Potential of Optical Satellite Time Series Data as Contribution to an Operational Spatiotemporal Mapping of Backdated and Recent Landslide Activity for Large Areas

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ABSTRACT: Landslides are a world-wide occurring natural hazard leading to severe loss of life and infrastructure. Objective and dynamic landslide hazard assessment requires profound knowledge about past and recent spatiotemporal occurrence of landslides. So far, for many parts of the world multi-temporal landslide inventories providing such information are largely missing, because the preparation relies mainly on time consuming and resource intensive conventional methods, i.e. visual interpretation of optical data supported by comprehensive field surveys. In this context, long-term archives of optical satellite remote sensing data open up the opportunity for analysing landslide occurrences at a regional scale. For this purpose, the focus of this study lies on the development of automated remote sensing based approaches for identifying the backdated spatiotemporal landslide activity as well as for monitoring of recent landslide occurrences in an area of 12,000 km² in Southern Kyrgyzstan. In case of the backdated long-term landslide analysis a combined usage of multiple optical sensors is required, in order to achieve best possible temporal data coverage for the longest possible time span. The established database consists of about 700 orthorectified multispectral mid- and high-resolution satellite remote sensing datasets acquired by Landsat-(E)TM, SPOT, IRS-1C (LISS3), ASTER and RapidEye during the last 28 years. In case of monitoring the recent landslide activity the approach takes advantage of the high spatial and temporal resolution data of the RapidEye sensor allowing the determination of the time period of landslide occurrence up to several days and weeks.

The developed approach comprises automated multi-sensor pre-processing and multi-temporal change detection methods enabling spatiotemporal identification of landslides in an object-based form. The change detection approach builds on the analysis of temporal NDVI-trajectories which are obtained for every pixel across the analysed time span. NDVI-trajectories represent specific temporal footprints of vegetation changes. They allow for automatic identification of landslide events due to landslide-specific footprints represented by short-term vegetation cover destruction as well as longer-term revegetation rates resulting from landslide related disturbance and dislocation of soil. In combination with DEM-derivatives (e.g. slope, stream order) the developed approach enables automated identification of landslides of different sizes, shapes and in different stages of development (i.e. fresh failures, reactivations and relocations) allowing spatiotemporal landslide mapping under varying natural and land use conditions. This approach has been applied to the multi-sensor database resulting in the identification of several hundreds of medium and large landslides with sizes up to 1.3 km². These landslide events have continuously occurred during the analysed time span between 1986 and 2014 revealing an ongoing landslide activity with an activity peak in the year 2004. In order to analyse the more recent landslide activity the approach has been applied to the RapidEye data acquired between the years 2009 and 2014. In the result 612 landslides could be identified with sizes ranging between 125 and 750,000 m² resulting in a total landslide affected area of approx. 7.3 km². The combination of high spatial resolution of 5 m and the frequent temporal repetition of the RapidEye data has allowed for identifying a variety of landslide processes including also small slope failures often representing precursors for subsequent large hazardous landslides which represents a valuable information in the context of early warning. Overall, the results demonstrated that the developed approach is very suitable for analysing the evolution of landslide occurrences in space and time representing an important contribution to objective hazard and risk assessments and a potential for an operational monitoring of recent landslide activity for large areas.