# MAPPING THE EVOLUTION OF THE KAIWHATA LANDSLIDE AND LANDSLIDE-DAMMED LAKE IN NEW ZEALAND USING SATELLITE IMAGE TIME SERIES

**Daniel HÖLBLING [1] & Kiarash POOLADSAZ [1]**

[1] *Department of Geoinformatics - Z_GIS, University of Salzburg, 5020 Salzburg, Austria (daniel.hoelbling@plus.ac.at; kiarash.pooladsaz@stud.plus.ac.at)*

## (1) Introduction

Landslides are serious natural hazards in the mountainous and hilly areas of New Zealand, where they frequently cause landscape changes and significant damage to people and infrastructure. The risk of landslides must not be ignored, not only because of the threat of damage to the immediate environment but also because of potential knock-on incidents. Massive landslides can block water courses and create landslide-dammed lakes, resulting in a high level of risk for both downstream and upstream areas. Monitoring the evolution of landslides, associated landslide-dammed lakes, and their consequences is important for disaster risk management and can help mitigate cascading hazards.

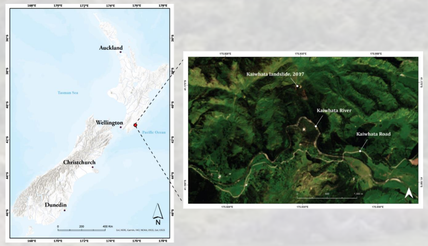
## (2) Motivation & Objective

Earth Observation (EO) data and advanced image analysis methods have enabled more efficient monitoring of landslides and related hazard analyses. Object-based image analysis (OBIA) mimics human perception by aggregating a set of pixels into meaningful objects with defined homogeneity (Blaschke, 2010). The advantages of OBIA over pixel-based approaches are distinctive when mapping complex natural hazards with twisted textures and spectral heterogeneity (Hölbling et al., 2015). The advances stem from the multi-scale integration of spectral information, spatial properties, and textural and contextual information.

This study aims to analyse the evolution of the Kaiwhata landslide and its impacts on the landscape in Wairarapa, New Zealand, using semi-automated OBIA and time series of Sentinel-2 images from 2017 to 2021.

## (3) Study Area

The study area is located in the south of New Zealand's North Island, in the Wairarapa region, east of Wellington. It is mainly characterised by the Kaiwhata River, which flows southeast to the Pacific Ocean.




The initial landslide occurred in 2017 and was comparatively small. The second landslide failure, in June 2019, was significantly larger. The debris formed a dam, created an extensive upstream lake, and closed the Kaiwhata road. The dam failure releasing approximately 1.1 million m³ of water in less than two hours to the area downstream (Morgenstern et al., 2021).



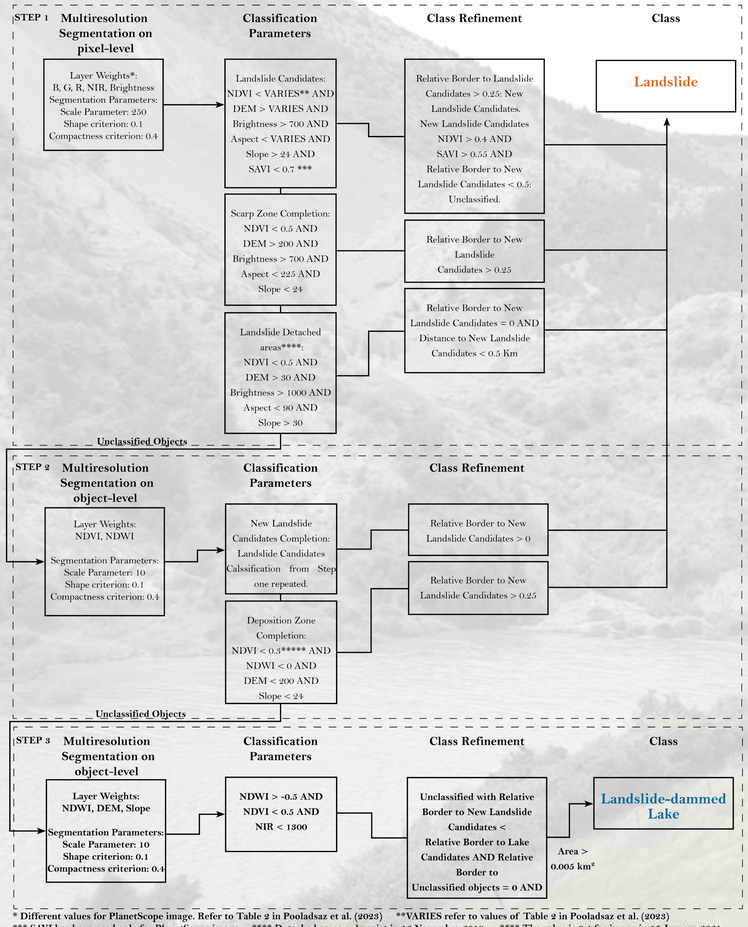


*a) South-to-north view of the second landslide failure (photo: © B. Rosser; June 2019);*
*b) Landslide formed a dam and blocked the river (photo: © R. Morgenstern; June 2019);*
*c) Lake was formed upstream and flooded the land and infrastructure (photo: © R. Morgenstern; June 2019);*
*d) Dam failed and enormous amount of water went downstream (photo: © R. Morgenstern; June 2019).*

## (4) Data & Methodology

We used a time series of Sentinel-2 (10 m), complemented by a PlanetScope image (3 m) because of the unavailability of a suitable cloud-free Sentinel-2 image in June 2019, and a digital elevation model (DEM; 1 m) and its derivatives (slope, aspect).

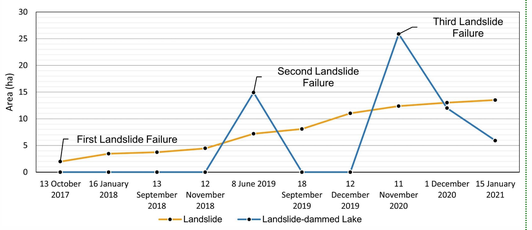
We applied a knowledge-based segmentation and classification workflow to map the landslide and landslide-dammed lake in each image. The segmentation parameters were determined based on trial-and-error and visual assessments of the resulting image objects. The classification parameters were developed continuously from the first image to the subsequent ones, following the landslide evolution, whereby only minor modifications concerning the used layers and thresholds were required when transferring the workflow.

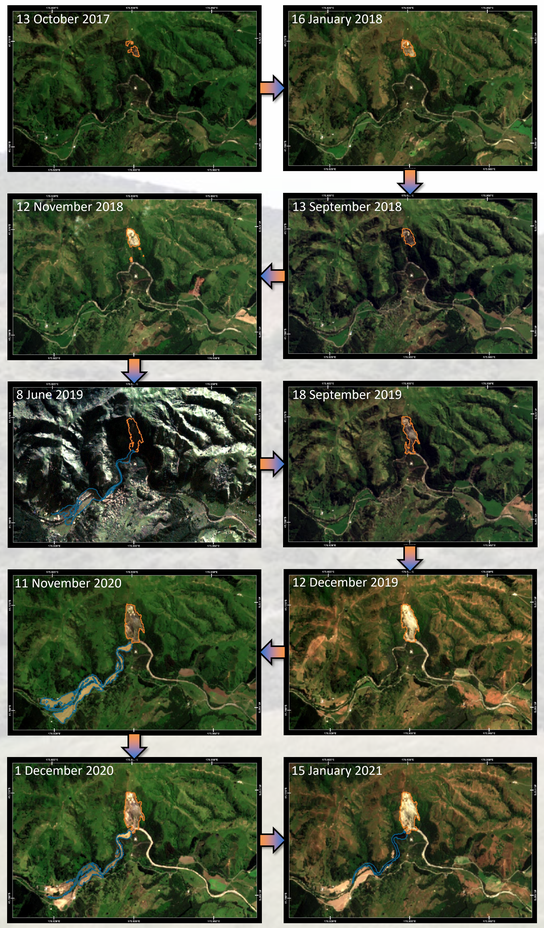


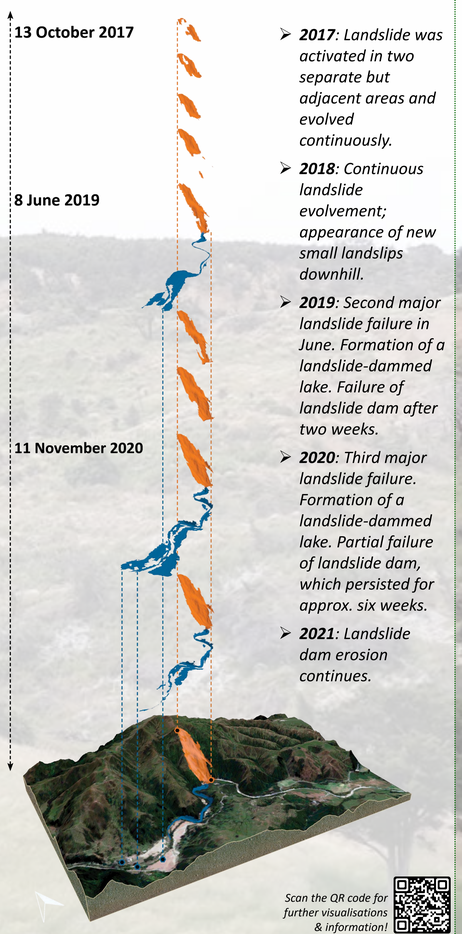

* Different values for PlanetScope image. Refer to Table 2 in Pooladsaz et al. (2023) **VARIES refer to values of Table 2 in Pooladsaz et al. (2023)
*** SAVI has been used only for PlanetScope image. **** Detached areas only exist in 12 November 2018. ***** The value is 0.4 for image in 15 January 2021.

## (5) Results

Despite cloud cover and shadow effects during certain seasons, the spatial resolution of Sentinel-2 images was sufficient to monitor the evolution of the landslide and landslide-dammed lake. The mapping results revealed a gradual increase in the landslide area, with two major events in June 2019 and November 2020. These events were followed by the formation of temporary landslide-dammed lakes along the Kaiwhata River (cf. Pooladsaz et al., 2023).




- ***2017**: Landslide was activated in two separate but adjacent areas and evolved continuously.*
- ***2018**: Continuous landslide evolvement; appearance of new small landslips downhill.*
- ***2019**: Second major landslide failure in June. Formation of a landslide-dammed lake. Failure of landslide dam after two weeks.*
- ***2020**: Third major landslide failure. Formation of a landslide-dammed lake. Partial failure of landslide dam, which persisted for approx. six weeks.*
- ***2021**: Landslide dam erosion continues.*

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## (6) Validation

The OBIA results were compared with manual mapping results to assess their accuracy, showing producer's accuracies from 83% to 86% for the landslide and from 68% to 90% for the landslide-dammed lake, and user's accuracies from 88% to 96% (landslide) and 79% to 94% (landslide-dammed lake; cf. Pooladsaz et al., 2023). Manual delineation identified vegetated areas mixed with flooded areas as landslide-dammed lake. The OBIA mapping excluded vegetated areas due to high NDVI and low NDWI values, indicating some level of generalisation in the manual reference. Thus, the comparison of the results should be considered with caution because manual reference data have a certain degree of uncertainty.

## (7) Conclusion

A knowledge-based OBIA approach was used to semi-automatically map a series of incidents. The Sentinel-2 satellite time series images provided us with suitable material to analyse the evolution of the Kaiwhata landslide and landslide-dammed lake areas. The use of OBIA and time series EO data can provide valuable insights into the evolution of landslides and landslide-dammed lakes and allow for a detailed assessment of their impacts.

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***Acknowledgements***

This study was partially supported by the New Zealand Ministry of Business, Innovation and Employment through the project STEC ("Smarter Targeting of Erosion Control"; Contract C09X1804). K. Pooladsaz received support from the Erasmus+ Programme of the European Union to engage in the Copernicus Master in Digital Earth, an Erasmus Mundus Joint Master Degree (EMJMD, project reference: 599182-EPP-1-2018-1-AT-EPPKA1-JMD-MOB 2018-2024) and 101128006 — CDE Erasmus Mundus Joint Master (EMJM, 2023-2029). The authors would like to thank J. Brus for his input. Background photograph: © A.-L. Argentin.

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