LANDSLIDE HOTSPOT MAPPING AND SUSCEPTIBILITY ASSESSMENT IN PAHIATUA, NEW ZEALAND

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(1) Introduction

Detailed landslide inventories are essential for understanding the distribution of landslides and their causal factors, and form the basis for landslide susceptibility mapping. Remote sensing data is well suited for detecting landslides and for deriving information on their spatial distribution.

Manually or semi-automatically mapped landslides from optical images can be used as input for creating landslide hotspot maps, which constitute an easy-to-grasp visual representation of the worst landslide-affected areas following a storm event.

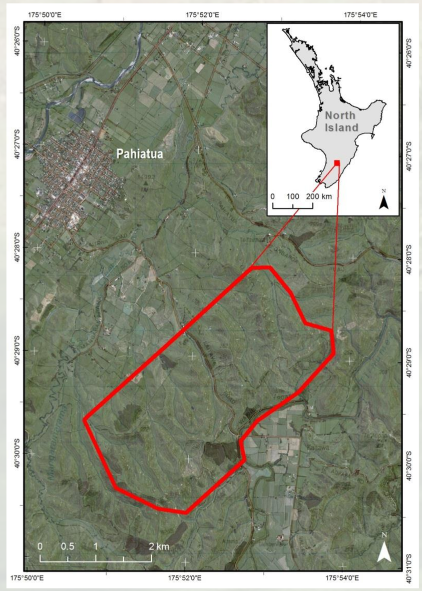
(2) Motivation and Objectives

- Landslide erosion is a serious land management problem in New Zealand
- Visual image interpretation and manual mapping, e.g. following major storm events, is time-consuming and labor-intensive
- Semi-automated image classification methods such as object-based image analysis (OBIA) offer the potential to improve landslide mapping efforts
- Effective mitigation measures against landslide erosion and its consequences require a detailed understanding of the location, extent and severity of landslides

The objectives of this study are I) to identify landslide hotspots by analyzing historical and recent aerial photography and II) to produce a landslide susceptibility map.

(3) Study Area & Data

The study area of ~1010 hectare is located approximately 5 km southeast of the town of Pahiatua, southeastern North Island, New Zealand. It comprises pastoral hill country on moderately indurated Tertiary sandstone and mudstone, with relief of 100-300 m a.s.l. and slopes typically in the 16-25 degree range. Most of the area's indigenous forest cover was cleared following European settlement in the late 1800s and early 1900s and, as a consequence, rain-triggered shallow landslide erosion is common.



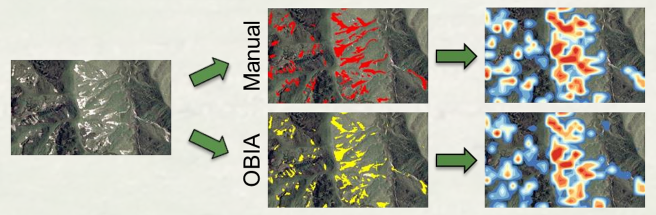
Historical and recent aerial photographs for five dates ranging from 1944 to 2011 were used for the analysis. Additionally, a DEM with 15 m resolution, based on 20 m contour lines available from the Land Information New Zealand (LINZ), was used as ancillary data.

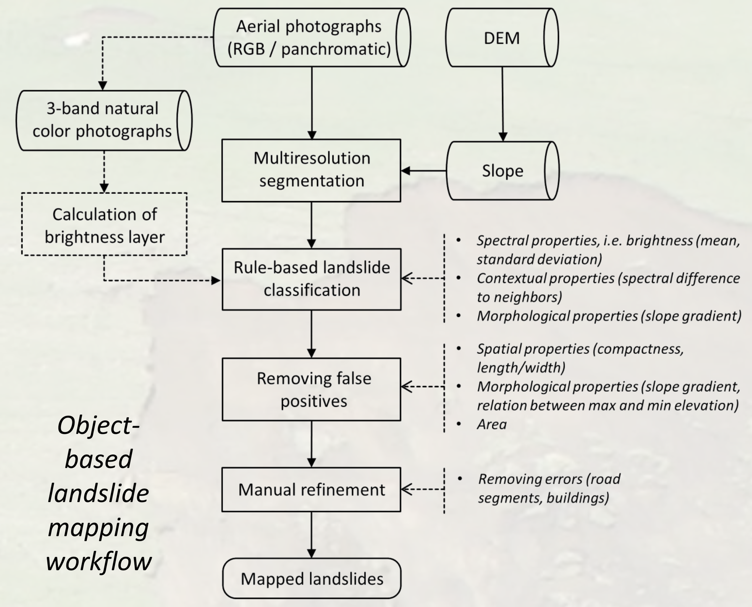
Acquisition Date	Spatial Resolution (m/pixel)	Spectral Resolution
25/01/2011	0.40	three-band natural color
16/01/2005	0.75	three-band natural color
01/05/1997	0.40	panchromatic
17/12/1979	0.40	panchromatic
31/03/1944	0.40	panchromatic

(4) Methods

Landslide hotspots were identified from the distribution of semi-automatically detected landslides using object-based image analysis (OBIA), and compared to hotspots derived from manually mapped landslides. The landslide features were rasterized at 1 m cell size and aggregated to 25 m pixel resolution by calculating the sum of 1 m landslide pixels per 25 m cell. The resulting map is a landslide cover map which can also be interpreted as a density map, as it displays the proportion of landslide area covering each pixel (625 m^2) in percent. Hotspot maps have the advantage that areas most affected by landslides can be immediately identified.

The maps also provide a more appropriate scale for comparing results as the general distribution of landslides is more pronounced.





Object-based landslide mapping workflow

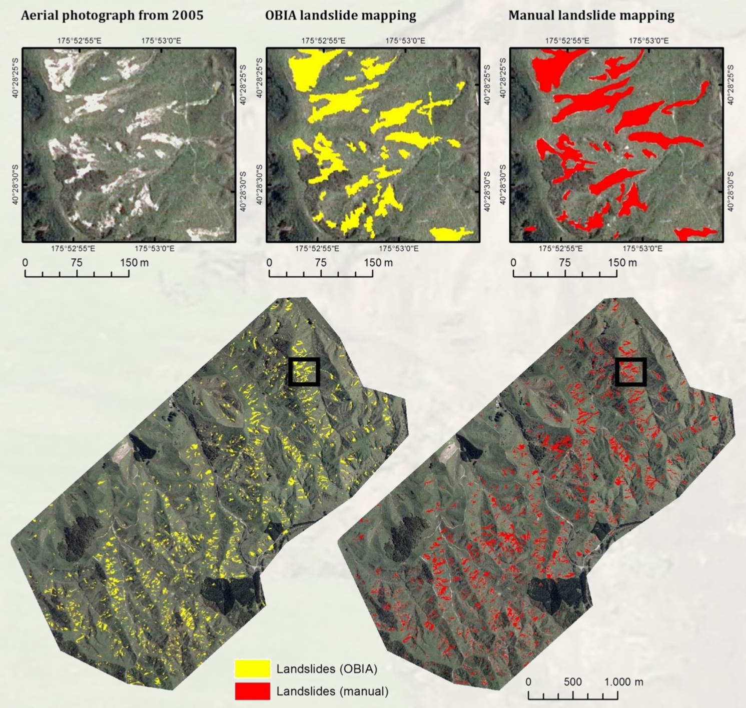
A **landslide susceptibility map** was produced using the manually mapped landslide scars from four different periods (1944 - 2005) as input data, and the 2011 inventory to validate the resulting map.

A probabilistic approach was used to characterise land according to its likelihood to erode further - in which the past is the key to the future. Due to the uniform land cover and lithology of the study area, two determinants of landslide susceptibility were selected: slope and aspect. A landslide connectivity model was also incorporated to assess the potential delivery of sediment to streams.

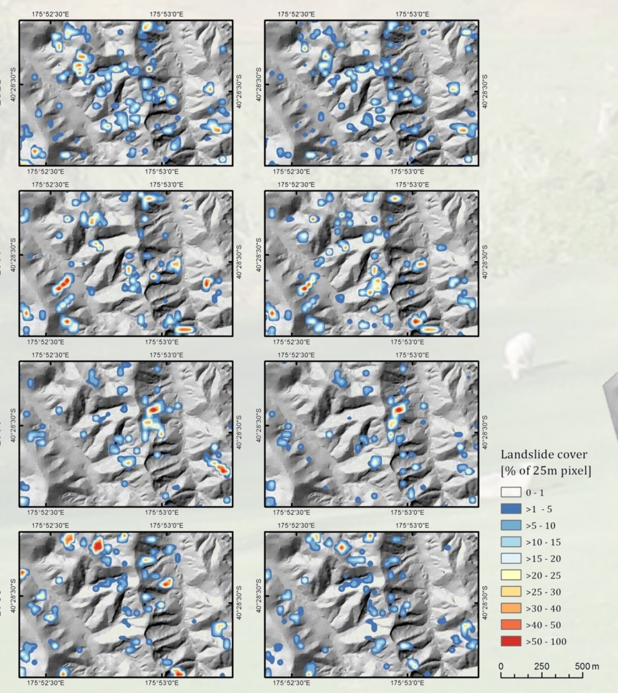
(5) Results

Landslide Hotspots

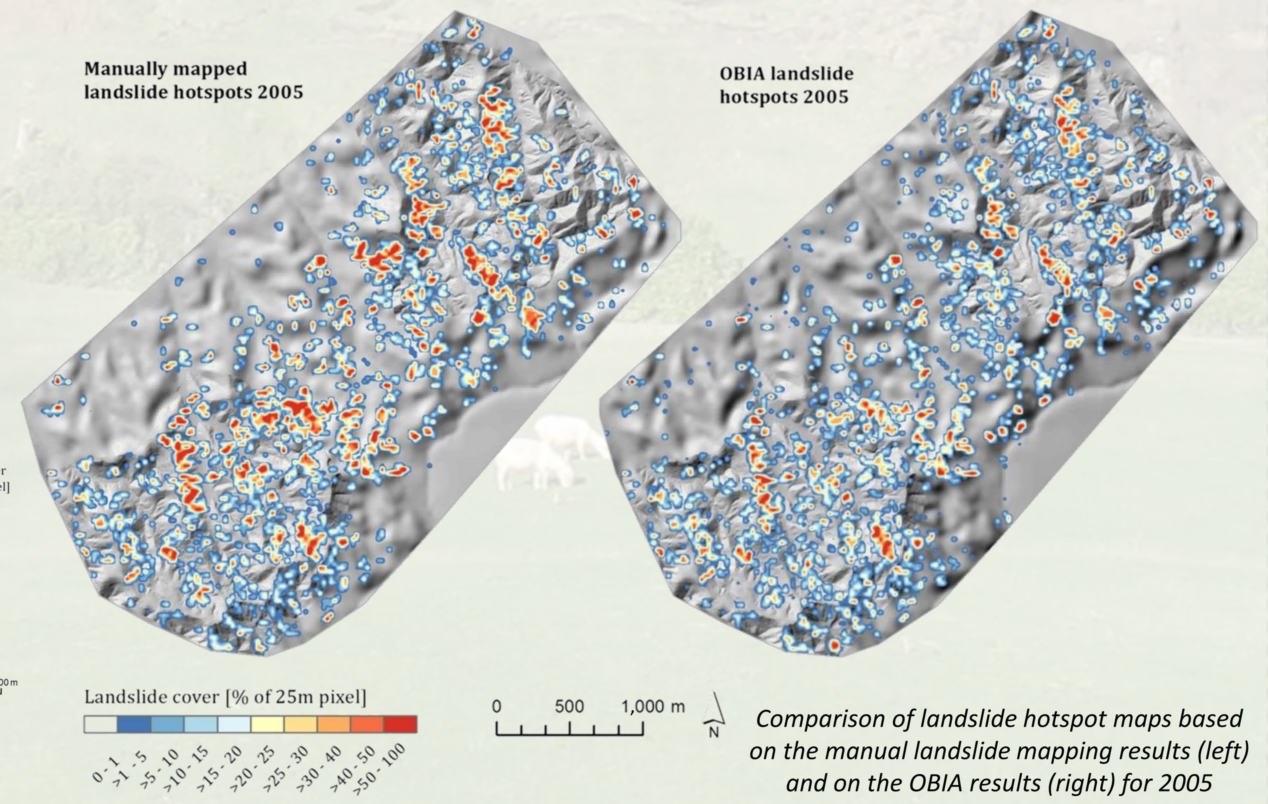
The comparison of the landslide hotspot maps shows that the distribution of the manually identified landslides and those detected with OBIA is very similar for all periods. However, differences can be observed in the proportion of landslides that cover an affected area. One explanation is that the total area of landslides identified by manual interpretation is greater than that detected by OBIA since the detection of landslide tails is more challenging with a semi-automated approach. This is due to the fact that tails revegetate faster and had often grassed over prior to aerial photography acquisition. Consequently, distinct (spectral) characteristics are not present anymore.



Semi-automatically mapped landslides using OBIA (in yellow color) and manually mapped landslides (in red color) for the aerial photograph from 2005.



Comparison of landslide hotspot maps based on the manual mapping results (left) and on the OBIA results (right) for the years 2011, 1997, 1979, and 1944 for a subset of the study area.

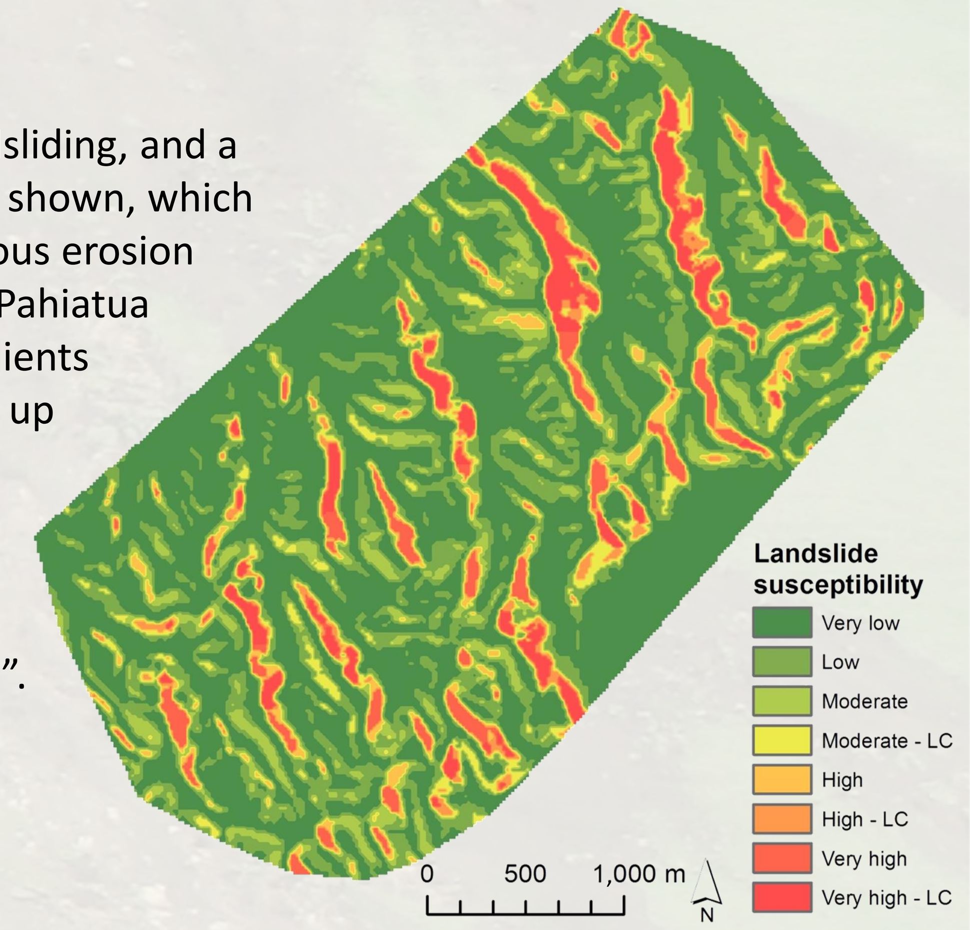


Comparison of landslide hotspot maps based on the manual landslide mapping results (left) and on the OBIA results (right) for 2005 displayed on a shaded relief.

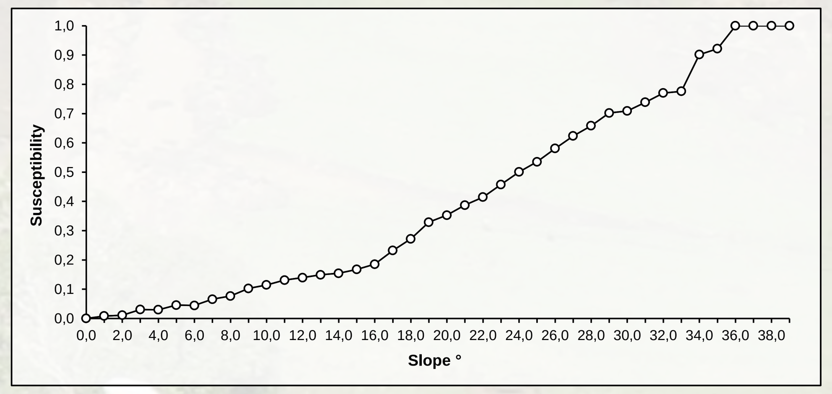
Landslide Susceptibility Map

Slope angle is the primary determinant of landsliding, and a preference for east and northeast aspects was shown, which may be influenced by storm direction or previous erosion events. The susceptibility of landsliding in the Pahiatua study area is relatively low on slopes with gradients less than 17°, and increases strongly on slopes up to 29°, peaking at very steep slopes >35°.

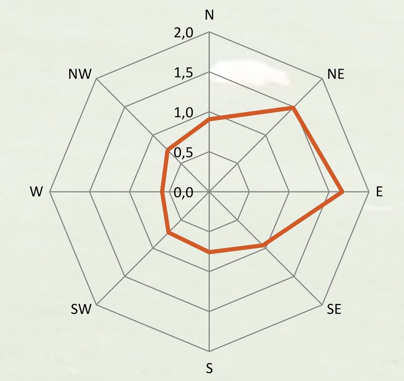
The 2011 landslide data were used to validate the map. 77% of the 2011 scars (1612 of 2099 scars) are found in susceptibility classes "moderate" to "very high".



Landslide susceptibility map based on manually mapped landslide scars (1944 - 2005), slope , aspect and landslide connectivity (LC).



Relationship between landslide susceptibility and slope angle in the Tertiary terrains of the Pahiatua study area.



Landslide scar – aspect density. A value of 1 would be expected if the occurrence of landsliding was proportional to the land area of the slope aspect.

Validation of landslide susceptibility analysis, showing the distribution of susceptibility classes in the study area and the 2011 landslide scars.

Landslide susceptibility	Count (15x15 m pixel)	% study area	% 2011 landslides
Very low	25414	52,5	6,9
Low	11474	23,7	16,3
Moderate	3456	7,1	12,1
Moderate - LC	1952	4,0	5,7
High	1365	2,8	9,5
High - LC	1281	2,6	6,9
Very high	1583	3,3	27,7
Very high - LC	1894	3,9	14,9

(6) Validation

The validation results show that 77% of the scars from 2011 (1612 from 2099 scars) were mapped in susceptibility classes "moderate" to "very high".

Comparison between OBIA and manual landslide mapping results

Aerial Photograph	OBIA Mapping (ha)	Manual Mapping (MM) (ha)	Difference OBIA-MM (%)	Overlap Area (ha)	Producer's Accuracy (%)	User's Accuracy (%)
2011	9.52	12.71	−25.10	6.57	51.65	68.96
2005	44.66	56.63	−21.15	34.59	61.08	77.46
1997	10.49	8.34	+25.75	4.66	55.85	44.41
1979	4.74	4.82	−1.68	2.29	47.57	48.38
1944	7.18	9.28	−22.68	4.35	46.86	60.60

(7) Discussion & Conclusion

Findings from the analysis of recent and historical images can help characterize individual landslide-triggering storm events (hotspot maps) and identify land susceptible to soil erosion (susceptibility map). Such products can provide valuable direction to improve land management and facilitate erosion mitigation planning. Therefore, improving our capability to map landslides, to detect landslide hotspots and to identify areas susceptible to landslides has considerable practical implications and socio-economic importance.

References

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