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Automated landslide identification based on temporal NDVI-trajectories using long-term optical multi-sensor time-series data

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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 spatiotemporal occurrence of landslides. Thus, landslide inventories, which are a prerequisite for landslide hazard and risk assessment, have to be as complete as possible in time and space. So far, for many parts of the world such multi-temporal landslide inventories are largely missing, because the preparation relies mainly on very time consuming and resource intensive conventional methods, i.e. visual interpretation of optical data aided by comprehensive field surveys. Against this background, long-term archives of satellite remote sensing data, such as the USGS level 1T Landsat-(E)TM database open up new opportunities for analysis of landslide occurrence at a regional scale. However, in order to achieve best possible temporal data coverage, multi-sensor data have to be used. In this study such a satellite remote sensing database has been established for an area of 12,000 km^2 in Southern Kyrgyzstan, which is strongly affected by landslides. The 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 27 years. This builds the methodological framework for developing a reliable and robust automated landslide identification approach with the potential for global applicability.

The developed approach comprises automated multi-sensor pre-processing and multi-temporal change detection methods. Change detection requires a precise spatial alignment of the whole database. Therefore an automated image-to-image co-registration approach has been developed using time series of USGS level 1T Landsat-(E)TM data as spatial reference. Accuracy assessment has shown a high relative image-to-image accuracy of 17 m (RMSE) and a high absolute accuracy of 23 m (RMSE) of the whole co-registered multi-temporal database making it suitable for automated landslide detection at a regional scale.

The developed change detection approach is based 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 as effects of landslide related disturbance and dislocation of soil. In combination with DEM-derivatives (e.g. slope, stream order) the developed approach enables automated object-based identification of landslides of different sizes, shapes and in different stages of development (i.e. fresh failures, reactivations and relocations) and thus is suitable for mapping spatiotemporal landslide activity under varying natural conditions (land cover and lithology). This approach has been applied to the spatial and temporal high resolution RapidEye database acquired between 2009 and 2013 for the whole study area. In the result 612 landslides could be identified with sizes ranging between 125 and 750,000 m^2 representing a total landslide affected area of approx. 7.3 million m^2. Currently, this approach is extended to the whole multi-sensor time-series database.