Modelling and web processing of early warning

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ABSTRACT: Within landslide early warning systems, a continuous challenge is the on-site implementation of a robust monitoring system, a reliable data collection and cross-checked analysis, and the presentation of respective results in a real-time mode. This paper will describe one concept of an integrated early warning system developed within the German BMBF-funded ILEWS project. This system is based on a variety of factors. The connection of geomorphological knowledge, geotechnical and geophysical information, sensor networks and web-based applications are examined. In the Swabian Alb, one system has been installed and first results will be presented. These results give some indications of the potential of a real-time landslide early warning system ready to be used by various end-users and stakeholders.

1 INTRODUCTION

Landslide early warning systems are rarely available. Often these focus on in-situ measurements, data storage in data logger, and final slope stability analysis (e.g. Husaini & Ratnasamy 2001). Web-based applications are not common. Sophisticated geotechnical slope stability tools allow modelling of various parameter settings and strongly aid geomorphological understanding of slope behaviour. These models can also be used within early-warning systems if continuously measured and reliability checked field data are provided.Therefore, robust on-site monitoring systems have to be installed to observe changes in destabilizing factors e.g. soil hydrology. In addition, climatic conditions need to be measured and information on displacement should be available. Commonly, displace- placement is measured by either subsurface (Lollino *et al*. 2002) or surface changes (Malet *et al*. 2002).

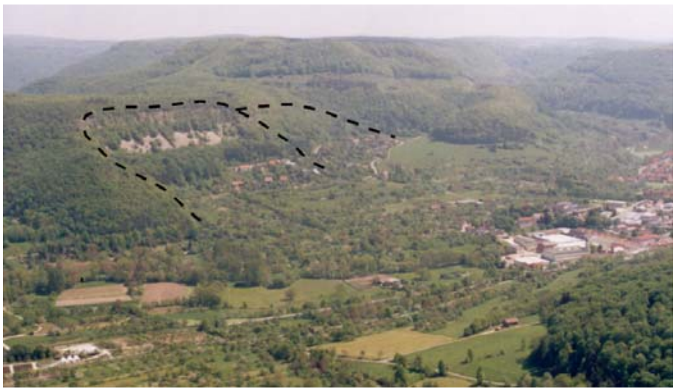

Figure 1. Landslide Lichtenstein-Unterhausen, Germany (Photograph: Rainer Bell)

To be able to respond quickly to changes in slope stability, data must be transmitted and computed in near-real time. Web-processing services can be used to implement stability models and give easy access to current slope stability status to stakeholders and end-users. It is evident, however, that the information needs to be provided in a format which is understandable also for non-experts and which is still scientifically correct and robust. Therefore, work has to be carried out to investigate in detail the demands and requirements of the respective users. Hereby, the users are not only experts, also administrative bodies or the interested public are a focal group.

The project Integrated Landslide Early Warning Systems (ILEWS) faces this challenge. It aims to combine both the natural scientific components (e.g. geotechnics, engineering, data measurement, transmission and storage, analysis) and the social system (e.g. legal framework, demands from different stakeholders). It is planned to develop a general and transferable landslide early warning system, which is implemented on a landslide in the Swabian Alb (Fig.1). The final concept will be tested in South Tyrol and be open for applications elsewhere.

The general conceptual scheme of the ILEWS project is provided in Figure 2. The total group consists of 10 sub-projects organized in the three clusters monitoring, modelling and implementation. This contribution focuses in particular on the soil moisture monitoring and touches also the web-based slope stability analysis and presentation.

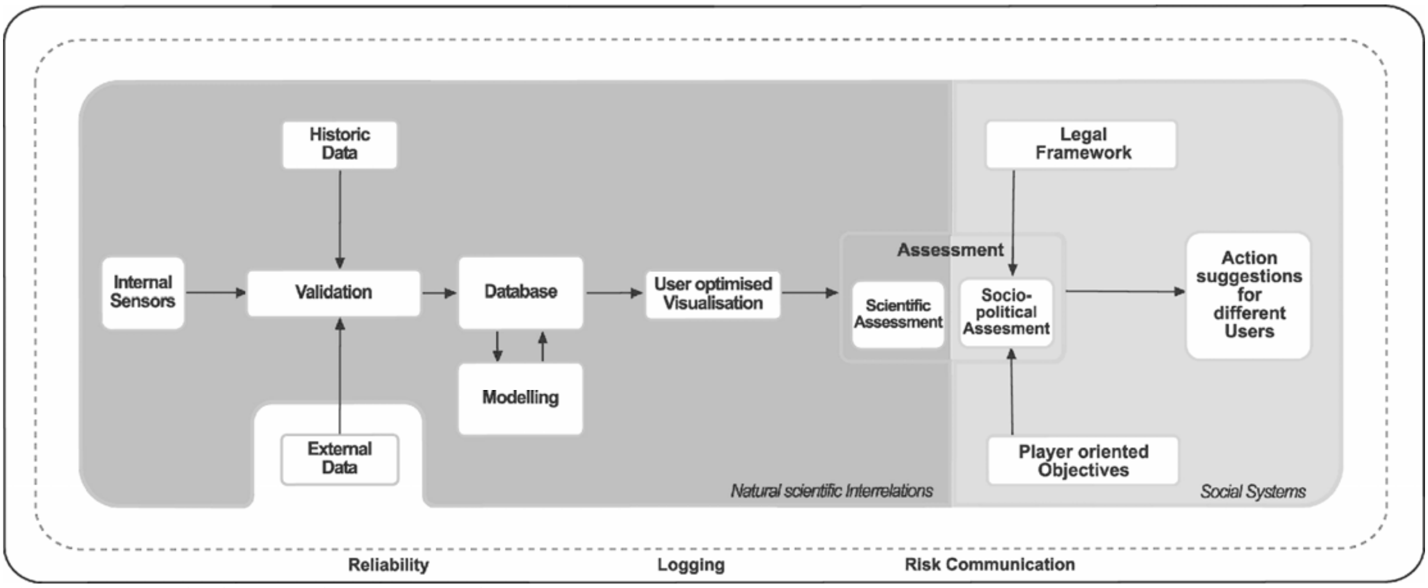

Figure 2. General scheme of the ILEWS project.

2 BACKGROUND AND METHODOLOGY

Soil moisture is one of the most important monitoring parameters for determining landslide activity. Therefore this analysis has to be included into the composition of a landslide early warning system.

Using a permanently installed 2D-Geoelectric monitoring system, the ILEWS subproject "moisture geoelectric" is based on the quasi-continuous measurement of the electrical conductivity combined with local in-situ soil moisture measurements in order to determine the spatiotemporal recording of the soil water saturation.

Drilling cores have been examined and grain size distribution has been analyzed. Results are combined with geophysical surveys to create the slope model necessary. All installations are located in Figure 3.

The web-based slope stability analysis uses the physically-based model CHASM^{TM} (Combined Hydrology and Stability Model). This software package is a commercial product for analysis of slope stability under varying rainfall events, soil moisture and vegetation conditions. The model has been applied in various slope stability studies e.g. in Hong Kong and New Zealand (Anderson 1990, Wilkinson 2000, Wilkinson et al. 2002, Brooks et al. 2004). However, no web based version of CHASM – or other comparable slope stability software – is currently commercially available.

The CHASM model is applied for calculation of most likely sliding surfaces and tested with various rainfall events. Parameter settings are calibrated using measured hydrological events. A general model of slope including underground conditions is prepared based on drillings, geophysical data (seismic and geoelectric surveys) and laboratory tests.

For calculation of the final early warning, a web processing service (WPS) is set up and the CHASM model is implemented. Input data consists of the slope model and monitored soil moisture and rainfall data. The analysis is carried out depending on the end user. The automatically running web processing service either provides only current safety factors or can be started manually allowing to select different rainfall scenarios.

3 RESULTS

Within the pre-exploration in June-August 2007 intensive seismic and geoelectric surveys were performed to understand the geometry of the landslide body and to identify appropriate sites for installing the permanent geoelectrical monitoring system.

From September 2007 to March 2008 the first part of the remote controlled geoelectrical monitoring system (GMS) including one profile with 47 fixed electrodes (spacing 3m) and a container for housing the technical equipment has been installed.

The monitoring is done automatically (one measurement with 322 data points per hour) and is transmitted using a virtual private network (VPN) via remote desktop connection. To date, all field installations of sensors and the weather station have been completed. The seismic surveys show a strong refractor in about 10-15m depth, which corresponds well to the depth of the shear plane. This has also been identified in the previous project *InterRisk,* as to the boundary Marls/Limestone. The inverted model of the geoelectrical resistivity shows inhomogeneous conditions along the slope (Fig.4).

Figure 3. Locations of respective installations (Note: Further equipment is implemented but here not displayed).

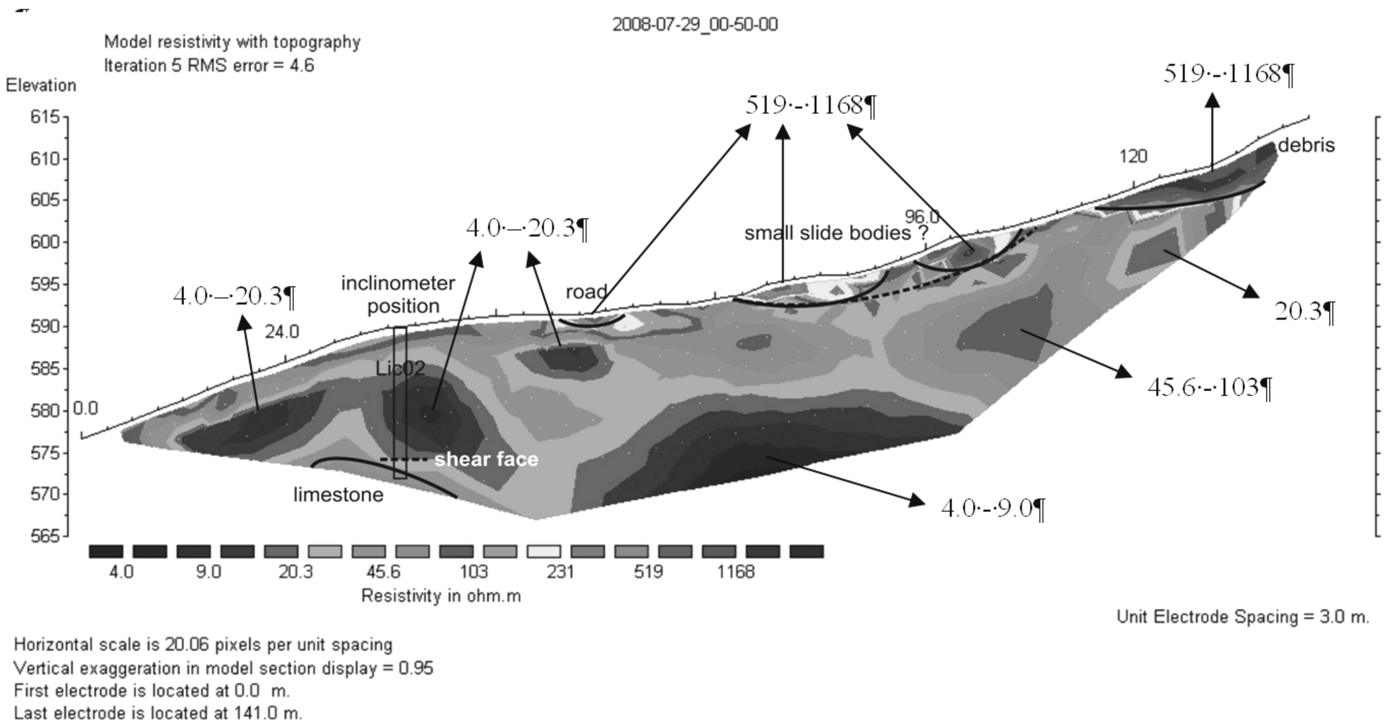

Figure 4. Model resistivity with topography of geoelectric profile 1 (Note: Some resistivity values are inserted for clarity.

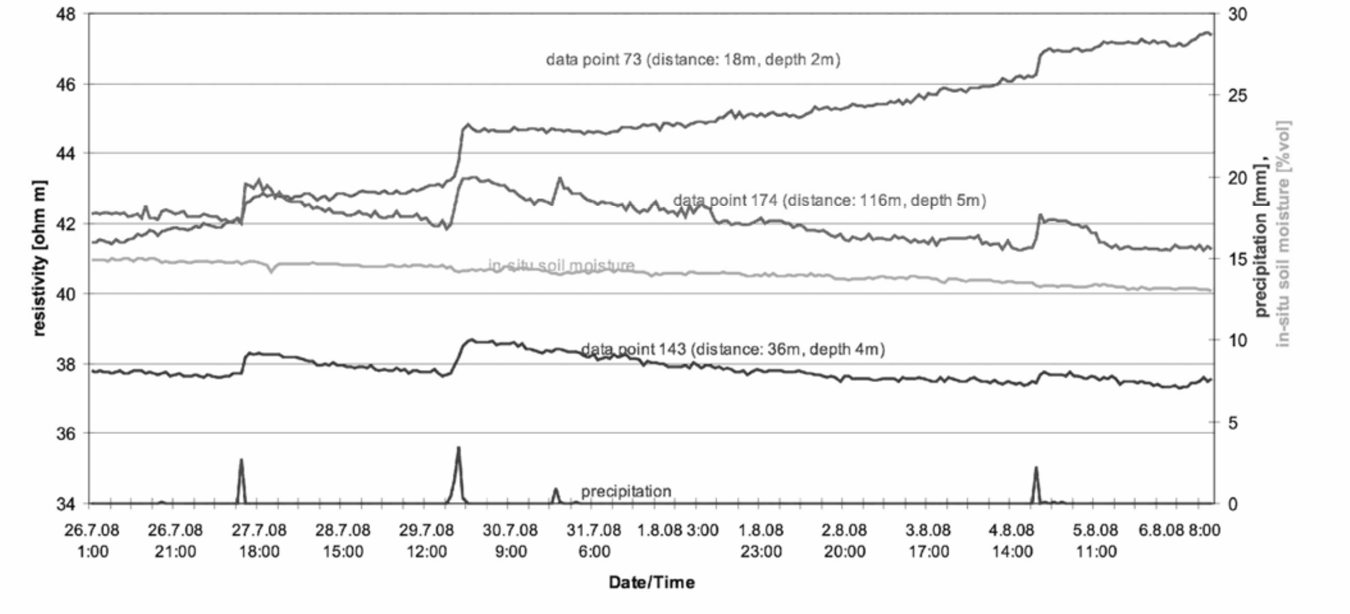

Figure 5: Measurements of the geoelectric monitoring system between 26.07 and 06.08.2008.

The analysis of the combined data of the geoelectric monitoring system and precipitation shows the effects of increasing resistivity at low depth during intense rainfall. One explanation could be, that this behaviour is due to decreasing concentration (attenuation) of dissolved ions in the pore fluid (Fig. 5). The effect seems to be limited to the upper part of the slope (rock debris), it is probably attributed to the high pore volume (fast infiltration). The web processing service of CHASM is implemented and currently works on a test data set. These tests show that further analysis and parameter calibration is necessary to explain slope behavior in the model more precisely. Due to the need of additional reliability tests, the results are not online and access is limited to project members only. Therefore, no further results can be provided at present.

4 PERSPECTIVES

Another installation of a second geoelectric profile perpendicular to the existing one is planned. The development of the automated data transfer and processing will continue. An important part of the analysis is the identification of critical parameters and values supported by the ILEWS-partner *Setup Monitoring* and *Geomorphic Modelling* to determine critical landslide activity. As soon as further calibrations of CHASM are accomplished the web processing service can be run with the real-time measured data. This includes not only soil moisture data, but also all other available information. The overall aim herein is that at the end of an optimisation period the system can run autarkic and has to be only supervised by experts.

The first results show already measurable effects of rainfall events. With continuing monitoring, larger scale effects, for example seasonally variations will become visible. At least it should be possible to determine critical soil moisture values, to predict the slope's active phases. The other sub-projects are also currently working on their specific research question. Within 2009, the links and interrelations between the different subprojects will be merged. As already pointed out in the introduction, of particular importance is herein to display and provide the information adopted to the different user groups and stakeholders.

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