INTEGRATIVE LANDSLIDE EARLY WARNING SYSTEMS

APPROACHES, IMPLEMENTATIONS AND CHALLENGES

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RATIONAL

Landslide cause significant damages worldwide. The response is manning fold and ranges for local sites from highly sophisticated engineering protection structures to early warning systems based on various approaches. Regional approaches include spatiotemporal inventories, susceptibility, hazard or even risk maps and spatial alert systems. Reviewing existing approaches leads to the following conclusions: Numerous well-established local protection measures are available; some highly active landslide sites are well-equipped with monitoring instruments; warning systems perfectly adopted to local conditions have been implemented; various inventories are available and include point information of damaging events as well as complete coverage of spatiotemporal landslide distributions; various regional susceptibility and hazard analysis methods are available and include heuristic/expert opinion, physically based approaches and deterministic assessments; and finally, some suggestions for landslide risk estimation on a local and regional scale are also available. One major draw-back of all approaches is the limited period of any monitoring program – and that most of the systems have been implemented independently.

OBJECTIVES

The main objective of this project was to develop comprehensive, integrative and adoptable concepts for local and regional landslide early warning systems. “Comprehensive” and “integrative” refers here to concepts, which include engineering, economic, natural science, social science and planning approaches. A major aim herein was to incorporate the stakeholders in the development of the system and to visualize the final results towards the required end-user demands. Consequently, the project “Integrative Landslide Early Warning Systems” – ILEWS is addressing the whole warning chain, from sensors and field installation to web-based visualization embedded in a risk governance strategy.

STUDY REGION

The study regions are in the Swabian Alb in Southwest Germany as the main target area and South Tyrol in Northern Italy as the testing area of the developed ILEWS concept. The innovative technical early warning system was developed, implemented and maintained in the Swabian Alb and embedded within important historical, social and urban planning aspects. The transferability and adaptability of the resulted integrative early warning system was tested in South Tyrol, a region which is characterized by a totally different environmental setting, with already existing data bases and within different social and political structures.

RESULTS

For any landslide early warning systems, the historical information on the specific location and the general region is of major importance. The landslide activity and its variety has to be known in order to design and implement a warning system which is suitable and most accurate for the required purpose. The focus of the historical investigation was on old handwritten sources and historic maps.

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The newly explored events date back to 1416 in the Swabian Alb and to 1570 in South Tyrol. These events were often previously unknown and increased the knowledge of landslide activity.
The monitoring and modelling results refer in particular to the well-equipped slope in Lichtenstein-Unterhausen, Swabian Alb. The complex landslide includes two large historic failures and numerous smaller ones. The surface surveys applying tachymetry and nivellement techniques showed significant movements of single locations. Partially, up- and down movements have been measured seasonally, indicating additionally a swelling and shrinkage of the clay soils. The subsurface movements has been investigated by manual and automated inclinometer measurements. The downslope creep of 2-3mm per year shows seasonal patterns. While the summer precipitation events caused movements in up to 8,5m depth, the snow thaw in spring led to movements in approx. 15m depth. Soil moisture was monitored in nine vertical profiles using a combination of geoelectric set-up's and local soil moisture sensors (TDR-probes and tensiometer). The data from the tensiometers have been applied in the physically-base slope stability calculation. The geoelectric data has been obtained using remotely controlled measurements and gave information of the progressing wetting fronts in the subsurface. Validation approximations have been developed and tested within trend and threshold analysis for characterizing the soil moisture which is critical for slope stability. All monitored data have been applied in relatively simple threshold models within the landslide early warning system. The physically-based early warning system is based on the CHASM software (Coupled Hydrology and Slope Stability Model) and was additionally implemented in a Web Processing Service (WPS). This WPS is the main ILEWS analysis, visualization and early warning platform which allows a semi-automated slope stability calculation without manual access to data and the software tool. This was coupled with extreme precipitation data from the German Weather Service KOSTRA-Atlas (DWD) in addition to own meteorological data measured at the implemented local weather station. The empirical early warning system linked the surface movements with the triggering factors. A dynamic deformation model combined with the climate data allowed the finalization of the empirical early warning system. The regional early warning system for debris flows (South Tyrol) and landslides (Swabian Alb) is based on rainfall threshold analysis combined with quantitative weather forecasts. The technical concept of both systems has been implemented. The major analysis-, visualization and early warning platform is based on the OGC-conform geodata infrastructure. Additionally to the WPS, also the Web Notification Services (WNS) and the Sensor Observation Services (SOS) have been implemented. The local and regional social and socio-economic settings have been investigated by the spatial planners and social science partners. Based on these results, the cooperative implementation of the early warning system was possible. While the developed ILEWS has not been adopted by the Swabian Alb communities due to the low landslide activity, the concept has been of major interest to the South Tyrol institutions. A manual with 15 rules for the successful implementation of early warning systems has been presented. The spatial planners analysed the protection target and calculated the damage potentials. In combination with an existing hazard plan for the community Nals (South Tyrol), a risk zone map has been calculated.

CONCLUSIONS

The transferability of the ILEWS has been proven successfully. The key issue herein was not to export and implement singly components of the system, but rather the whole set-up of all components to ensure its functionality. The central ILEWS idea was to develop an integrative concept ranging from sensor development and implementation to early warning guidelines for the stakeholders. This system demonstrates that indeed the technical components are most important, but also the components of the social sciences are crucial. The developed guidelines demonstrate the successful combination of different expertise ranging from spatial planners, engineers, historians, social scientist to natural scientists and geomorphologists. In the future it is highly recommended to include in any landslide early warning system also social scientists in the planning and implementation of these systems to ensure a successful and efficient implementation – and consequent warning.

Keywords: Early warning, landslides, debris flows, monitoring, data handling, guidelines