Detection of landslide-dammed lakes and triggering landslides in Taiwan using Landsat imagery

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(1) Introduction

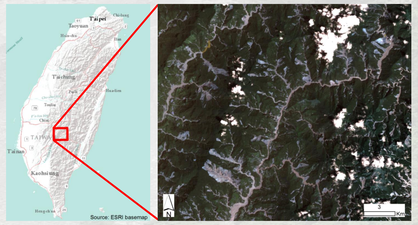
Taiwan is frequently affected by severe landslide events, most notably caused by high-magnitude earthquakes or heavy rainfalls brought by typhoons. The large amount of mobilized debris significantly affects the drainage system, representing a downstream threat. The Taiwanese mountains are, at least in part, densely populated and human lives and infrastructure are frequently affected by large landslides and landslide-river interference, such as the formation of landslide dams and lakes, dam breaching and river course changes. Especially in hardly accessible and remote mountain regions the use of remote sensing data can help to investigate landslide-river interference. Better understanding of landslide-river interaction is crucial to assess and predict the resulting natural hazards.

(2) Background and Objectives

New techniques for analyzing remote sensing data can advance our capabilities for improved mapping and assessment of geomorphological systems. Object-based image analysis (OBIA) offers a methodological framework for the efficient identification and change analysis of natural phenomena such as landslide-induced lake formation, because of its ability to consider spectral, spatial, textural, morphometric, as well as hierarchical properties of segmentation-derived image objects.
The main objective of this study is to semi-automatically detect landslide-dammed lakes as well as the triggering landslides by object-based image analysis (OBIA).

(3) Study Area & Data

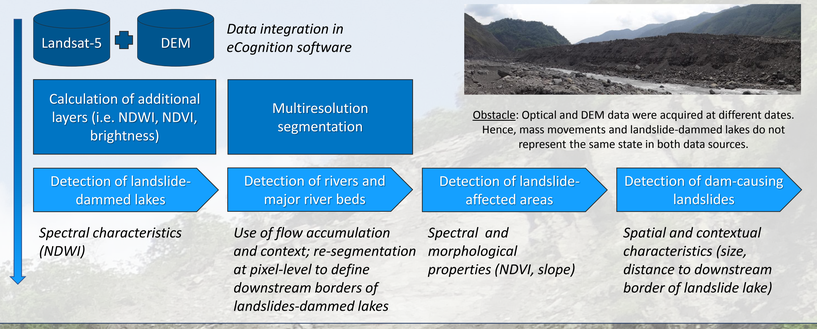
A sub-region of different river catchments in the Central Mountain Range of Southern Taiwan, where landslide-induced lake formation was observed after Typhoon Morakot which made landfall on Taiwan on 07/08/2009, is considered in this study.



The semi-automated analysis is based on post-event Landsat-5 imagery acquired on 12/09/2009 and digital elevation data including its derived products obtained through SRTM, both at 30 m spatial resolution.

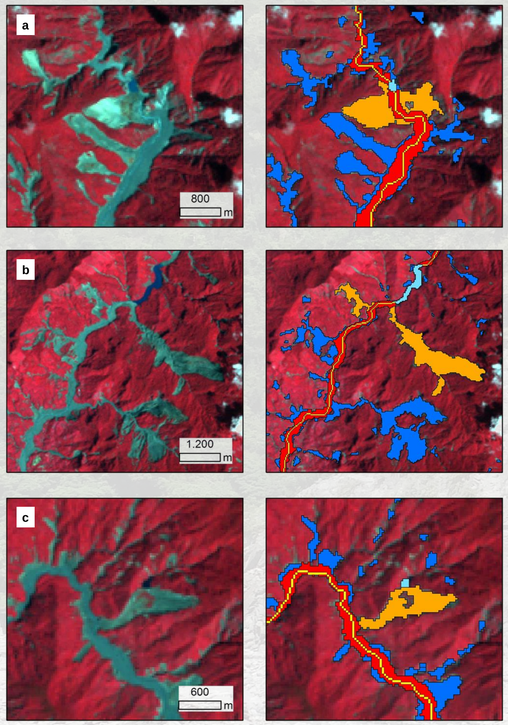
(4) Methods

Pre-processing of Landsat-5 data comprised the Top of Atmosphere (TOA) correction of Digital Numbers (DN) values; DEM (digital elevation model) data processing included the calculation of various DEM derivatives, i.e. surface characteristics such as slope and curvature, and hydrological parameters as for instance flow accumulation, or flow direction.
Landslide-dammed lakes were initially detected by applying the Normalized Difference Water Index (NDWI). The integration of flow accumulation allowed the delineation of major rivers and river beds based on morphology and context. A re-segmentation at pixel-level was done to define the downstream border of landslide-dammed lakes (higher flow accumulation values as compared to the upstream section). Landslide-affected areas were identified based on spectral difference between landslides and their surrounding using the Normalized Difference Vegetation Index (NDVI) and slope. The potentially dam-causing landslides were finally detected based on spatial and context information (e.g. size, distance to downstream border of landslide-dammed lake).



Obstacle: Optical and DEM data were acquired at different dates. Hence, mass movements and landslide-dammed lakes do not represent the same state in both data sources.

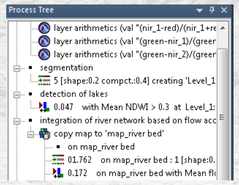
(5) Results

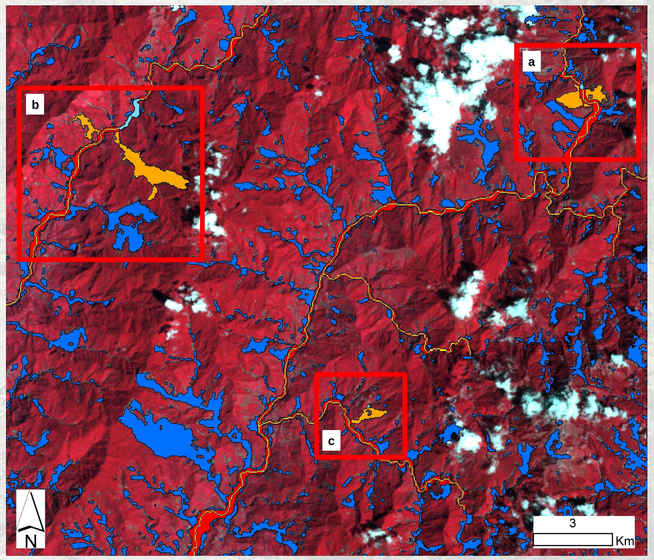


Landslide-dammed lakes and potentially dam-causing landslides detected by OBIA

- In the present study, three landslide-dammed lakes and the respective potentially dam-causing landslides could be identified using OBIA. The largest landslide dam detected measures 24.12 ha and the largest triggering landslide is 161.01 ha in size.
- The developed classification routine will be applied and transferred to further freely available optical satellite imagery (Landsat-8, Sentinel-2) for time series analysis and to other study areas.
- The results are stored in a geospatial database which is consecutively updated with information derived from post-event satellite imagery from different events and complemented with data from other sources such as existing landslide inventories or geomorphological maps. The geospatial database will serve as basis for further analysis of landslide-induced river course changes and lake formation.

Class
- Landslide-dammed lake
- Landslide-affected area
- River network
- Potentially dam-causing landslide
- Major river bed





	Class name	Area (ha)		Mean slope (°)	
Subset (a)	Landslide-dammed lake	2.88		34.30	
	Triggering landslide *(*)*	52.83	31.14	36.92	45.98
Subset (b)	Landslide-dammed lake	24.12		22.69	
	Triggering landslide *(*)*	161.01	32.85	29.71	32.02
Subset (c)	Landslide-dammed lake	1.35		24.33	
	Triggering landslide	34.29		30.20	

(*) Two landslides were identified as potential triggers

(6) Discussion & Conclusion

The developed classification routine can be adapted for time-series analysis of historical and recent optical remote sensing data from different sensors (Landsat, Sentinel-2, FORMOSAT, etc.) to monitor the evolution of landslide-dammed lakes over time.
An inventory of landslide-induced lakes and triggering landslides and a better understanding of landslide-river interaction are crucial to assess and predict natural hazards and hazard cascades.

Acknowledgements
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