

Combining landslide research with capacity building: the experience of the United Nations University – ITC School for Disaster Geo-Information Management.

By:

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1. INTRODUCTION

Given the increasing trend in disasters and disaster related losses, there is an urgent need to include the concepts of disaster risk management into planning, sustainable development and environmental impact assessment. One of the important requirements to carry out an effective disaster risk management is capacity building and training of disaster management experts and professionals, such as planners, engineers, architects, geographers, environmental specialists, university teachers etc. The Hyogo framework of action 2005-2015 of the UN-ISDR indicates risk assessment and education as two of the key areas for the development of action in the coming years. Disaster risk management requires the assessment of risk, which is a multi-disciplinary endeavour that requires the integration of many types of spatial information. ITC is one of the world's leading organizations that combine research, training and capacity building in the field of geo-information science and earth observation.

The International Institute for Geo-Information Science and Earth Observation (ITC) was founded in 1950 as the International Training Centre for Aerial Survey, with the aim to foster the international exchange of knowledge, focusing on capacity building and institutional development in developing countries and emerging economies. ITC provides international postgraduate education, research and project services in the field of geo-information science and earth observation using remote sensing and GIS. Due to government policy ITC was embedded as the sixth faculty in the University of Twente (UT) in January 2010. The core activities are executed by about 245 staff, organized in six scientific departments covering ITC's knowledge field: Earth Observation Science, Geo-Information Processing, Natural Resources, Earth Systems Analysis, Urban and Regional Planning and Geo-Information Management, and Water Resources.

Over the years, ITC has developed a wide selection of courses in its degree, diploma and certificate programmes in geo-information science and earth observation. These courses are offered in the Netherlands, online and abroad by ITC itself or by ITC in collaboration with reputable qualified education organizations (joint courses). Our courses aim at providing in-depth study of a particular set of problems in developing countries and emerging economies. They attract young and mid-career professionals with an interest in development-related issues. More than 20,000 students from over 175 countries have completed ITC courses since 1950 (See figure 1). The majority of these participants are professionals in their respective fields, with prior academic training and (often) professional experience.

2. UNU – ITC DGIM

Since 2005 ITC is an associated institution of the United Nations University (UNU). The cooperation between ITC and UNU is directed at developing and carrying out a Joint Programme on Capacity Building in Disaster Management and in Land Administration, and at disseminating knowledge of these and directly related issues.

The main objective of the UNU-ITC School for Disaster Geo-Information Management is to support capacity building of organisations in developing countries through training of individuals in the

collection, management, analysis and dissemination of spatial information before, during and after disaster events, in order to reduce the impacts of natural and related environmental and technological hazards. The central component of UNU-ITC DGIM is to support networks of Universities and training institutes from developing countries that are involved in training and research in the use of geo-information science and earth observation for disaster risk management. UNU-ITC DGIM carries out joint training courses, of long duration, leading to postgraduate or Master degrees, and short duration courses with members of the network, as well as actively promoting research collaboration and joint consulting projects, also involving international organizations in the field of disaster management. The activities within UNU-ITC DGIM can be grouped as follows:

Training, education and curriculum development

- Support of university network programs with universities from Africa, Asia and Latin America.
- Organisation of decision maker workshops in developing countries
- Organisation of short courses with university partners
- Organisation of medium duration tailor-made training courses at ITC and in target countries
- Development of joint education programmes with universities from developing countries on disaster geo-information management.
- Development of distance education courses on geo-information science and earth observation for disaster risk management.

Knowledge development and research collaboration

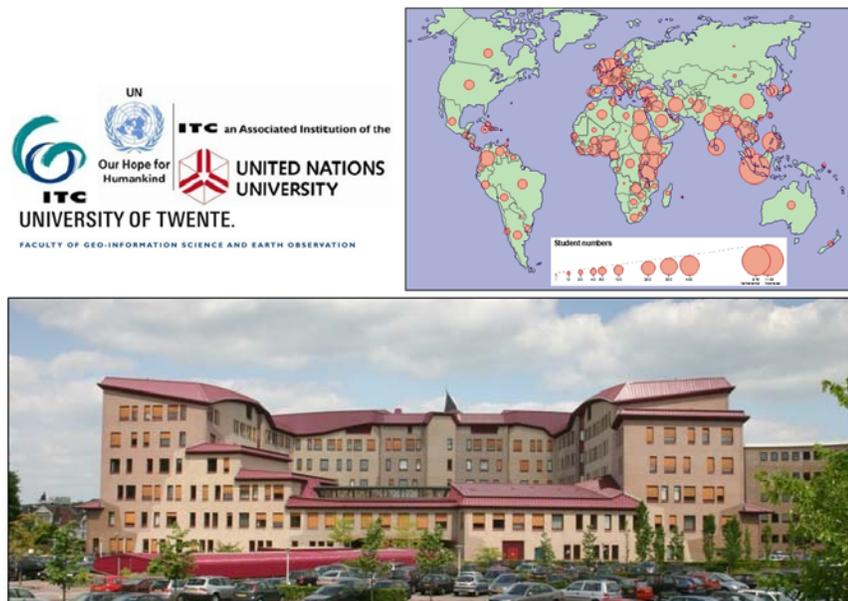
- Research projects
- PhD research
- Visiting scientist programme
- Support in setting up research programmes with partner organizations.
- Small grants programme for presentation of results in conferences

Capacity building projects

- Aimed at supporting organizations
- Aimed at training of individuals
- Aimed at networking of organizations
- Aimed at development of methodologies for spatial analysis and Disaster Risk Management

The UNU-ITC DGIM School is housed by the Department of Earth Systems Analysis, which has 25 scientific staff and 30 PhD researchers.

Figure 1: United Nations University – ITC School for Disaster Geo-Information Management. Upper left: logo; Upper right: distribution of alumni from ITC; bottom: ITC building in Enschede, The Netherlands.



2. LANDSLIDE RESEARCH AT UNU-DRM

The UNU-ITC DGIM School focuses on several types of hazards, but landslide hazard and risk forms one of the key components. The focus of the landslide research is on the application of spatial information, with emphasis on Remote Sensing and GIS, in landslide inventory mapping, and the use of landslide information in landslide susceptibility, hazard and risk assessment. In the following sections some of the components of the landslide related research are presented.

2.1 Development of methods for landslide inventory-mapping

A comprehensive landslide inventory is a prerequisite for planning immediate landslide disaster response, and for quantitative landslide hazard and risk assessment. Landslides are generally isolated natural processes, which individually may not be of very large in size but can occur with a high frequency in an area (van Westen et al., 2006). Landslide inventories can be prepared through various methods (van Westen et al., 2008) such as historical archive studies, interviews, detailed geomorphologic fieldwork, and mapping from remote sensing data and topographic maps. Techniques used to prepare landslide inventory maps depend on the quality and accessibility of desired information, the scope and the extent of the study area, the scales of base maps and the resources available to carry out the work.

Only for specific cases landslide inventories could be complete such as those recording cut slope failures along transportation corridors, collected for maintenance purposes. In our research we develop methods to utilise maintenance records to prepare a substantially complete landslide inventories along transportation lines (Jaiswal et al, 2010a). These inventories can be used for quantifying landslide hazard and risk along transportation lines and use this information for the adjacent natural slopes where landslide data are scarce. The historical records can also be used in rainfall threshold analysis, which later formed the basis for the identification of hazard from slope failures on natural slopes and for the development of a landslide warning system (Jaiswal et al, 2010b).

In order to be able to express the spatial and temporal probability of landslides in medium scale hazard maps, it is important to have insight in the location of landslides and their behaviour through time. One of the techniques used to generate such maps is to generate multi-temporal landslide maps, linking the landslides to triggering events and use the temporal probability of the event in the hazard assessment combined with the spatial probability resulting from the statistical analysis (Blahut et al, 2010). The research focuses on the development of landslide inventory maps for different triggering events, based on the available information in the forms of landslide maps, images and archives. These maps should portray the landslide patterns and types of triggering events with a range of return periods, which can be used to analyse the temporal and magnitude probabilities (Ghosh et al., 2009; 2011).

Although the generation of inventory maps using stereo-image interpretation by experts is considered to be most accurate, it is also very time consuming. Alternative approaches for (semi) automated mapping using remote sensing data are also being developed, either using InSAR (Singh et al., 2005), LiDAR (Razak et al., 2011), or optical high resolution satellite data (Tapas et al., 2010c). Since pixel-based methods have not produced sufficiently accurate results for detection and classification of landslides, object-oriented analysis (OOA) which imitates the human interpretation process in identification of landslides, has emerged as a good alternative recently due to the inherent ability of OOA to incorporate additional information layers such as digital terrain models (DTMs) and thematic maps in the analysis (Lu et al., 2011; Tapas et al, 2010a; 2010b; 2010c). The research focused on the development of semi-automatic image analysis algorithms that combine spectral, shape, texture, morphometric and contextual information derived from high resolution satellite data and DTMs for the preparation of new as well as historical landslide inventories. The main innovative aspect of the research lies in the selection of landslide diagnostic parameters and their use in the comprehensive characterisation of different types of landslides, a concept which is addressed for the first time for detection of landslides in an object-based environment.

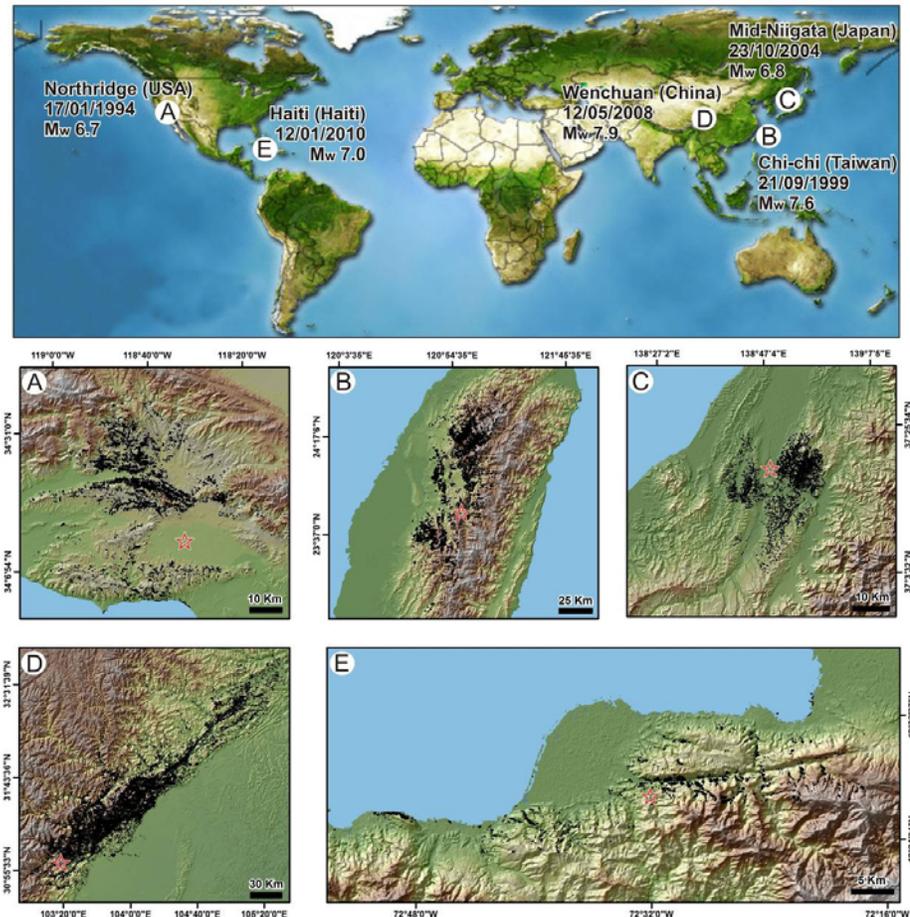
2.2 Earthquake-induced landslide studies

Large earthquakes (above M 6.5) may trigger thousands of landslides in mountainous terrains. Studies from past earthquakes show that the density of earthquake-induced landslides generally decreases

with distance from coseismic faults and epicenters. However, the roles of different fault types and geometries in coseismic landsliding and their controls on the spatial distribution of earthquake-induced landslides are not fully understood. One of the research areas is the study of landslides induced by historical earthquakes and its associated types of coseismic faulting mechanisms (See Figure 2). We found that the density of coseismic landslides was varied with changes in fault type, coseismic slip rate and stress rotations. Studies have been carried out in relation to the 2005 Kashmir earthquake in Pakistan (Bahar Saba et al., 2010), the 2008 Wenchuan earthquake in China (Gorum et al., 2011) and the 2010 Haiti earthquakes (Gorum and van Westen, 2011).

A specific research component deals with the analysis of earthquake induced landslides dams. Landslide dams caused by earthquakes are extremely dangerous phenomena, as they may trigger devastating dam-break floods that can affect large areas downstream. We analyzed an unprecedented inventory of 828 landslide dams triggered by the 2008 Wenchuan earthquake, China (Xu et al., 2009; Fan et al., 2011). Of the 828 landslide dams, 501 completely dammed the rivers, while the others only caused partially damming. Four types of dams were identified based on their composing materials and deposition features. We also analyzed the failure rate of dams, as the percentage of the number and area of landslide dams that have failed over time. The survival time of landslide dams agrees well with two worldwide datasets. A comparison with relations of lake volume in worldwide datasets revealed that the volume of lakes triggered by the Wenchuan earthquake were higher than those elsewhere given the same landslide volume, thus posing a higher consequent dam-break flood risk to the downstream area.

Figure 2: Different landslides inventories compiled for future activities, both from own work and from other sources. (a) Northridge earthquake (1994); (b) Chi-Chi Taiwan earthquake (1999), (c) Mid-Niigata Japan earthquake (2004); (d) Wenchuan earthquake, China (2008) and (e) Haiti earthquake (2010).



2.3 Methods for landslide susceptibility and hazard assessment

One of the main aims of our research is to propose effective methods for landslide susceptibility and hazard assessment for different scales that are suitable for application in different regions with variable data availability.

In the rare occasions when nearly complete landslide inventories are available, for instance along transportation corridors, landslide hazard can be analyzed directly based on frequency analysis of the landslide events. In a study in the Nilgiri hills in India, a Gumbel analysis was carried out to determine the frequency of landslides on cut slopes and on natural slopes for certain units of the transportation line. Logistic regression analysis was carried out to model the susceptible areas to landslides on natural slopes. Rainfall threshold analysis was used to estimate the temporal probability of landslides, and magnitude-frequency analysis to obtain the probability of landslide size. These data were combined in an analysis of landslide initiation hazard on cut and natural slopes (Jaiswal et al., 2009; 2010a; 2010b).

For medium scale landslide hazard analysis the variability and complexities of the landslide-prone terrains and the landsliding processes prevalent there, need to be analyzed in detail, so that the aspects of variable controls of landsliding factors can be better understood. This is often challenging because landslide source data sets and factor information are usually scarce and/or filled with incomplete information. Despite many efforts, predictive mapping of landslide susceptibility remains a complicated first step for any hazard and risk analysis. Due to variable terrain conditions and different landsliding processes, predictive mapping of landslide susceptibility based only on heuristic/subjective methods, could be a useful approach, especially when not enough data is available to carry out additional statistical analysis (Castellanos and van Westen, 2007a). In the case where sufficient data is available, empirical methods for landslide susceptibility assessment, such as logistic regression (Ghosh et al. 2010), and Artificial Neural Networks (Mechiorre et al., 2011) can perform better. These empirical methods (e.g., statistical or mathematical) depend on two types of spatial associations: (a) spatial associations of individual spatial factors with historic landslides of a certain type; and (b) the relative importance of individual spatial factors with respect to one another in relation to landslide occurrences. Although, multivariate statistical methods can simultaneously model both the above two types of empirical spatial associations, yet some of the spatial factors selected and used by them according to certain (statistical) criteria are sometimes not representative of specific genetic processes associated with the type of landslides being studied (Ghosh et al., 2010). Whereas, bivariate statistical methods, although intuitive, can only model the first type of spatial association, and thereby, exhibit moderate prediction rates. Therefore our research focuses on the development of suitable empirical methods to study the spatial association to select the most appropriate spatial factors that approximate realistic genetic associations with landslides of a certain type, and objectively determine the importance of every spatial factor with respect to the others in relation to the landslide type under study and combine them using the multivariate methods.

The drawback of the heuristic and statistical methods is that they cannot be used to simulate the effects of changing conditions on slope stability, e.g. due to climate change or land use change. In these cases dynamic deterministic models for slope stability are preferred. Our research focuses on the use of Open Source software for dynamic modelling of slope stability (PCRASTER). In a recent study carried out in a steep catchment along the western slopes of the Western Ghats of Kerala state, India, the effect of land use change on slope stability was modelled. A physically-based spatially distributed shallow landslide initiation model named STARWARS (Storage and Redistribution of Water on Agricultural and Revegetated Slopes) + PROBSTAB (Probability of Stability) model was used after comparing it with other available GIS based models (e.g. SINMAP, TRIGGRS, SHALSTAB) (Sekhar et al., 2008). Climatic and hydrological data necessary for this was acquired from automated open stand pipe piezometers, automated discharge stations (stage gauge) and automated weather station. The parameterization of the model, especially in relation to soil depth and properties, and the vegetation characteristics proven to be a very intensive procedure, which may hamper the application of such models over larger areas (Sekhar et al. 2009).

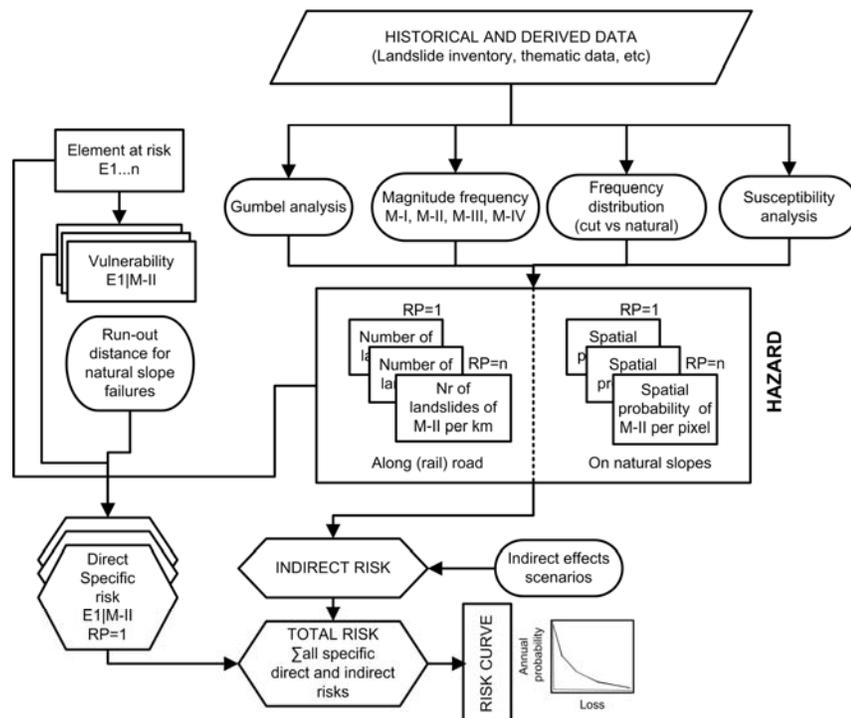
After analyzing the initiation hazard, a subsequent landslide run-out analysis has to be included as many of the landslides cause damage to the elements at risk located downslope of their initiation

areas. Several approaches for landslide runout analysis are being used in our research, ranging from empirical methods based on reach angles (Castellanos et al., 2008) to numerical modelling approaches using runout models such as RAMMS, Flo-2D, MASSMOV or DAN-3D (Quan Luna et al., 2010b). One of the main challenges again is the parameterization of the runout models, especially when they are used over larger areas as input in a probabilistic risk assessment.

2.4 Landslide risk assessment.

Landslide risk assessment remains one of the main challenges in our research, as it contains many aspects which are difficult to quantify (van Westen et al., 2006). Nevertheless, we have developed different approaches for different scales of analysis. In Cuba we developed a methodology and its implementation for spatial landslide risk assessment, using a multi-scale approach at national, provincial, municipal and local level (Castellanos and Van Westen, 2007a; 2007b). At the national level a landslide risk index was generated, using spatial multi-criteria evaluation techniques in a GIS system. The results were analysed per physiographic region and administrative units at provincial and municipal levels. The risk assessment at the provincial scale was carried out by combining heuristic and statistical landslide susceptibility assessment, its conversion into hazard, and the combination with elements at risk data for vulnerability. Five different landslide types were analyzed separately (small slides, debris flows, rock falls, large rockslides and topples). The susceptibility maps were converted into hazard maps, using the event probability, spatial probability and temporal probability. Semi-quantitative risk assessment was made by applying the risk equation in which the hazard probability is multiplied with the number of exposed elements at risk and their vulnerabilities. At the municipal scale a detailed geomorphological mapping formed the basis of the landslide susceptibility assessment. At the local level, digital photogrammetry and geophysical surveys were used to characterize the volume and failure mechanism of the existing landslides and a runout model was used to model runout. Several scenarios with different initial volume were simulated and the landslide risk for houses was estimated considering their typology and condition. The methodology developed in this study can be applied in with certain modifications, in other countries as well (Castellanos and Van Westen, 2007a; 2007b).

Figure 3: Example of a flow diagram showing the process for landslide risk analysis (Jaiswal et al., 2010a).



More recent work on quantitative landslide risk assessment focused on estimating the direct and indirect risk to landslides based on a procedure illustrated in Figure 3 (Jaiswal et al., 2010a). To assess direct risk the following steps were taken: (1) estimation of landslide hazard for a specific return period; (2) estimation of run-out distances for potential landslides, (3) mapping and quantification of the elements at risk, number of people and properties (monetary value), and assessment of their temporal and spatial probability to be in an exposed position, (4) assessment of probability of the landslide reaching the elements at risk (Quan Luna et al., 2010a), (5) assessment of the vulnerability of the elements at risk, in terms of property damage (monetary loss) or loss of life, resulting from the specified landslide magnitudes, and (6) estimation of specific risk for each element at risk for various landslide hazard. The analysis of indirect risk requires determination of the most important elements and activities in the area and how they could be affected due to the disruption (e.g. local businesses, residents, tourists, and transport department). Specific risk is estimated individually for each element at risk for a specific landslide hazard and then total risk is calculated by adding all the specific losses of both direct and indirect risks, separately for the property loss and the loss of life.

Another important component in our research is on the use of risk information for disaster risk reduction. One of the components focuses on the visualization of risk information using WebGIs applications, and the development of collaborative Web-mapping applications for landslide mapping (Frigerio and van Westen, 2010). Also the comparison of landslide risk with risk due to other hazard types, and the analysis of multi-hazard risk is an important aspect, which is also closely linked to our capacity building activities.

3. RESEARCH COLLABORATION

Research within the UNU-ITC DGIM School takes place within the Disaster Management research programme, lead by Prof. Victor Jetten. The Disaster Management research has as an overall goal to reduce the impact of disasters by means of prevention, mitigation/conservation, protection and awareness building. To achieve this we focus on three areas of investigation: (1) Understanding and predicting geohazard processes, (2) Analyzing and modelling the risk on multiple scales, and (3) Use of spatial information in Disaster Management. In the past years we have seen a steady growth of PhD researchers, and currently we have people from China (1), Colombia (1), Costa Rica (1), Ethiopia (1), Guatemala (1), Indonesia (1), India (7), Kenya (1), Malaysia (2), Pakistan (2), Turkey (1), Rumania (1), Germany (1) and Vietnam (1), working on topics such as landslide hazard and risk assessment, earthquakes intensity mapping, soil erosion and land degradation monitoring, and multi-hazard risk assessment. The School also welcomed several visiting scientists and PhD students, who came to ITC for a short period. Research projects are either carried out through bilateral agreements with partner organisations, or through internationally funded projects.

3.1 Bilateral research projects

Below a number of bilateral research projects are mentioned:

- In **Cuba** a joint research project was initiated with the Instituto de Geología y Paleontología (IGP). This resulted in a PhD research by Castellanos Abella (2008) on Multi - scale landslide risk assessment in Cuba. The author became director of IGP and created a national expert group on landslides which produced national guidelines, and participated in a national project on multi-hazard risk assessment in Cuba together with the Cuban Civil Defence organisation.
- In **India** a joint research project was carried out with two Indian partners: National Remote Sensing Centre (NRSC), and the Geological Survey of India (GSI). A separate agreement was made with the Centre for Earth Science Studies (CESS). The research focuses on the use of geo-information science and earth observation for landslide hazard and risk assessment in several test sites in the Himalaya and in the Western Ghats in India. The research was carried out by scientists from the organizations, who carry out a sandwich PhD. In December 2010 and in July 2011 5 Indian PhD researchers defended their PhD at ITC/University of Twente:
 - Sekhar Lukose Kuriakose (CESS, Kerala, India): Physically - based dynamic modelling of the effect of land use changes on shallow landslide initiation in the Western Ghats of Kerala.

- Tapas Ranjan Martha (NRSC, India): Detection of Landslides by Object-Oriented Image Analysis.
- Saibal Ghosh (GSI, India): Knowledge-Guided Empirical Prediction of Landslide Hazard.
- Pankaj Jaiswal (GSI, India): Landslide risk quantification along transportation corridors based on historical information.
- Iswar Das (IIRS, NRSC, India): Stochastic approaches for landslide hazard and vulnerability assessment.
- In **Pakistan** research was initiated after the 2005 Kashmir earthquake and two researchers from Pakistan are carrying out their research in ITC:
 - Sumbal Bahar Saba (Pakistan): Remote Sensing methods for monitoring changes in landslide activity
 - Mohammed Shafique (Pakistan): Modelling topographic seismic amplification
- In **China** collaboration was initiated in 2007 with the Chengdu University of Technology (CDUT), China. CDUT has become the State Key Laboratory of Geo-hazards Prevention and Geo-Environmental Protection (CDUT-SKLGP). A joint research was initiated with two PhD researchers who are working on earthquake induced landslide hazard assessment following the 2008 Wenchuan earthquake:
 - Tolga Gorum (Turkey): Analyzing the relation between earthquake induced landslide distribution and seismic and environmental factors.
 - Xuanmei Fan (CDUT, China): Analyzing the causal relationships, hazard aspects and decay rates for earthquake-induced landslide dams.
- In **Vietnam** research collaboration is ongoing with the Water Resource University (WRU) and the Research Institute of Geology and Mineral Resources. Currently one PhD, Nguyen Thi Hai Van is carrying out a research on “Geohazard and risk assessment for a Vietnamese mountainous municipality by combining participatory GIS and modelling - A case study in Yen Bai town, Vietnam”.
- In **Indonesia** ITC has been collaborating with the Geography Department of Gadjah Mada University in Yogyakarta for many years. Some years ago a joint MSc course on Geo-Information for spatial planning and risk management was initiated. Linked to this many MSc research topics were conducted on landslide related aspects and currently one joint PhD researcher, Nugroho Christanto, is carrying out a research on “Integrated analysis of the hydrological cycle, land use/cover change and landslide risk in a tropical mountainous area”.
- In **Malaysia** ITC is collaborating with several organizations, such as the University Putra Malaysia (UPM) and currently two PhD researchers are carrying out their PhD research in ITC:
 - Khamarrul Azahari Razak: Landslide Mapping and Displacement Analysis in Forested Terrain using High Resolution Airborne Lidar Data
 - Frederick Francis Tating: Slope Stability Assessment of Former Open Pit Mine: Integrating Slope Stability, Slope Failure Impact and Hazard Assessment
- In **Thailand** a programme on joint research and capacity building has been developed with the Land Development Department. This collaboration deals with the organization of joint courses and the execution of joint PhD research in the field of land degradation, flood modelling and risk assessment.

3.2 International research projects

Apart from bilateral research agreements the UNU-ITC DGIM School has also been active in several international research projects related to landslides, most of which were funded by the European Commission under the 6th and 7th framework programmes. The most important ones are:

- **DESIRE** is an EU FP6 Integrated Project on desertification mitigation and remediation of land. The project aims at developing strategies to combat land degradation in the Mediterranean region and other dry areas around the world. Although this project mostly deals with land degradation there

are also certain components dealing with landslides. Currently ITC has 3 PhD researchers working for this project.

- **Mountain Risks.** This project was part of the EU Marie Curie Human Resources and Mobility Programme, and took place from 2006 to 2010 with the aim to develop an advanced understanding of how mountain hydro-geomorphologic processes behave and to apply this knowledge to long-term cohabitation with such hazards. The Mountain Risk project involved 18 research positions with a total of 14 partners, working on topics such as hazard analysis, quantitative risk assessment, risk management and risk governance. ITC has been involved in the development of methods for the use of landslide runout models in probabilistic hazard and risk assessment. One of the PhD researchers, Byron Quan Luna, has developed a method on this topic.
- **SAFELAND:** this is a large EU FP7 landslide project, which started in May 2009 under the leadership of NGI (Norway), and comprises of 25 partners. It is aimed at developing generic quantitative risk assessment and management tools and strategies for landslides in Europe. ITC is involved in several components:
 - The development of tools for automated landslide detection using Object Oriented Image Analysis based on optical high resolution remote sensing data. One PhD researcher, Andree Stumpf is working on the development of advanced OOA techniques for landslide recognition, characterization and monitoring with remotely sensed data from passive optical sensors, together with CNRS, Strasbourg, France.
 - The development of guidelines for landslide hazard and risk assessment, together with several partners, lead by the Polytechnical University of Catalunya, Spain.
 - The application of Decision Support Systems for group decision making related to the inclusion of landslide information within land use planning, together with IIASA, Austria.
 - The development of a GIS-based training course on landslide hazard and risk assessment, together with the University of Salerno, in relation with the international LARAM School on landslide risk management.
- **CHANGES:** Changing Hydro-meteorological Risks – as Analyzed by a New Generation of European Scientists. This EU FP7 Marie Curie Initial Training Network started in 2011 and has a total duration of 4 years. It will develop an advanced understanding of how global changes (related to environmental and climate change as well as socio-economical change) will affect the temporal and spatial patterns of hydro-meteorological hazards and associated risks in Europe; how these changes can be assessed, modelled, and incorporated in sustainable risk management strategies, focusing on spatial planning, emergency preparedness and risk communication. A schematic representation of the project is given in Figure 4. High-level training facilities as well as scientific and technological excellence will be provided to the next generation of researchers in the field of hazard and risk management. The network consists of 11 full partners and 6 associate partners of which 5 private companies, representing 10 European countries. A series of 12 PhD positions, financed by the European Community, are available with the partners.

3.3. International support

Although the UNU-ITC DGIM does not aim being a rapid damage mapping organizations, such as DLR-ZKI, UNITAR/UNOSAT or SERIT, we have been active in collecting and providing geo-information to partner organizations after the occurrence of major disaster events. For instance after the Kashmir earthquake in 2005, there was a large need to topographic maps expressed by relief organizations. ITC provided support by producing 49 topographic maps at scale 1:50,000 of the Pakistan earthquake area to aid relief workers and agencies in the field. After the Indian Ocean tsunami ITC developed a website with links to a number of websites with relevant images and map data products of the areas affected by the tsunami disaster. ITC staff also provided support in Aceh and Sri Lanka. ITC supported its counterpart University Gadjah Mada with the assessment of damage to buildings in the Yogyakarta area after the earthquake of 6.2 Magnitude which occurred on 27 May 2006. ITC provided 25 GPS systems which were used by staff and students from UGM in the house-by-house survey, especially in the Bantul area. ITC also supported UGM financially so

that overflights could be made and a series of small format aerial photographs could be taken of the Bantul area. Also after the earthquakes in Wenchuan (2008), Haiti (2010) and Chili (2010) support was given by mapping landslides triggered by the earthquake events.

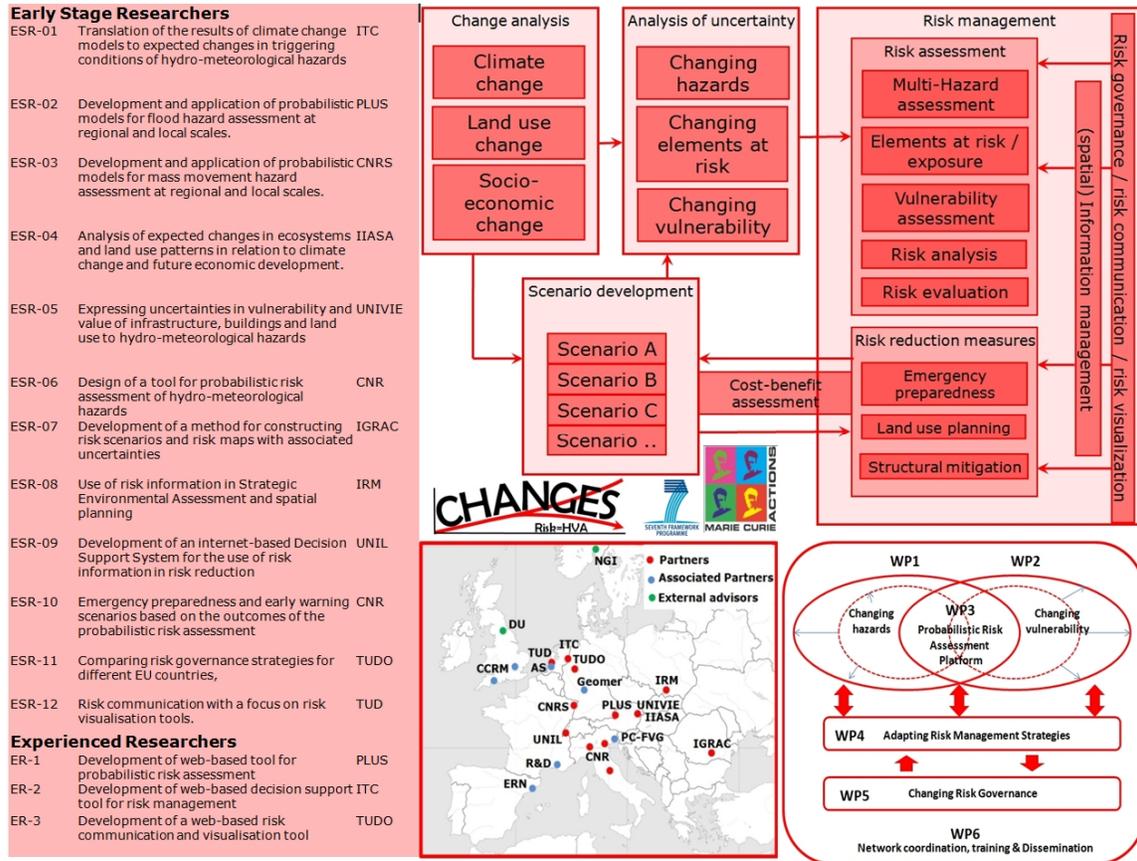


Figure 4 : The CHANGES project. Overview of the project structure, the partners and the research positions.

4. CAPACITY BUILDING

Capacity development is identified by a recent UN-ISDR study as one of the most important themes in disaster risk reduction. It is defined as “the process by which people, organizations and society systematically stimulate and develop their ability over time to achieve social and economic goals, including through improvement of knowledge, skills, systems, and institutions - within a wider social and cultural enabling environment.” Capacity building related to landslide hazard and risk assessment is one of the key-activities within the UNU-ITC School for Disaster Geo-Information Management. In ITC itself, the School organizes together with the Department of Earth Systems Analysis a challenging programme of MSc courses and short courses:

- Remote Sensing and GIS for Natural Hazard Assessment
- Natural Hazards Modelling and Risk Assessment
- Risk Management and Environmental Assessment for Spatial Planning
- Distance course in Multi-Hazard Risk Assessment

These courses are targeted at professional workers who wish to increase their knowledge and skills. But also MSc. students who are interested to follow courses outside their home institution will find these courses beneficial. Information on the courses can be obtained from www.itc.nl

4.1 Development of training materials

As part of the capacity building activities of the United Nations University – ITC School on Disaster Geo-Information Management (UNU-ITC DGIM) we developed a training package on the application of GIS for multi-hazard risk assessment. The package, called RiskCity comprises a complete suite of exercise descriptions, together with GIS data and presentation materials on the various steps required to collect and analyse relevant spatial data for hazard, vulnerability and risk assessment in an urban environment. The exercises deal with a hypothetical case study, hence the name RiskCity. Most of the data was derived from the city of Tegucigalpa in Honduras, but has been adapted to make the exercises more didactical. They aim to give an understanding of the basic concepts involved in risk assessment, and allow the students to have an idea on how GIS can be used for analysing the different types of hazards, creating an elements at risk database, assessing vulnerability, making loss estimations using qualitative and quantitative methods, carry out a cost benefit analysis, and use the data for urban planning and disaster risk management. The package has been developed in collaboration with several partner organizations in different continents, and is used as the basis for a series of courses. The package is used also in a distance education course (See Figure 5). Courses on multi-hazard risk assessment are offered annually in the Netherlands, Mexico, Bolivia and Thailand and frequently in India and China as well. The materials have been translated into Spanish, Chinese, Vietnamese and Georgian and form the basis of many short courses that are given with partner organisations in different countries.

In the framework of two European projects (FP6-PEOPLE-2006-ITN Marie curie Mountain risks and FP7 SafeLand) a training package has been developed on the use of spatial information for the assessment and management of mountain risks (Van Westen et al., 2010). This training package explains the procedures to collect analyze and evaluate spatial information for risk assessment from natural hazards in a mountainous environment. It aims at researchers and practitioners that have to carry out risk assessments at a medium scale, and use the risk information in disaster risk reduction planning. The training package guides the participants through the entire process of risk assessment, on the basis of a case study of an area exposed to multiple hazards in Barcelonnette, France. In order to achieve maximum applicability the training package is made for use with Open Source software. Three-dimensional stereoscopic image interpretation using images downloaded from Google Earth is used to familiarize the participants with the hazard phenomena. These are then used in either a statistical or heuristic approach for modelling the initiation areas for landslides, debris flows, snow avalanches and rock falls. The source areas are used for run-out modelling on a medium scale using a routing-spreading model and the results are converted into impact maps. The source maps and run-out maps for mass movements and the flood maps are then used in a quantitative multi-hazard risk assessment, by calculating the exposed elements at risk, the temporal and spatial probability and the vulnerability of the elements at risk. Also emphasis is given to the evaluation of uncertainty in the risk assessment process. A qualitative method for multi-hazard risk assessment is also included, using Spatial Multi-Criteria Evaluation, in which a hazard index and a vulnerability index are generated. The final part of the training package deals with the use of risk information for disaster risk management, e.g. by incorporating the risk information in preparedness planning, cost-benefit analysis for the planning of remedial measures, and land use zoning.

4.2 Supporting University Networks

Contacts with universities with existing curricula in disaster risk management or plans for development hereto were strengthened through the formation of university networks. Three of such networks are now functioning:

- UNeDRA: the United Nations University Network for Disaster Risk Reduction in Africa was initiated during an international workshop at Makerere University in Kampala, Uganda in September 2005.
- CASITA: “Capacity building in Asia using information technology applications in disaster management“, network in SE Asia, with the Asian Disaster Preparedness Center (ADPC) as main counterpart.

- RULER: focusing on Universities in Latin America. The University network, with the name RULER (Red Universitaria Latinoamericana de Estudios de Riesgo) was established in a workshop in Guatemala in June 2008.

The aims of the University networks are to:

- share experiences on course activities that have already been initiated;
- identify universities that have interest in developing such courses;
- learn about other initiatives on disaster management training programmes;
- learn about other programmes on the use of Geo-Information for disaster management;
- make an inventory of the requirements for support for setting up educational programmes on Geo-Information for disaster management.

Several meetings were held with representatives of the participating universities and e-mail discussion groups and websites were made. Training courses were offered to the teaching staff of the participating universities and a number of fellowships were provided to participants from universities related to the university networks to study at ITC in the Netherlands, either for short courses of 3 months, or for full 18 months courses in Geo-Information Science and Earth Observation for Geohazard Assessment.



Figure 5: Capacity Building at UNU-ITC DGIM. Upper left: Opening screen of the distance education course on Multi-hazard risk assessment; Upper right: website for course information; Bottom: multi-cultural group of students at ITC following a course on risk assessment.

4.3 Joint courses

Over the past years UNU-ITC DGIM developed a number of joint educational programmes, with the following institutes:

- The Indian Institute of Remote Sensing (IIRS), Dehradun, India: a joint course on Geo-Information for Disaster Management at Postgraduate and MSc level.

- Also with the IIRS a joint short course is organized annually on “Image interpretation for natural hazard applications”
- The Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP), in Dehradun, India: a joint course of 4 weeks which focuses each year on a different type of hazard.
- The Geography Department of Gadjah Mada University, Yogyakarta, Indonesia: a joint MSc degree course was established on Geo-Information for spatial planning and risk management
- The Centro de Investigaciones en Geografía Ambiental (CIGA) of the Universidad Nacional de Mexico (UNAM): an annual joint short course on "Geo-Información para la Evaluación y Manejo del Riesgo a Múltiples Amenazas".
- The Centro de Levantamientos Aeroespaciales y Aplicaciones de Sistemas de Información Geográfica para el Desarrollo Sostenible de los Recursos Naturales (CLAS), UMSS, Cochabamba, Bolivia: an annual joint 3 weeks course on "Evaluación del Riesgo de Amenazas y Desastres Naturales".
- The Asian Disaster Preparedness Center (ADPC) and the Asian Institute of Technology (AIT) in Bangkok, Thailand: annually we organize two joint 2-week courses on “GIS for Disaster Risk Management”.
- The Regional Centre for Mapping of Resources for Development (RCMRD), Nairobi, Kenya; Egerton University, Njoro, Kenya; Addis Ababa University, Addis Ababa, Ethiopia: a joint 4-month short course on “Applications of Earth Observation and GIS in Integrated Water Resources Management”.

In the coming period also joint courses are planned in South Africa, East Africa and Brazil.

4.4 Short courses and workshops

Apart from the regular courses UNU – ITC DGIM also organises short courses and workshops on a case-by-case basis. Some examples of courses related to landslides which have been given in the past years were:

Africa

- Short course entitled “Geo-information for Disaster Management in Eastern Africa”. As a contribution to the UNEDRA University network a series of courses were given in several African countries, with the Makerere University, Kampala, Uganda.
- Building Disaster Management Capacity in Western Africa with Indigenous Space Infrastructure, with the Regional Centre for Training in Aerospace Surveys (RECTAS), and the National Space Research and Development Agency (NASRDA), Nigeria
- Contribution to the CEOS TIGER programme, which aims at organising training workshops for space technologies for water resources management in Africa
- An IEE-IGARSS pre-conference workshop on GEONETCast Data Dissemination System for Environmental Resource Management” was organised at the IGARSS Conference in Cape Town, South Africa. Also such courses were as an AFRICAGIS pre-conference workshop in Kampala.

Asia

- CASITA: “Capacity building in Asia using information technology applications in disaster management”, Hanoi, Vietnam. The course was organised by ITC, the Asian Disaster Preparedness Center (ADPC), Bonn University (Germany) and Hanoi Architectural University (HAU). It was attended by academic staff from universities that are part of the CASITA network, aimed at establishing courses on the use of geoinformation for disaster risk management in Asia.
- Geo-information for Landslide Hazard and Risk Assessment. This training course and field workshop is organized by Geological Survey of India Training Institute in association with ITC, the Centre for Earth Science Studies (CESS), Trivandrum and Institute of Land Management (ILM), Trivandrum.
- A course on the Application of High Resolution Imagery for Landslide Inventory, Hazard and Risk Assessment, was organized in 2006 at the Geological Survey of India Training Institute (GSITI) in Hyderabad, India.
- A course on Dynamic modelling for landslides and floods using GIS and Remote Sensing, was organized in Peradeniya, Sri Lanka, which was followed by another training course on “Applications of GIS & RS for Hazard and Risk Assessment”.

- Regional Course on Hydro-Meteorological Risk Assessment and Community Preparedness, organized by AIT and ADPC (Bangkok, Thailand) and funded by US-AID through the PROMISE project.
- A course on “expert opinion in landslide inventory and hazard assessment” was organized by the Geological Survey of India Training Institute in association with the Indian Institute of Remote Sensing (IIRS), NRSC, WIHG, DGIM, ADPC, Norwegian Geotechnical Institute (NGI), Canadian Geological Survey, and International Consortium on Landslides.
- In China, a two-week course with Chengdu University of Technology was organized on Slope Stability Probability (SSPC), data collection and handling.
- In Sri Lanka, a two-week course was organized together with the Postgraduate Institute of Peradeniya University on “Innovative approaches to multi-scale landslide hazard and risk assessment”.
- In Georgia a two weeks course on “Multi-hazard risk assessment” was organized in November 2009, which was attended by staff from the National Environmental Agency (NEA) and the Caucasus Environmental NGO Network (CENN).

Latin America

- Geo-information tools for community-based disaster management in Colombia, University of Tolima, Ibague, Colombia.
- A short course on Rapid Response to Natural Disaster in the Andean Community — New Approaches to connect those involved with Spatial Information, was given together with the Instituto Geografico Agustin Codazzi (IGAC), Colombia.
- In Nicaragua a course was organized on “Landslide hazard and risk assessment” as a contribution to the University Network RUNIRED in Central America.

At ITC an international Executive Seminar on “Capacity Building in Disaster Geoinformation Management in Developing Countries” was held at ITC from 23 to 25 September 2009. Forty-five experts dealing with capacity building in the use of geoinformation for disaster risk management gathered to discuss the state of currently existing capacity as well as remaining gaps, and optimal modes of CB implementation for different beneficiary types. Representatives from international organisations (e.g. World Bank, UN-ISDR, UNITAR/UNOSAT, UN-OOSA), geodata providers (e.g. NASA, EUMETSAT), non-governmental organisations (NGOs, e.g. MapAction), knowledge centres and university networks (e.g. UN-affiliated training centres, ADPC), as well as user organisations attended the seminar.

4.5 Capacity building projects

UNU-ITC DGIM is also involved in externally financed capacity building projects related to landslides. Some examples are:

- **CASITA:** Sustainable Capacity Building on Urban Disaster Mitigation in Asia. As part of the Asia IT&C Programme of the European Commission the CASITA network was formed of 14 universities from Asia, for institutionalising modern disaster mitigation tools in higher education to reduce disaster vulnerability of human settlements in Asia. The CASITA project resulted in an active network of universities from Thailand, Sri Lanka, Bangladesh, Indonesia, India, Nepal, Pakistan, Lao PDR, the Philippines and Vietnam.
- **UNESCO CBNDR RAPCA.** One of the first networks established was in the Central American region, in the period 1999- 2004 through the UNESCO CBNDR project, which was funded by the Netherlands government through UNESCO. The overall objective of the program was capacity building for natural disaster reduction (CBNDR) in Central America and the Caribbean, and included the following countries: Costa Rica, Dominican Republic, El Salvador, Guatemala and Honduras.
- **Institutional building for natural disaster risk reduction (DRR) in Georgia:** in collaboration with the counterpart Caucasus Environmental NGO Network (CENN), ITC has started an institutional strengthening project in Georgia funded by the Dutch Ministry of Foreign Affairs/DGIS under the Dutch funding programme MATRA to support civil strengthening processes in former

Soviet countries. This project aims to assist the Georgian Ministry of Environmental Protection and Natural Resources to enhance its capacity for effective DRR.

- **CAPRA:** CAPRA stands for Central American Probabilistic Risk Assessment and is a World Bank funded programme. ITC was contracted by the World Bank to review the CAPRA software and methodologies developed so far, and to develop a CAPRA training plan for the Central American region.
- **GITHRA:** ITC is lead partner in the Geo-information Technology for Hazard Risk Assessment (GITHRA) project in Vietnam, funded by the Asian Development Bank. Other project partners are the Asian Institute of Technology (AIT) and the Asian Disaster Preparedness Centre (ADPC). The projects objective is to build capacities in flood-related hazards and ICT tools in Vietnam.
- **GARNET-E:** an EU FP7 supporting action project aimed at the construction of a new networking activity in the frame of GMES and Africa. The network is entitled GARNET-E, derived from: "GMES and Africa: Regional Network for Information Exchange and Training in Emergencies". Lead partner is Infoterra.

5. LARAM- ASIA

The UNU-ITC School for Disaster Geo-Information Management has expressed its interest and made an application to the IPL to be recognized as a World Center of Excellence in the field of "Capacity building for landslide hazard and risk assessment in developing countries".

UNU-ITC DGIM recently submitted a proposal, entitled "LARAM-ASIA: an International course on "Landslide Risk Assessment and Management in Asia". The aim of this project is to establish an annual 2 weeks high level course for PhD students from Asian countries, with international experts on landslide risk assessment and mitigation as teaching staff, in order to improve research collaboration between Asian researchers and increase interaction with international initiatives. In this proposal UNU-ITC DGIM collaborated with the following organizations: CDUT-SKLGP (Chengdu, China), UNISA (Italy), NGI (Norway) and ADPC (Thailand).

LARAM is an International School on "Landslide Risk Assessment and Mitigation" that was founded by the University of Salerno (<http://www.unisa.laram.it>). The School gives training to 40 PhD students, selected every year, from the following fields: Civil Engineering, Environmental Engineering, Engineering Geology or other related studies. The Scientific Committee consists of international experts in the fields of Landslide Risk. The LARAM School has proven to be a very good concept and since its initiation more than 200 PhD researchers have followed this course. However, the participation from students from Asian countries has always been limited.

The LARAM-ASIA international courses will be conducted in Chengdu, China, with fieldwork in the nearby area where 60000 landslides were generated during the 2008 Wenchuan earthquake. The LARAM-Asia courses will be organized by the State Key Laboratory on Geohazards Prevention, of Chengdu University of Technology (SKLGP). SKLGP has very good facilities, including lecture rooms, computer rooms, laboratories, and guesthouse. ITC, LARAM, and ICG will also be involved in providing advice and support. SKLGP has signed an agreement with ITC in December 2007, in the fields of geo-hazards survey, risk assessment and capability building. SKLGP together with ITC have organized 2 training courses, "Landslide risk assessment" in 2008 and "Slope Stability Probability Classification" 2009. During 12-14 April 2010, SKLGP and ITC have organized an expert workshop on "Assessing the state of art of landslide hazard and risk assessment in China" in Chengdu, as one of the deliverables of the EU FP7 SafeLand project. One of the aims of the project is the Harmonisation and development of procedures for quantifying landslide hazard and risk, and the project includes also components related to comparing methods developed in Europe with those in Asia. India and China were selected as countries where interaction should be enforced between European and Asian landslide researcher. The proposed annual courses therefore fit in the objectives of the SAFELAND project. The project aims to establish the course in Chengdu in a similar way as is the case in the LARAM School in Europe. Through a website and announcements through e-mail, the course is announced and PhD researchers from Asia are invited to apply. The courses will be organized by SKLGP, with support from ITC, LARAM and SafeLand. A group of about 10 internationally known landslide experts

will be approved as resource persons in the course, of which half is expected from China. Topics that will be treated are: Methods used for landslide susceptibility, hazard and risk assessment at various scales of analysis; risk theory and probabilistic risk assessment; earthquake induced landslides; landslide initiation modelling; landslide runout modelling; landslide risk mitigation. The course will also include a field excursion to the landslide areas caused during/and after the Wenchuan earthquake, which is one of the best locations in the world to learn about landslide features in all its forms.

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