Analysis of landslide-induced river course changes - the RiCoLa Project

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Introduction

• Landslides are among the most serious threats to human lives and infrastructure in mountain ranges worldwide.

• Beyond the direct hazard through the moving mass, landslides can initiate natural hazard cascades by damming rivers and initiating catastrophic flash floods and debris flows (Figure 1).

• Through such long-range effects even unwitnessed landslides occurring in remote areas matter.

• The hazard posed by landslide dam failures is often orders of magnitudes greater than that of the initial landslide event.

• Growing population and climate change have increased the impact of landslides on society.

• Insufficient information exists on the hazard potential of landslide hazard cascades, as well as possible prediction and prevention measures.

• The presented interdisciplinary project at the University of Salzburg, Department of Geography and Geology and Department of Geoinformatics - Z_GIS, combines geomorphology, remote sensing and geoinformatics to better understand the role of extreme events in the interaction of hillslope and channel systems.

http://landslides-and-rivers.sbg.ac.at

Figure 1: examples of landslide impact on the drainage network. (a) Bhote Kosi Landslide, Nepal (photo: The Landslide Blog), (b) Young River Landslide, New Zealand (photo: The Landslide Blog), (c) Randa Landslide, Switzerland (photo: Wikipedia), (d) Xiaolin Landslide, Taiwan (photo: Chen et al. (2009))

Approach

The development of the RiCoLa database is depicted in Figure 2.

• Freely available optical satellite imagery and digital elevation models are used as input data.

• Water and vegetation-free sediment is detected on pre-selected and pre-processed datasets using object-basedimage analysis (OBIA).

• Satellite image-derived data are matched with DEM-derived flow paths to produce a reference drainage network.

• Change detection is performed based on remotely sensed images acquisitioned at different points in time.

• Detected changes to the reference drainage network (i.e. relative to the state of the drainage network at a certain point in time) is validated based on reference data.

• Reference data comprises of existing databases from manual digitization, geomorphological maps and other landslide datasets.

• Landslide/waterbody/sediment location and related drainage network topology are stored in the RiCoLa database.

• Landslide and river course change distribution is statistically analyzed to detect hotspots in space and time and link them to pre-disposing, prepriatory and triggering factors.

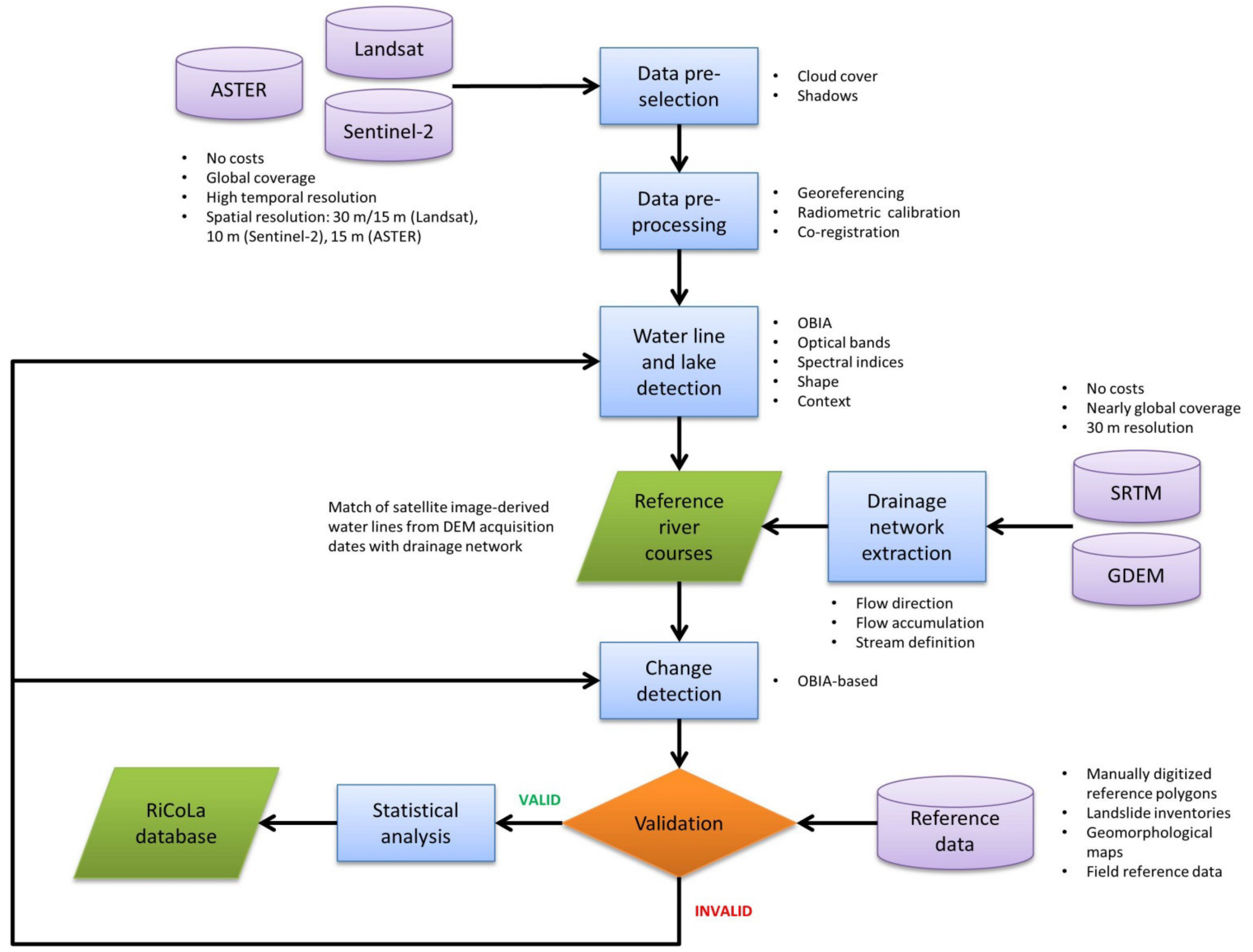


Figure 2: Flow chart of the general approach to arrive at the RiCoLa database of landslide-induced river course changes and lakes. Events are stored location-based and drainage topology-based.

Objectives

In the RiCoLa project:

• a semi-automated and transferable technique for detection of landslide-induced river course changes through time is developed based on OBIA and optical satellite imagery.

• landslide events sufficiently large to affect the drainage system and thus representing a downstream threat are detected.

• an inventory of landslide-induced river course changes is created and activity hotspots in space and time are identified (RiCoLa database).

• statistical relationships between landslide-induced river course changes and (a) triggers, (b) causes , and (c) resulting natural hazard cascades are established.

Our technique is designed to:

• Combine information on the drainage system derived from LANDSAT, SENTINEL-2 and ASTER satellite imagery, as wells as SRTM and ASTER GDEM terrain data (DEMs) with (nearly) global coverage and available at no cost.

• offer a high level of automation for object-based change detection and time-series analysis.

• be transferrable to other regions, different spectral domains or spatial scales (e.g., VHR satellite imagery, aerial photographs).

• be transferable to other fields of application such as flooding, etc.

Methods

• Identification of river courses, lakes and sediment deposits on optical satellite data is based on OBIA. Image segmentation algorithms such as the multi-resolution segmentation (Baatz & Schäpe, 2000) are used. The segmentation procedure is objectivized and automated by applying statistical pre-evaluation.

Figure 3: Pixel-based flow path tracing and change detection based on Sentinel-2 imagery. River course before (green) and after (red) the 1991 Randa Landslide.

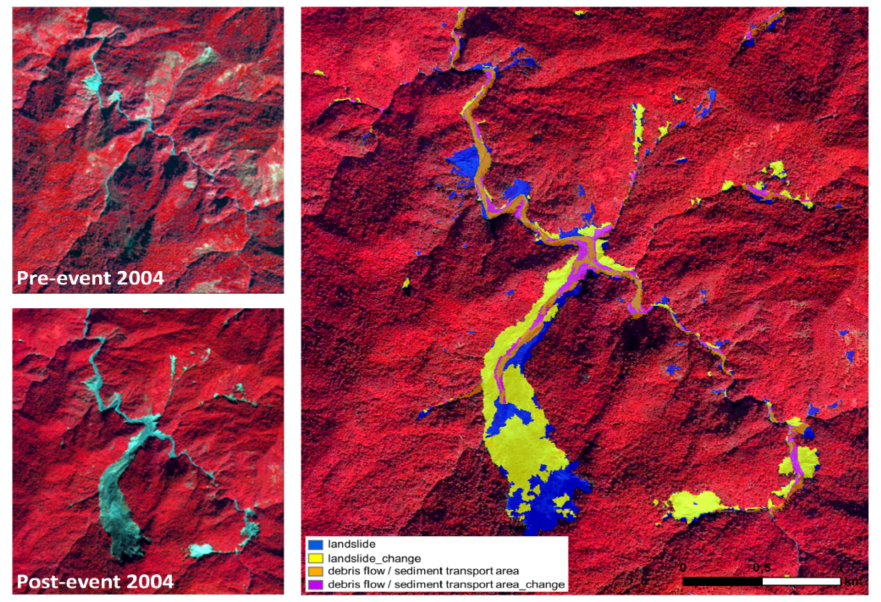
• DEMs are used to derive landsurface parameters such as flow direction, flow accumulation, flow paths (D8 algorithm, Jenson & Domingue, 1988) slope (Zevenbergen & Thorne, 1987) and stream power (Whipple & Tucker, 1999).

• This information is used to (a) fill gaps in the satellite image-derived water lines to create a reference drainage network, (b) enrich image segments with additional attribute data such as drainage area, stream segment identifier and slope, and (c) classify landscape patches based on satellite image-derived and DEM-derived information (see also abstracts 6349 and 14915).

• The reference drainage network is defined by matching DEM-derived flow paths with the water courses extracted from satellite scenes. Occasionally, further processed SRTM data such as Hydro SHEDs are used to correct flow paths.

• Eventually, change detection is performed on different levels: pixel level (Figure 3) and various levels of aggregated image segments (Figure 4, object-based change detection) to identify changes in the drainage network and the surrounding sedimentation areas and hillslopes. Detected and validated changes are fed into the RiCoLa database and stored with spatial information on location and drainage network topology.

Figure 4: Object-based change detection for a test site in Taiwan based on pre- and post-event SPOT-5 images from 2004. New landslides and debris flows/sediment transport areas and those already existing before the typhoon event are shown.



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Study areas and project partners

• The **European Alps** have a high population density and a long tradition in hazard research. Hazard and risk assessment are well established and provide historical data for method testing and validation. The Geological Survey of Austria is the regional project partner.

• The **Southern Alps of New Zealand** feature an exceptional variety in tectonic and climatic influences and are an earthquake hotspot. Landslides are a key factor of orogen evolution. The Department of Geological Sciences (University of Canterbury) is the regional project partner.

• The **mountains of Taiwan**, are situated in the active subduction-collision region between the Eurasian Continent and the Philippine Sea plates, and on major typhoon tracks. They are subjected to frequent earthquakes and highly susceptible to landslides. The Disaster Prevention Research Center (National Cheng Kung University) is the regional project partner.

• The **Himalayas of Nepal** host some of the highest peaks and rock faces worldwide and were repeatedly affected by large earthquakes. The International Centre for Integrated Mountain Development is the regional project partner.