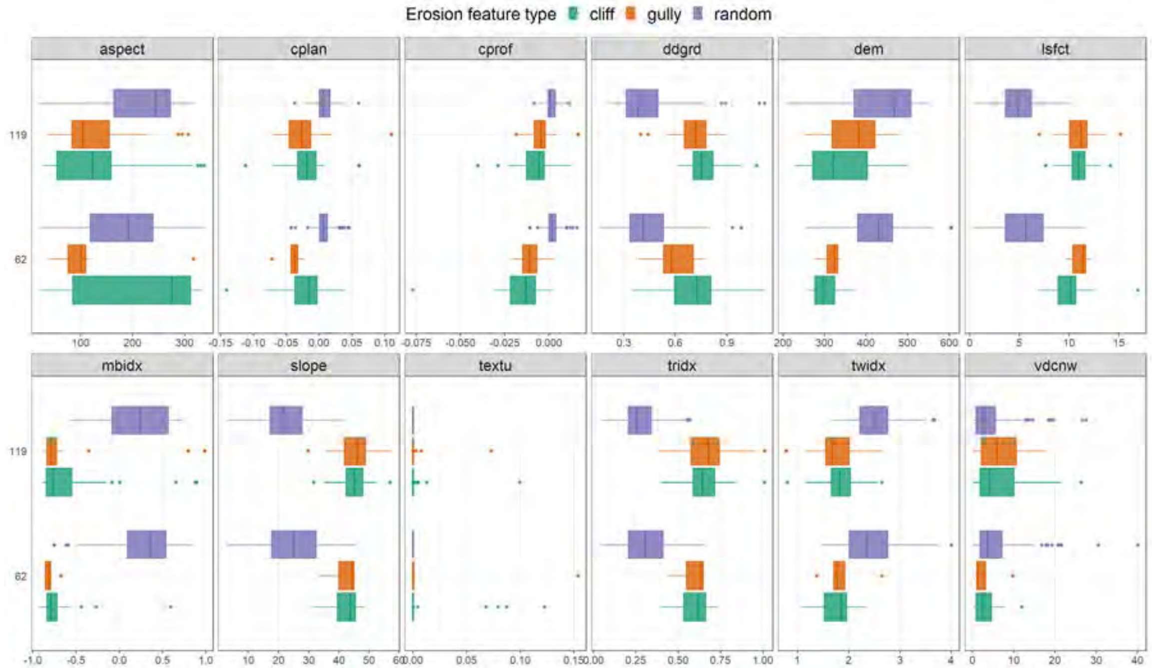

- *Abad et al., in preparation. Data-driven and knowledge-based mapping of gully and cliff erosion features in Wairoa.*
- *Abad, L., Hölbling, D., Smith, H., Neverman, A., Betts, H., Spiekermann, R., 2023. Expert-based and data-driven gully and cliff erosion feature detection in New Zealand. 28th IUGG General Assembly, Berlin, Germany, 11-20 July.* https://doi.org/10.57757/IUGG23-0228
- *Abad, L., Hölbling, D., Smith, H., Neverman, A., Betts, H., Spiekermann, R., 2023. Gully and cliff erosion feature detection in the Wairoa catchment in Hawke's Bay, New Zealand. EGU General Assembly 2023, Vienna, Austria, 24–28 April, EGU23-1468.* https://doi.org/10.5194/egusphere-egu23-1468

# Deep Learning

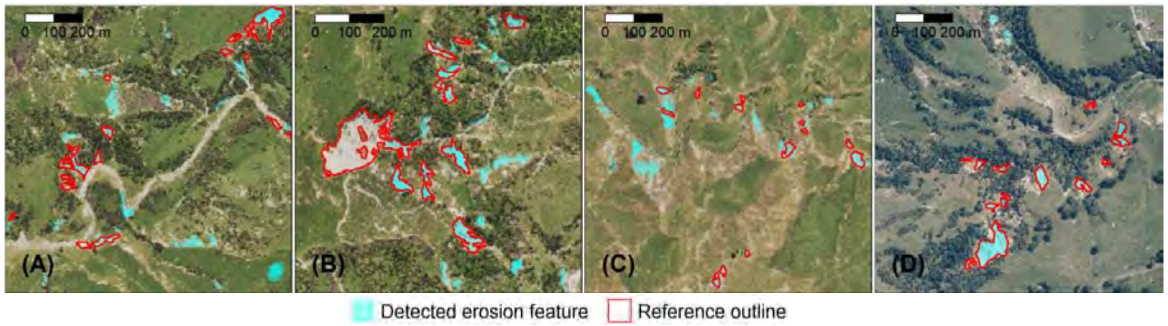



Several parameter iterations for model training were tested, using different grids as training and validation regions. Results are based on the band combination R, G, NIR, slope, LS-factor.

Terrain derivatives differentiate between random features and erosion features, but the differentiation between gullies and cliffs is difficult.

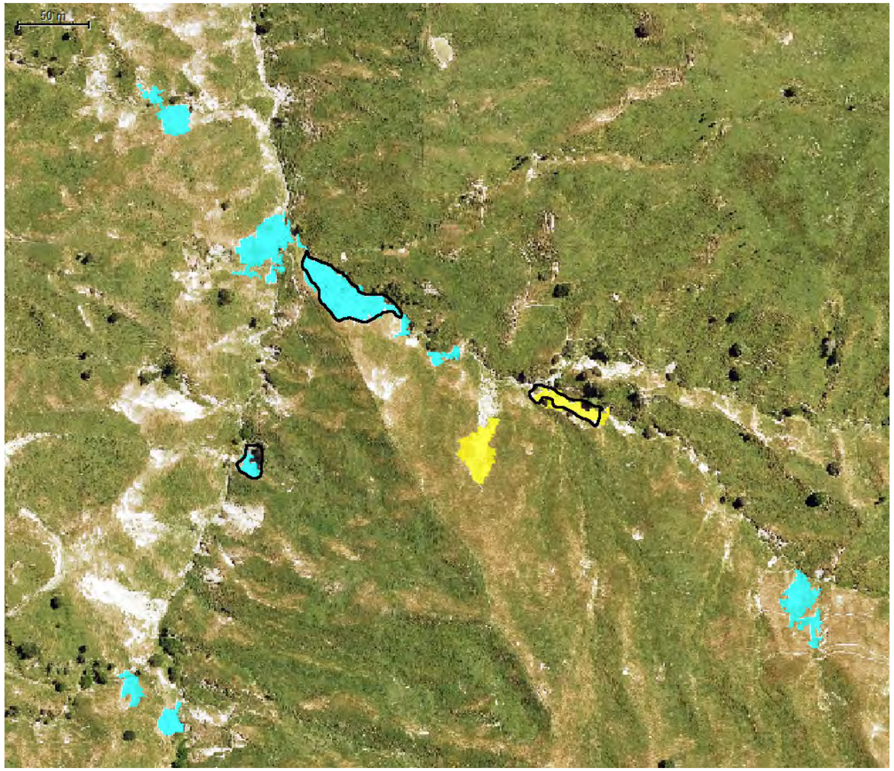


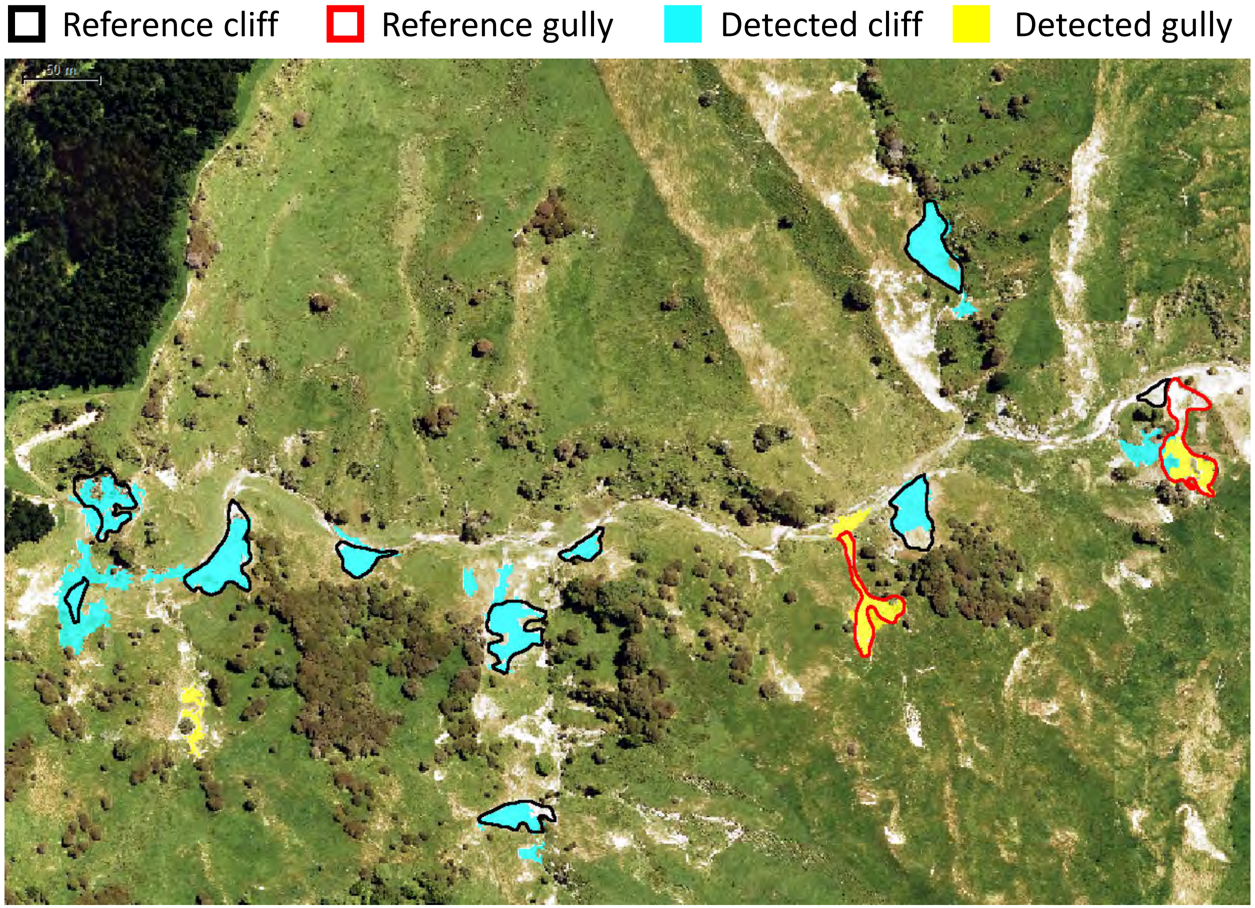

Comparison of deep learning results and reference data.



# Knowledge-based OBIA

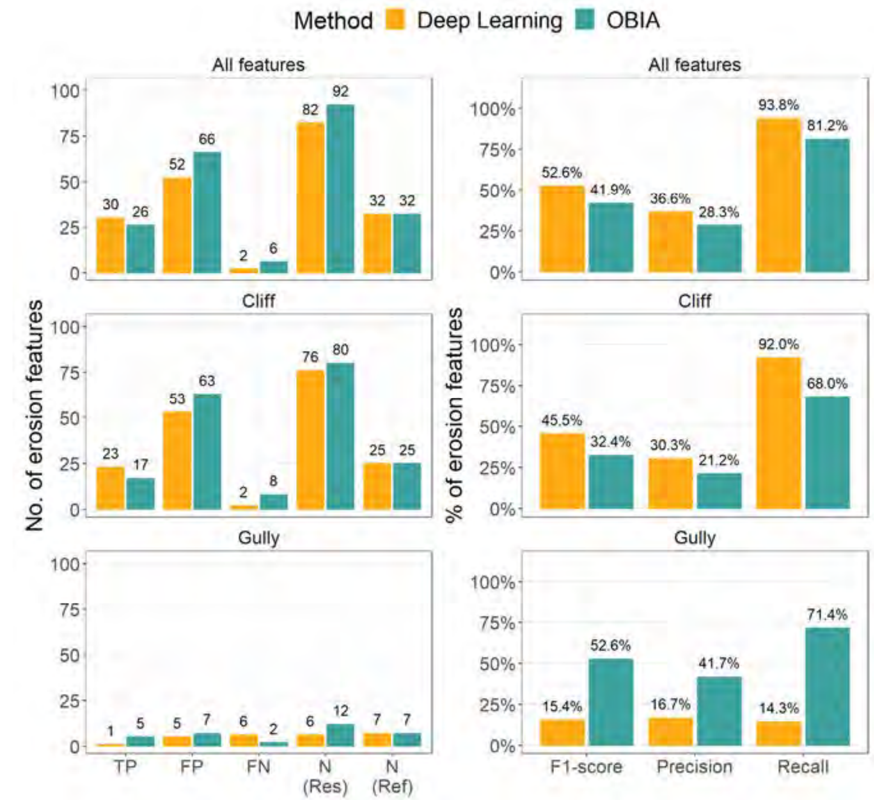
- Creation of homogenous image objects by automatically grouping neighbouring pixels
- Classification of objects by combining spectral, spatial, and morphological characteristics of features




- Integration of expert knowledge in a flexible segmentation and classification workflow
- Challenges are mainly the creation of suitable image objects and the differentiation of different erosion features

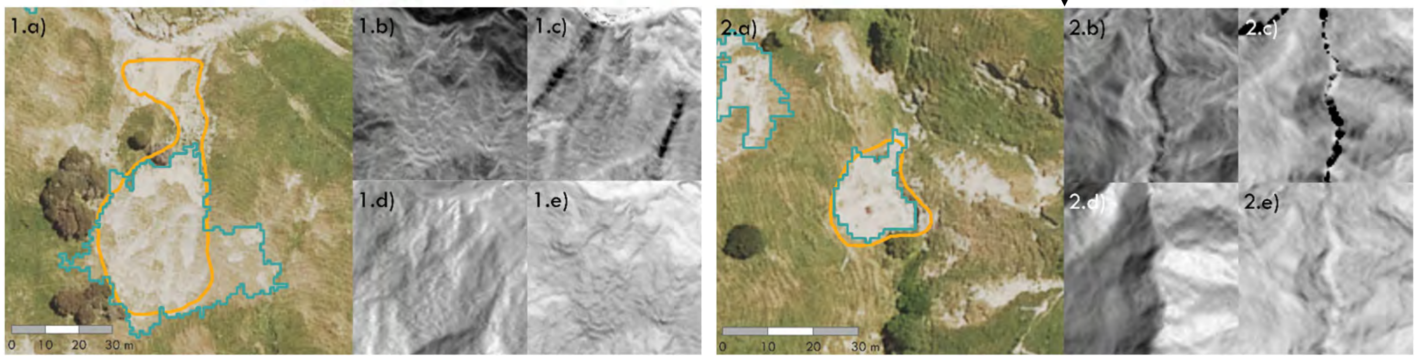
# Deep Learning vs. OBIA

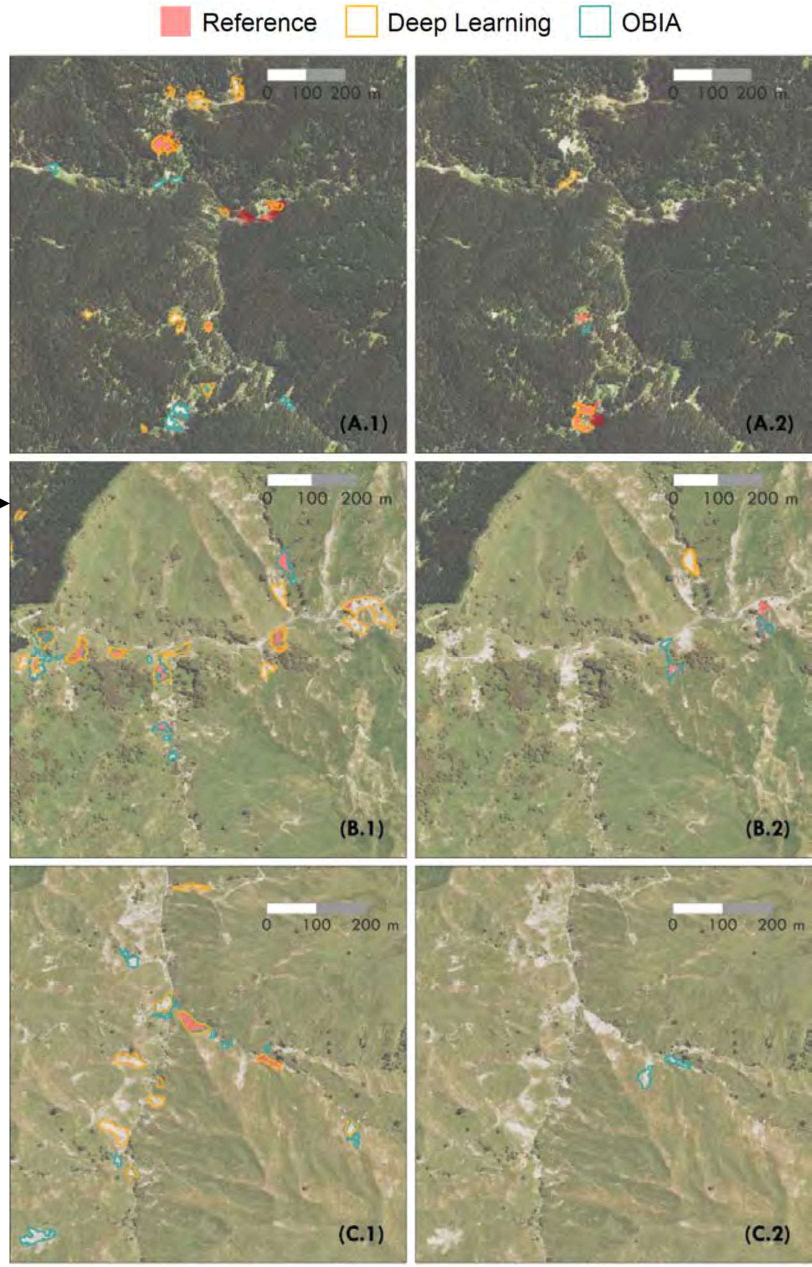



Accuracy measures according to the detection method. The upper panels compare all reference data without differentiation of classes.

Feature detection examples in zoom regions **(A, B, C)**. **(1)** shows features classified as cliffs, **(2)** shows gully features.

Close-up view of two **(1 & 2)** cliff features classified as false positives (FP) by both methods. a) Aerial imagery and detected features per method, DEM derivatives for the close-up area: b) slope, c) LS-factor, d) hillshade, e) terrain ruggedness index.

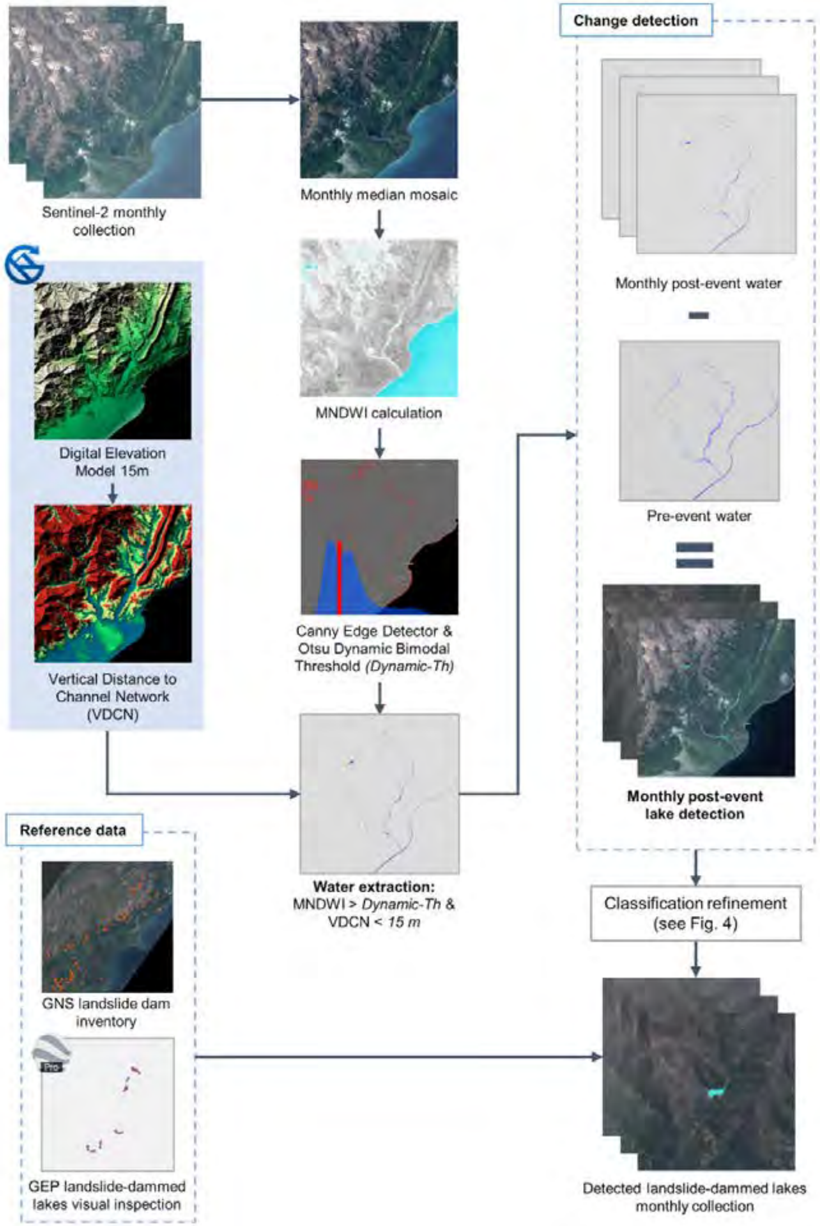


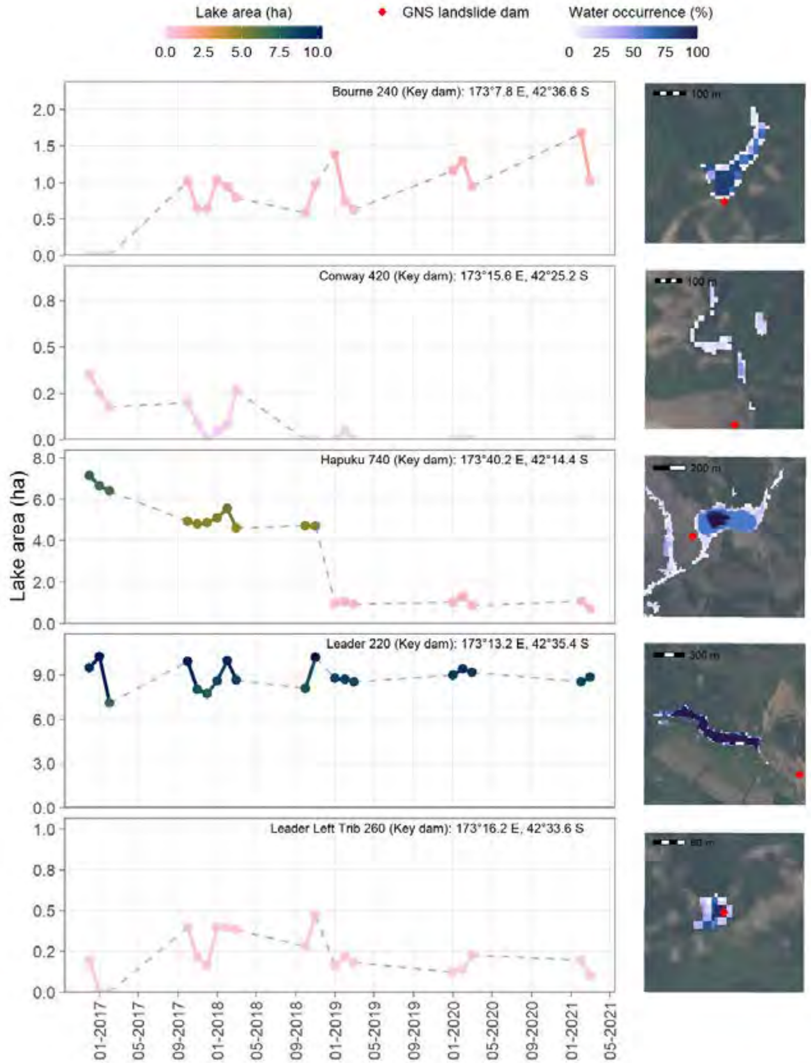
# Mapping and monitoring landslide-dammed lakes

- Time series analysis using Sentinel-2 images
- Automated analysis at regional scale
- Knowledge-based OBIA approach on local scale

*Photograph © A.-L. Argentin*




# Detecting landslide-dammed lakes and monitoring their spatio-temporal evolution following the Kaikōura earthquake

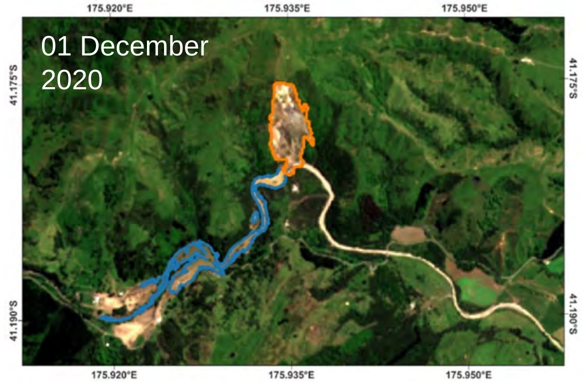



Dammed lakes are categorised into four groups based on their spatio-temporal evolution:

1) constant
2) increasing
3) decreasing
4) variant


*Abad, L., Hölbling, D., Spiekermann, R., Prasicek, G., Dabiri, Z., Argentin, A.-L., 2022. Detecting landslide-dammed lakes on Sentinel-2 imagery and monitoring their spatio-temporal evolution following the Kaikōura earthquake in New Zealand. Science of The Total Environment, 820, 153335.*
*https://doi.org/10.1016/j.scitotenv.2022.153335*

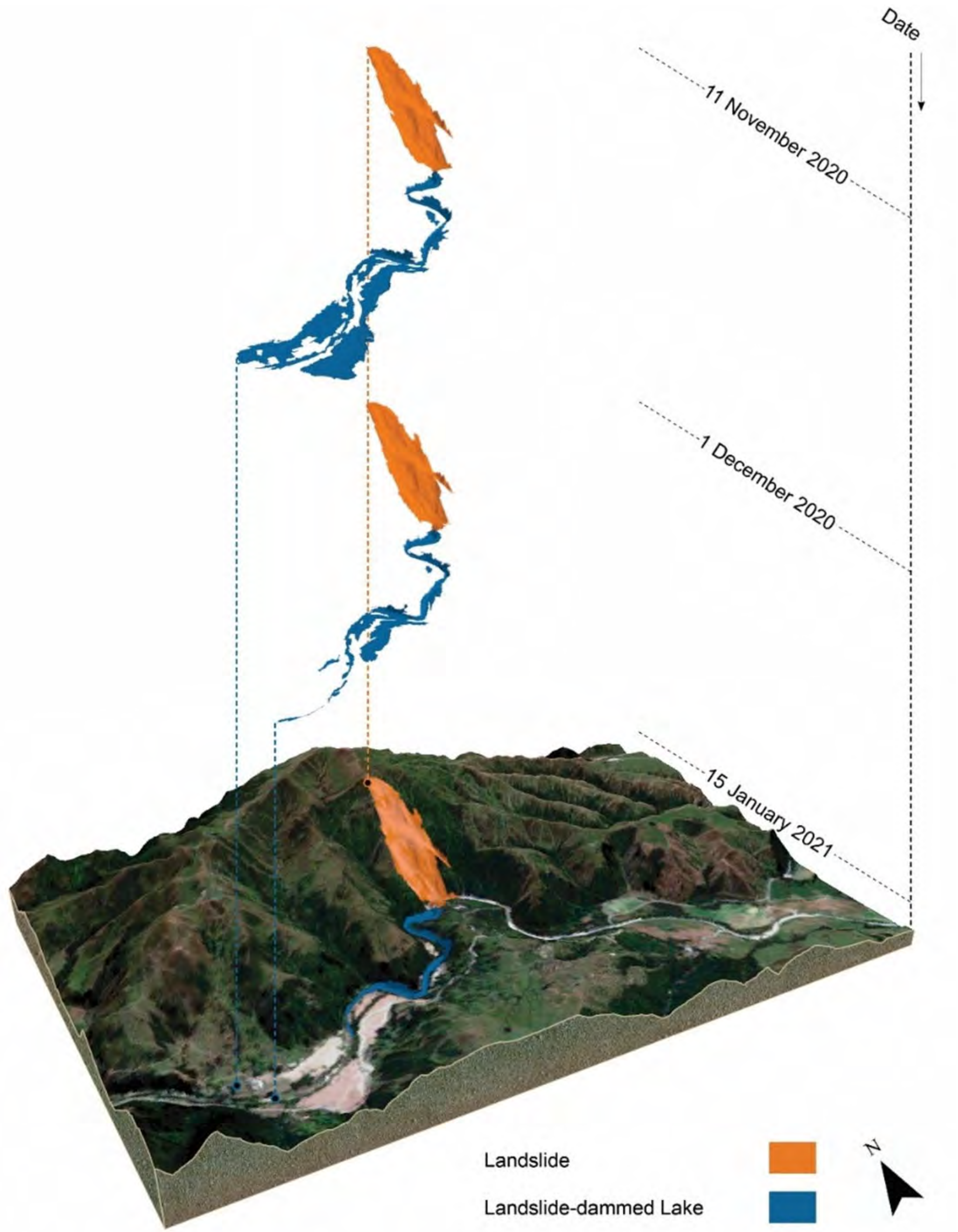
# Monitoring the evolution of the Kaiwhata landslide and landslide-dammed lake



- OBIA workflow to monitor the changes of the landslide and landslide-dammed lake between 2017 and 2021 using Sentinel-2 imagery
- Semi-automated knowledge-based OBIA approach

*Pooladsaz, K., Hölbling, D., Brus, J., accepted. Monitoring the Evolution of the Kaiwhata Landslide in New Zealand using Object-based Image Analysis and Sentinel-2 Time Series. GI_Forum.*



# Conclusions

- Reliable analysis methods are needed to better understand the spatial and temporal occurrence of erosion features
  - Improved representation of erosion processes in catchment sediment budget models
  - Implement effective erosion mitigation measures
  - Support disaster risk reduction
- Remote sensing and advanced image analysis techniques provide remarkable opportunities for erosion feature mapping and monitoring
  - Integration of expert knowledge and modern data-driven methods
- International collaboration was very fruitful
  - Developed technologies and joint research contributed to an increased science understanding
  - Mutual benefit: exchange of knowledge, methods, and ideas; joint fieldwork; joint publications





# Thank you for your attention!

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