Remote sensing observations for landslide identification in South Tyrol, Italy and the Longnan region, China

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ABSTRACT

Landslide inventory mapping is an essential asset for hazard assessment and mitigation. Despite significant progress in the development of automated image processing chains for landslide inventory mapping, tedious manual interpretation of aerial and satellite images remains the de facto standard (European Centre on Geomorphological and Seismological Hazards, 2017). Optical remote sensing is until today not used as an operational tool in contrast to SAR interferometry and LiDAR. The reasons are a lack of adapted image processing techniques that address the specific information needs of landslide investigations while remaining sufficiently generic to a broad range of different landslide types and environmental settings. This study investigates in automated change-detection workflows using annual Sentinel-2 (S2) composites and S2 multi-temporal imagery. Landslide areas in the time period 2015-2019 were analyzed based on already-known landslide location points, downslope-oriented moving windows and supervised classifications of change-vector-intensity and -angle using Receiver Operating Characteristic (ROC) curves. Subsequently, time-series analysis was applied on the resulting change-pixels to derive temporal breakpoints (i.e. the timing of the landslide occurrence). Our findings highlight that out of 65 reported landslide locations in South Tyrol, only 9 (13.8%) are recognizable by means of S2 imagery. Large landslides, however, were detectable both spatially and temporally by means of the multi-temporal change-detection approach. By applying a quantitative accuracy assessment for the independent test site in Longnan, China, our results show that the approach is highly transferable with minimal adjustments and is suitable for efficient spatial-temporal landslide mapping across large areas.

1 OBJECTIVES

The aim of this study was to test the applicability of multi-temporal change indices derived from Sentinel-2 to detect landslides for two landslide-prone study sites in Italy and China: South Tyrol and Longnan, respectively.

2 LANDSLIDE INVENTORY DATA

South Tyrol, Italy (development area)

Landslides are widespread in South Tyrol. Both the distribution and frequency of mass movements have shown to be strictly connected to climatic conditions. Increases in landslide activity are showing correlations with climatic changes since the Late glacial (Piacentini, D. et al., 2012). Shallow landslides are favored by forest cutting and urbanization through the development of roads and human settlements.

Landslide inventories:

- South Tyrolean Hazard event inventory: ed30
- Italian inventory for mass movements: iffi (*inventario dei fenomeni franosi in italia*)

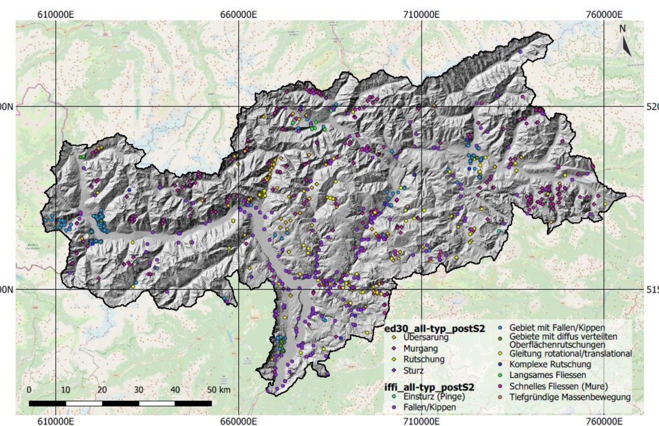


Figure 1: Inventoried landslide events classified by landslide type recorded since 2015 ('ed30' and 'iffi' inventories)

Longnan Admin. Area, China (test area)

Represents one of the four most active landslide and debris flow regions in China, given the combination of earthquakes, high relative relief, steep slopes, strong seasonal (monsoonal) climates and widely distributed thick loess and argillitic rocks. There have been severe landslide triggering events:
Wenchuan earthquake, 2008
Jiuzhaigou earthquake, 2017

Landslide inventories:

- Event-based inventory maps (see below)
- NASA Global Landslide Catalogue
- Indication of landslide-prone regions by local authorities

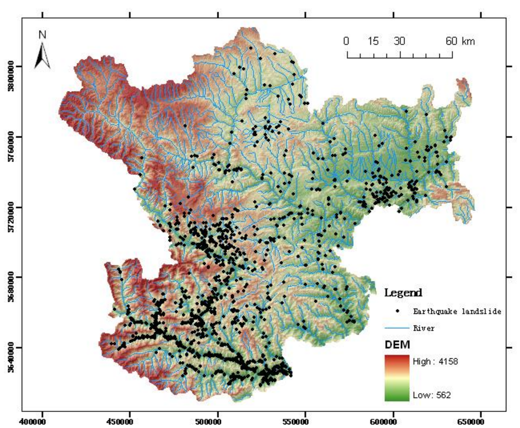
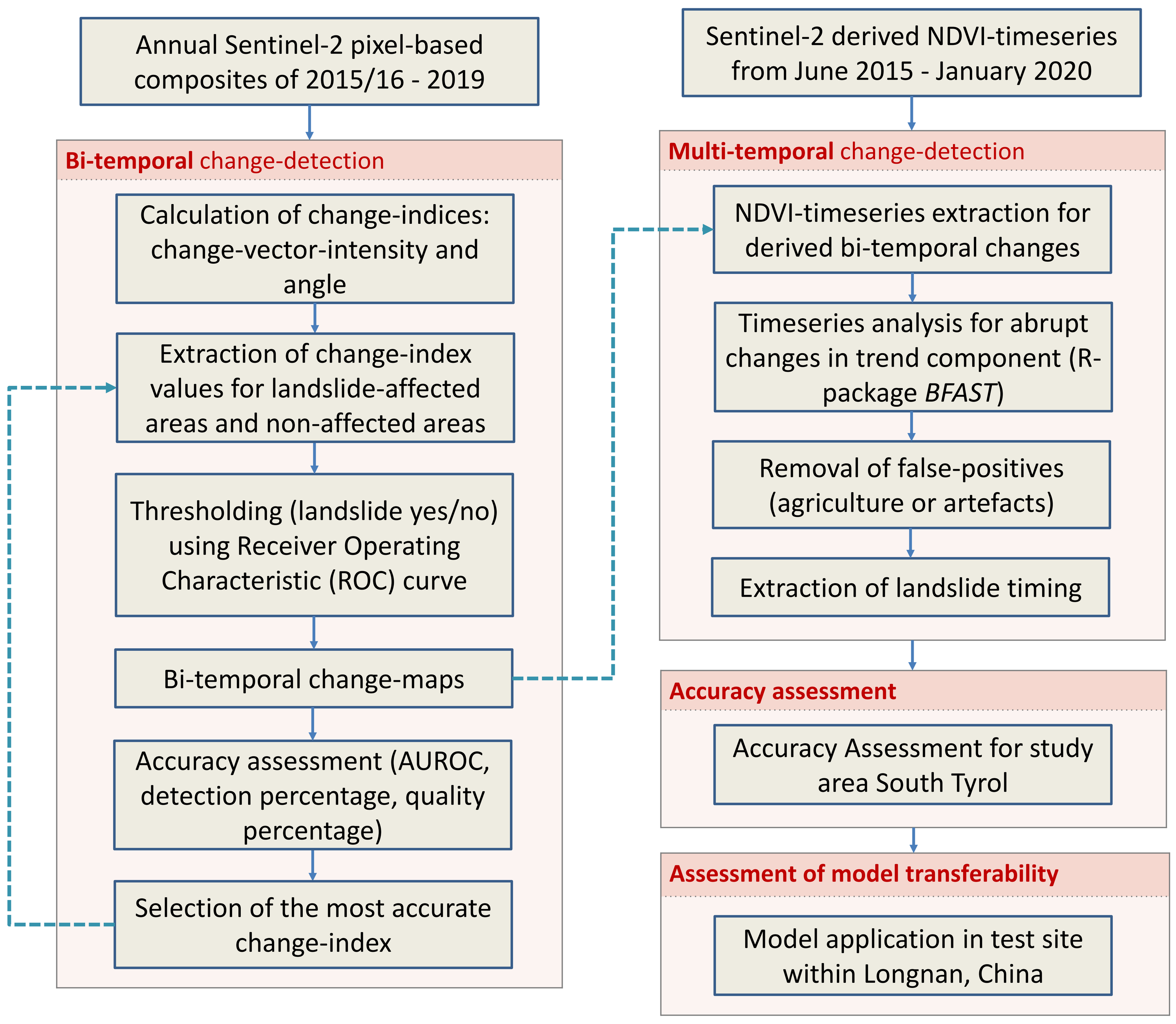


Figure 2: Spatial distribution of landslides triggered by Wenchuan Earthquake in Longnan (Bai S., 2011)

3 METHODOLOGY

We apply bi-temporal and multi-temporal change-detection methods to detect land-cover disturbances using optical remote sensing imagery of Sentinel-2:



4 RESULTS

Development area (South Tyrol):
13.8% of inventoried landslide events of type "slide" are securely recognizable using S2 imagery

Independent test site (Longnan):
The stepwise application of bi- and multi-temporal change-indices increases overall accuracies:

Change-detection approach	OA
Change vector intensity	35.5%
Change vector angle	42.8%
NDVI-timeseries breakpoint analysis	75.8%

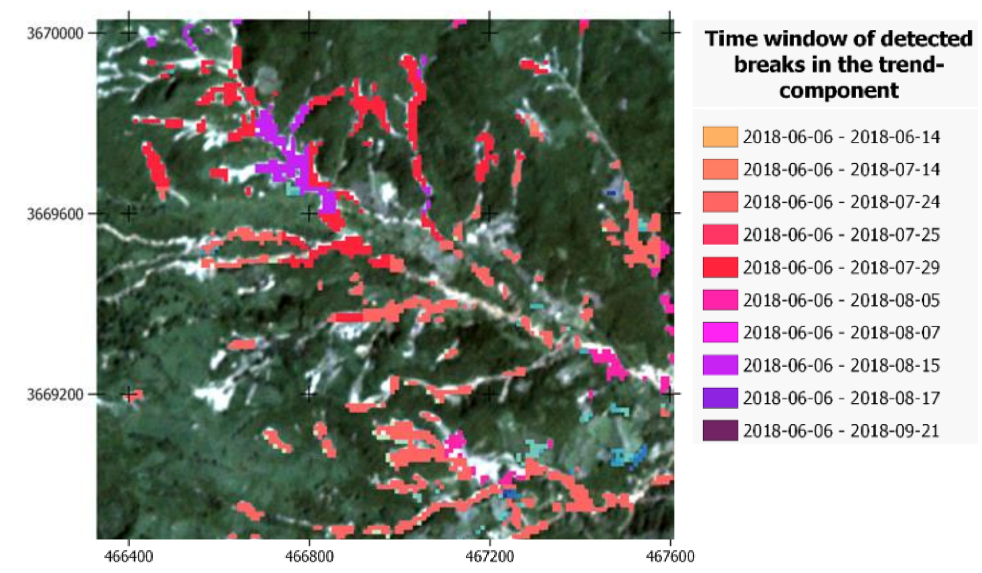


Figure 3: Details of detected slide and debris-flow landslides at Paifangcun, Longnan (background imagery: Planet)

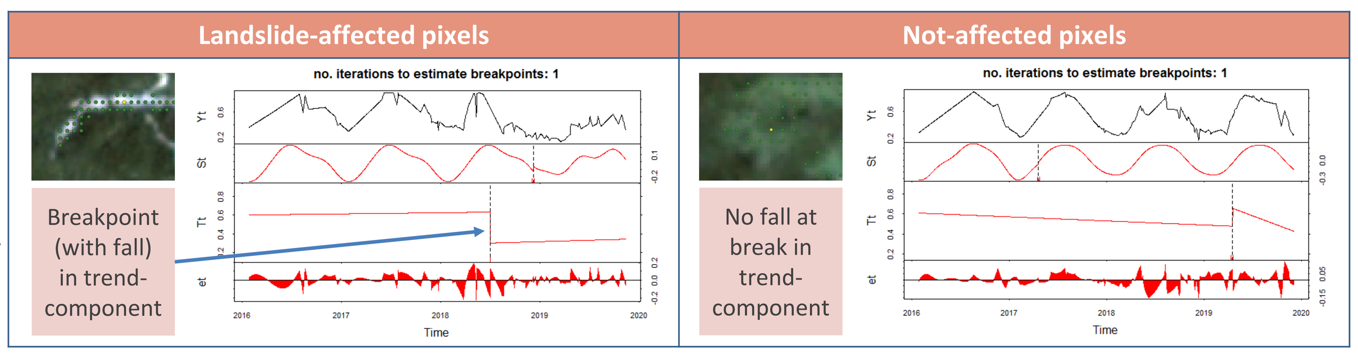


Figure 4: NDVI-timeseries analysis of bi-temporal change-pixels

Higher accuracies on:

- South-facing slopes in both regions due to a higher number of unmasked images
- Open-slope slide events compared to narrow debris-flow-landslides

5 DISCUSSION

- Combining bi- and multitemporal approaches allows to both spatially locate landslide features and to track their timing of failure
- Multi-temporal analysis largely removes salt-and-pepper noise resulting from bi-temporal analysis through image variations and challenges in threshold-definition
- Both study areas are strongly managed: Remaining commission errors by confusion with other disturbances (e.g., windthrow, logging and construction activities)
- Omission of small-scaled features through the given spatial sensor resolution

6 CONCLUSIONS

- High transferability for large-scale mappings across varying regions with minimum adjustments
- Restrictions remain in the ability to detect small-scaled features and through confusions with other land-cover disturbances
- Results can facilitate further research in process-understanding of landsliding and regional susceptibility analysis by
    (1) investigating landslide predisposing conditions through the recognition of preceding land-cover changes
    (2) investigating landslide triggering causes by linking the results with rainfall data or seismic activity records

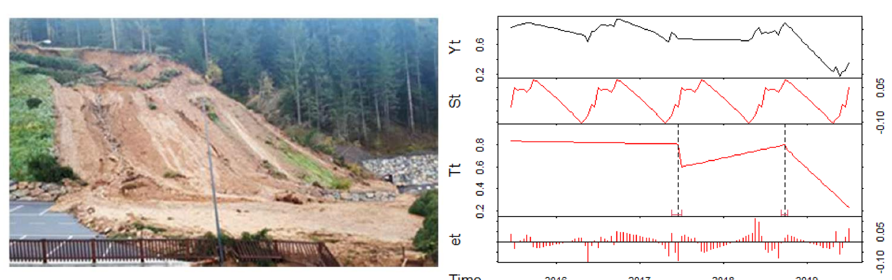


Figure 4: Landslide at Welschnofen on October 29, 2018 (Natural Hazards Report, 2019) with preceding landcover change detected in spring 2017 (forest to grassland)

KEY REFERENCES

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