RiskCity: a GIS-based training package for Multi-Hazard Risk Assessment

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Abstract

The International Institute for GeoInformation Science and Earth Observation (ITC) and the United Nations University have established a collaborative programme on the use of spatial information for disaster management, which resulted in the formation of the UNU-ITC School for Disaster GeoInformation Management. The main activities of the DGIM School focus on training, education, curriculum development, knowledge development and research collaboration. This is done through the establishment of University networks in Asia, Africa and Latin America, of which the member Universities exchange spatial information, course materials and jointly carry out training and research projects. Rather than selecting a full distance education training approach, the DGIM School develops training packages and courses that are given jointly with the partners of the networks in various countries. The materials are uniform, and have been developed in different languages, and the support is given by local University staff who have followed earlier training, and which is supported by (distance) lecturers by staff from the UNU-ITC DGIM School. One of these courses is on Multi-hazard risk assessment, which is centered around a case study on the use of Geographic Information Systems, and Remote Sensing for the assessment of hazard, vulnerability and risk in a hypothetical case study area, called RiskCity, based on a dataset from the city of Tegucigalpa, Honduras. The dataset has been modified in such a way that most of the hazard types and vulnerability and risk concepts can be demonstrated in one area. The exercises have been made with open GIS software, called ILWIS.

KEY WORDS

GIS, training package, hazard assessment, elements at risk, vulnerability assessment, multi-hazard, risk assessment.

1. INTRODUCTION

One of the important components of disaster risk management is capacity building and training of disaster management experts and professionals working in many different disciplines that have an important disaster reduction component, such as planners, engineers, architects etc. Worldwide a number of organizations are specialized in providing short training courses on disaster risk management related issues, for example the Asian Disaster Preparedness Center (Thailand), Asian Disaster Reduction Center (Japan), Pacific Disaster Center (USA), or the Disaster Management Center at the University of Wisconsin (USA) (ISDR, 2004; ADPC, 2005). A number of organizations have also prepared training materials that are accessible through the internet, for example the Disaster Management Training Programme (DMTP, 2007), or the International Federation of Red Cross and Red Crescent Societies (IFRC).

Disaster risk management courses at BSc or MSc level are now available in many Universities in Europe (e.g. Benfield Hazard Research Center, UCL London; Un. of Geneva; ETH, Zurich), Asia (e.g Indira Gandhi Open Un., India; Gadjah Mada Un., Indonesia), Africa (e.g. Un. of Johannesburg; Western Un. College of Science and Technology, Kenya; Un. College of Lands and Architectural Studies, Tanzania; Makarere Un., Uganda), Latin America (e.g. Universidad Nacional, Colombia, Universidad de Costa Rica) and the USA (e.g. Un. of Colorado) etc.

The development of innovative forms of learning and teaching oriented towards building new curricula in the field of natural risk has attracted attention in European initiatives such as DEBRIS (2006) and NAHRIS (2006). As far as GIS-related training courses in hazard and risk assessment are concerned, the ESRI Virtual Campus offers various courses such as “Solving disaster management problems using ARCGIS 9”, “Spatial Analysis of Geohazards Using

ArcGIS 9” and “HAZUS-MH (Multi-Hazards) for Decision Makers” (ESRI, 2007). However, complete GIS bases training packages on spatial hazard and risk assessment using low-cost or free GIS software are still not freely available, to the knowledge of the author.

This paper describes the integration of a GIS-based training package in a course on multi-hazard risk assessment, which has been developed as part of the UNU-ITC School for Disaster Geoinformation Management.

2. UNU-ITC School for Disaster Geoinformation Management

On 4 April 2005, the United Nations University (UNU) and the International Institute for Geo-Information Science and Earth Observation (ITC) entered into an agreement appointing ITC as an Associated Institution of UNU. ITC develops and transfers knowledge by means of research, education, capacity building, institutional development and advisory services on geo-information and earth observation. The UNU-ITC agreement has an initial duration of five years and is directed at developing and carrying out joint programmes on capacity building in Disaster Management and in Land Administration, and the dissemination of knowledge on these and directly related issues.

According to the agreement between the United Nations University (UNU) and ITC, the long-term objective is "to strengthen the capacity of institutions at national and local level in developing countries to reduce the vulnerability to natural hazards". The School for Disaster Geo-Information Management aims to develop activities related to training, education, curriculum development, knowledge development and research collaboration. The activities in training, education and curriculum development are focused on joint educational programmes with Universities in developing countries, the development of distance education courses, short courses and workshops, and the provision of fellowship support. The knowledge development and research collaboration activities are the execution of sandwich PhD programmes with staff members from institutes in the target countries, visiting scientists, and the provision of small grants for research projects of the partner organizations within the networks in Asia, Africa and Latin America.

The DGIM School aims to support capacity building in Disaster Geo-Information Management through the formation of University networks. Up to now such networking activities have been carried out in Central America, SE Asia and East and Southern Africa.

1.1 UNESCO-RAPCA

One of the first networks established before the formation of the UNU-ITC DGIM School was in the Central American region, in the period 1999- 2004 through the UNESCO-CBNDR project (UNESCO, 2004). 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, Honduras, Nicaragua and Panama. The results of the UNESCO CBNDR-RAPCA project were made available as an online training package (ITC, 2004). The training package is both in Spanish and English and contains exercises and lecture materials on the use of GIS and Remote Sensing for natural hazard and risk assessment, with case studies from the Central American region.

The materials can be accessed from the following website: **http://www.itc.nl/external/unesco-rapca/start.html**. Villagran and Zeil (2006) in their external evaluation report on this project recommended: "*If the weak points, as identified by the evaluation, are addressed, a modified approach can be replicated by UNESCO and partners such as ITC in other regions affected by natural hazards (Asia, Africa, Latin America)* "

1.2 CASITA and UNEDRA

As a follow-up of the UNESCO-RAPCA activities a similar initiative was initiated in the SE Asia region. As part of the Asia IT&C Programme of the European Commission the CASITA network was formed of universities from Asia. The CASITA project started in 2003 and has resulted in a network of some 14 universities in Thailand, Sri Lanka, Bangladesh, Indonesia, India, Nepal, Pakistan, Lao PDR, the Philippines and Vietnam. The project was coordinated by ITC and the Asian Disaster Preparedness Centre (ADPC) in Thailand. In the framework of the CASITA project a training package (in English) has been prepared on the use of GIS and Remote Sensing for hazard and risk assessment for the Asian region. The package is available on Internet and can be accessed through: **http://www.adpc.net/casita/** **.**The CASITA training materials can also be obtained through the distance education software Blackboard, which is used in this project. **http://bb.itc.nl** (Password: Casita Username: Casita).

Recently in Africa a similar network was started: University Network for Disaster Risk Reduction in Africa (UNeDRA). UNeDRA's main aim is to forge interaction amongst universities in Africa with interest in teaching on disaster risk reduction, through information sharing, capacity building and collaborative research. More information on UNEDRA can be found on: **http://www.itc.nl/unu/dgim/unedra/default.asp**

3. DEVELOPMENT OF MULTI-HAZARD RISK ASSESSMENT COURSE

As part of the UNU-ITC DGIM training activities it was decided to develop a course on Multi-hazard risk assessment, which could be given in different countries together with the partner Universities of the networks that have been established in Asia, Africa and Central America. It was decided to develop the course together with the Asian Disaster Preparedness Center (ADPC). The course materials were developed over the years 2005-2007. In December 2005 a course development workshop was held in Hanoi Vietnam, with representatives of the partner Universities within the CASITA network.

The course was conducted as a distance education supported course, rather then a full distance education course, where the participants are in different locations. In the development workshop it was concluded that it is better to have the participants in the same location, which will greatly improve the possibilities for interaction between the participants, and teaching staff especially concerning the GIS computer exercises. All of the training materials were made available on the Internet, through the Blackboard software for educational support.

The first trial run of the course on Multi-Hazard Risk Assessment was given from 24 April to 12 May 2006 in ITC, Enschede, the Netherlands. Part of the lectures were done using Internet using MSN Messenger, and through videoconferencing. The course is given annually at different locations, both in English (e.g. in the Netherlands and Thailand) and Spanish (e.g. in Mexico and Bolivia with local partners).

The course on Multi-hazard risk assessment guides the participants through the entire process of risk assessment. Participants receive an understanding of the concepts of hazard assessment, elements at risk mapping and vulnerability assessment through the elaboration of a scenario-based GIS case study. The course has the following main learning objectives:

- Understand the procedure for carrying out a multi-hazard risk assessment in different settings (urban and rural) and different types of hazards (slow versus rapid onset, geological, hydro-meteorological, ecological, technological etc).
- Have insight in the data requirements for hazard assessment, elements at risk assessment, vulnerability assessment and loss estimation;
- Apply Remote Sensing for hazard assessment, and elements at risk mapping;
- Apply field data collection methods for hazard and vulnerability assessment, including the use of mobile GIS, and community based methods combined with GIS;

- Hands on experience with techniques for mapping and classifying elements at risk;
- Work with qualitative and quantitative risk scenarios for urban areas in a GIS;
- Carry out the various phases of risk assessment (including hazard assessment, element at risk mapping, vulnerability assessment);
- Provide an overview of mitigation options and effect on risk reduction and distribution
- Use of Spatial Multi Criteria Analysis to combine the results of different risk scenarios.

The GIS training package which is entitled “RiskCity” forms the central component of the Multi-hazard risk assessment course, and all above mentioned components are worked out as GIS exercises using the ILWIS software.

The Integrated Land and Water Information System (ILWIS, 2005) is a PC-based GIS & Remote Sensing software, developed by ITC. ILWIS has extended functionalities for image processing, spatial analysis and digital mapping. It is easy to learn and use; it has full on-line help, extensive tutorials for direct use in courses and many case studies of various disciplines. Recently the ILWIS software has been made available free of charge and is converted into open source software.

4. RISKCITY TRAINING PACKAGE

The RiskCity exercises on the analysis of multi-hazard risk in an urban environment deal with a hypothetical case study, although most the data have been obtained from one particular city: Tegucigalpa in Honduras. Tegucigalpa suffered severe damage from landslides and flooding during Hurricane Mitch in October 1998 and the city received 281 mm of rain in 3 days (Mastin and Olsen, 2002). Due to the river flooding, an old landslide was reactivated and an entire neighborhood on top of it was destroyed. The landslide caused the damming of the river and resulted in severe flooding in large parts of the city center for several weeks. These events are well identifiable on the high resolution image which serves as the basis for the exercises (See

Figure 1). Only part of the exercises is based on the actual situation in Tegucigalpa. However, in order to be able to reach the learning objectives, modifications and additions were made to the original data for didactical purposes. It is very difficult to have a dataset for a particular area where all aspects of multi-hazard risk assessment can be properly demonstrated. Either because particular hazard types do not happen in the city or because particular data sets are incomplete, restricted or erroneous. As this is a basic training package the methods for hazard and vulnerability assessment have been simplified quite a bit. Nevertheless they intend to give an understanding of the basic concepts involved, and allow the students to have an idea on how GIS can be used for analyzing the different types of hazards, assessing vulnerability and making a loss estimation.

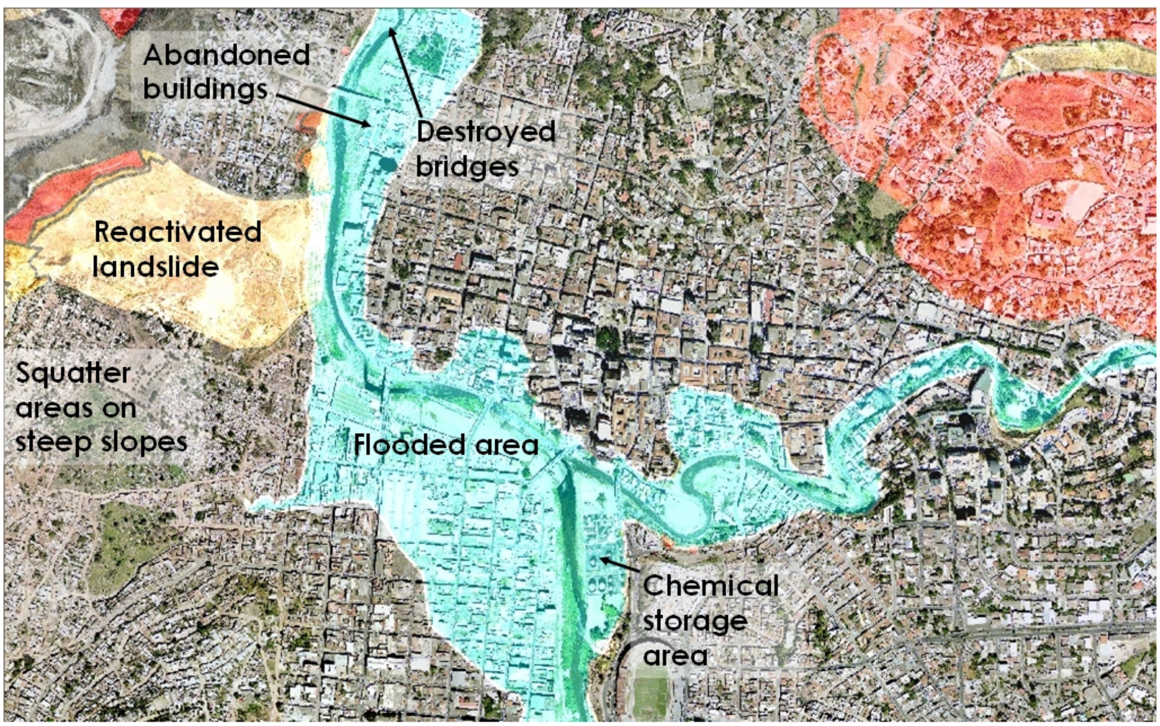

Figure 1: High-resolution image of the center of RiskCity with some of the hazard and vulnerability features indicated. Note that some of the features (e.g. the chemical storage facility in the flooded area in the city center) have been added and do not appear in the real world case study.

4.1 General structure of the training package

The overall structure of the RiskCity training package is given in figure 2. Four different types of hazards are evaluated: landslides, floods, earthquakes and technological hazards. Also emphasis is given on the generation of a database of elements at risk in order to evaluate the vulnerability of buildings and population to these types of hazards. For the generation of the element at risk database it is assumed that there is no spatial data available in the form of cadastral or census databases.

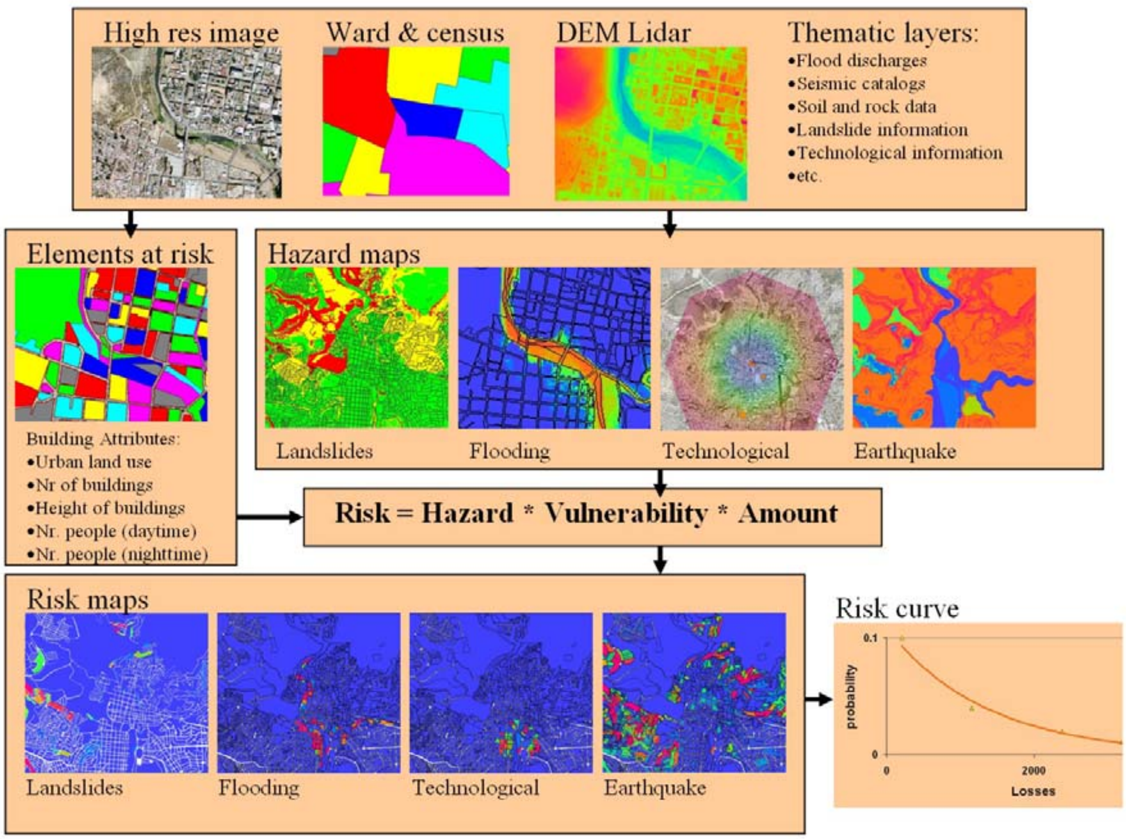

Figure 2: General structure of the RiskCity training package. See text for explanation

The RiskCity exercises are listed in table 1. Each exercise takes approximately half a day to complete, although some are more extensive than others.

Nr		Exercise	Description
1	Basic	Basic concepts	Evaluation of the basic concepts of hazard, vulnerability and risk, by viewing hazard evidences on the high-resolution image
2		Spatial data needs	Evaluation of the spatial data that will be required for risk assessment, and searching for free and low-cost data on the internet.
3		Image interpretation	Use of stereo-image interpretation, using an anaglyph image. The stereo interpretation could be used to map both hazardous features (e.g. landslides) as well as elements at risk;
4		Image processing	Use of multi-temporal imagery for the assessment of land use changes in the entire catchment.
4	Elements at risk	Mapping units	Interpretation of a high-resolution image for the definition of basic mapping units for which the risk assessment will be done;
5		Urban landuse	Interpretation of high-resolution image for urban landuse mapping and design of appropriate legend for vulnerability assessment;
6		Building height	Use of a Digital Surface Model, made from Lidar data, in combination with a Digital Elevation Model made from large scale topographic maps for estimation building heights;
7		Building numbers	Using sample information on building numbers per mapping unit in order to calculate the number of building in each block, based on the size of the mapping unit and the landuse
8		Population distribution	Calculating population densities on the basis of the number of buildings for a daytime and nighttime scenario
9	Hazard and vulnerability assessment	Statistical landslide assessment	Generating a basic landslide susceptibility map, using a simple statististical method
10		Deterministic landslide hazard assessment	Generating a landslide hazard map, making use of dynamic modeling in which the groundwater level and the resulting slope stability is simulated in time steps based on daily rainfall
11		Semi-quantitative landslide risk	Generation of a qualitative landslide risk map
12		Flood frequency analysis	Frequency analysis of flood discharge data to establish return periods for different floods magnitudes.
13		Runoff modeling	Using a dynamic model at catchment level to estimate runoff based on Elevation, soil types and land use information.
14		Qualitative flood risk	Using the results of flood simulation models in order to assess the extend of the flooded area for different return periods
15		Quantitative flood risk	Using the flood modeling results in combination with the Digital Surface Model in order to estimate the number of floors that are flooded per building
16		Earthquake frequency analysis	Frequency analysis of an earthquake catalog to establish magnitude frequency relation for earthquakes based on the Gutenberg-Richter relation.
17		PGA analysis	Using a basic method for Peak Ground Acceleration, and the amplification due to soft soil. Conversion to Modified Mercalli Intensities;
18		Seismic loss of buildings	Estimation of buildings likely to be damaged during an earthquake based on vulnerability curves for different building types
19		Seismic population loss estimation	Estimation of population losses during an earthquake for a day and nighttime scenario
20		Technological hazard and risk	Use of two different scenarios for the explosion of a chemical storage facility and the calculation of the number of buildings affected and the number of people affected in a daytime and nighttime scenario
21	Risk assessment	Vulnerability indicator	The use of Spatial Multi-Criteria Evaluation for the weighting of indicators related to physical vulnerability, social vulnerability and capacity, in order to derive an general vulnerability indicato
22		Annual loss estimation	The calculation of annual losses for the different scenarios, both in terms of buildings and population. The scenarios are consisting of the combination of hazard types and return periods
23		Loss comparison	The evaluation of the resulting multi-hazard risk for different parts of the city, and the assignment of priorities for vulnerability reduction
24		Emergency planning	The use of the risk data in planning activities such as the planning of emergency centers, hospitals, and the allocation of evacuation routes and areas

Table 1: List of exercises in the RiskCity training package.

Each of the exercises can be carried out individually, and comes with its own data. Also for the exercises that require input data from the previous ones (which is the case for most of them) the results from the previous exercise are supplied. This is done to avoid that errors which are made in one exercise would lead to problems in sequential ones. Also it is possible to compose a course with variable duration, ranging from a few days to 1 month, and select the appropriate exercises.

4.1 RISKCITY input data

The input data for the RiskCity training package is shown in table 2. The basis for most of the exercises is an IKONOS high-resolution image of 1 meter resolution, from the year 2000. Apart from the high resolution image, also low resolution images are available for different periods from Landsat ETM and ASTER. As part of the exercise, the students should search for the available digital data on the internet. The multi-spectral images are used together with a Digital Elevation Model, which is also downloaded from Internet, to make an analysis of landuse types and landuse changes in a larger catchment of the Choluteca River, upstream of Tegucigalpa. Also digital stereo aerial photographs are available, which are used within a module of the ILWIS GIS system for the generation of a digital stereo model for visual interpretation, of landslides and urban changes. The changes in landslides and urban development are compared with the high-resolution image from 2000, as well as the recent high-resolution images that can be obtained from Google Earth.

Elevation data is available in three different forms: SRTM, contour maps, and LiDAR data. The Shuttle Radar Topographic Mission (SRTM) image is a subset of a much larger area, which can be downloaded for free from the Global Land Cover Facility website (http://glcfapp.umiacs.umd.edu/index.shtml) All data are georeferenced to the coordinate system WGS84. The contourlines were digitized from 1:2000 scale topographic maps, and the the LiDAR data was obtained from the USGS (Mark and Olsen, 2002) in raster format.

.	Name	Type	Meaning
Image data	High_res_image	Raster image	A high resolution colour image derived from an IKONOS image. It has been orthorectified, and the the panchromatic band is fused with the colour bands, and resample to 1 meter.
	Aster	Raster Image	ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer) is a high resolution imaging instrument that is flying on the Terra satellite.
	Landsat	Raster Image	The Landsat ETM and ASTER images are used to evaluate landuse and landuse changes in the regional area over time.
	Photos_1975	Raster Images	Digital Stereo Aerial photographs from 1975 which can be used to analyze the changes in vulnerability and hazards.
Altitude data	Lidar_dem	Raster map	A Digital Elevation Model which has been derived from a laser scanning flight. The original data points have been interpolated into a 1 meter resolution raster map.
	Contour_map	Segment map	Contour lines with 2.5 meter contour interval. These have been digitized from a series of 1:2000 scale topographical maps. From this map a DEM is made as well as derivative maps such as a slope map and aspect map.
	SRTM_dem	Raster Map	Shuttle Radar Topography Mission (SRTM) Digital Elevation Model of the region, made from downloading and patching different parts from the Internet.
Elements at risk data	Unit_boundaries	Segment map	Boundary lines of the mapping units that will be used as basic units for the elements at risk. It has been made through screen digitizing on the high-resolution image. The segments of the street pattern have been used as the basis for the screen digitizing.
	Mapping_units	Polygon map and table	Mapping units used for elements at risk mapping. Each of the mapping units has a unique identifier, so that in the accompanying table information can be stored for each unit. In the accompanying table information is given on the number of buildings and number of people for both daytime and nighttime scenarios, and on the urban landuse for each mapping unit.
	Wards	Polygon map	Polygon map representing the administrative units within the city. In the accompanying table information is given on the number of buildings, number of people, and other attributes used in the vulnerability assessment.
	Districts	Polygon map	Polygon map representing the most generalized administrative units within the area. Some the vulnerability attributes are only available at this level. The attributes are stored in accompanying tables.
	Rivers	Segment map	Segment map of the drainage network in the city, digitized from topographic maps
	Roads	Segment map	Segment map of the streets, roads and paths, made by digitizing from topographic maps.
Hazard related data	Geological map	Polygon map	Geological map with main rock and soiltypes and their characteristics.
	Slides	Polygon map	Landslides in the study area
	Flood_100_year	Polygon map	Flood hazard with 100 year return period, from hydrological modeling
	Flood_50_year	Polygon map	Flood hazard with 50 year return period, from hydrological modeling
	Flood_25_year	Polygon map	Flood hazard with 25 year return period, from hydrological modeling
	Flood_10_year	Polygon map	Flood hazard with 10 year return period, from hydrological modeling
	Seismic catalog	Point map	Point map with earthquake catalog, and information on depth, magnitude and location
	Rainfall stations	Point map	Point map with rainfall data, and information on daily rainfall for different rain gauges.
	Hazardous storage	Point map	Point map with hazardous storage facilities.

Table 2: Available input data

The Lidar images, flood inundation maps, and landslide inventory maps were obtained from previous studies carried out by USGS (Harp et al., 2002; Mark and Olsen, 2002) and through MSc research (Eugster, 2002).

Most of the urban data for the exercises were invented, in order to be able to reach the learning objectives without having to wonder about incomplete data. The urban data is linked to administrative units on three levels. At the detailed level mapping units may be individual large buildings or plots with a specific landuse, although they are mostly building blocks, bounded by streets. The next level is the ward level, and the lowest level consists of districts, which are groups of wards. The urban data base linked to these three levels contains information on building types, urban land use, population, and a number of attributes used for the vulnerability and capacity assessment (see later). Figure 3 gives the simplified procedure for the generation of the elements at risk database. In the following sections some examples are given of a few of the exercises, as listed in table 1.

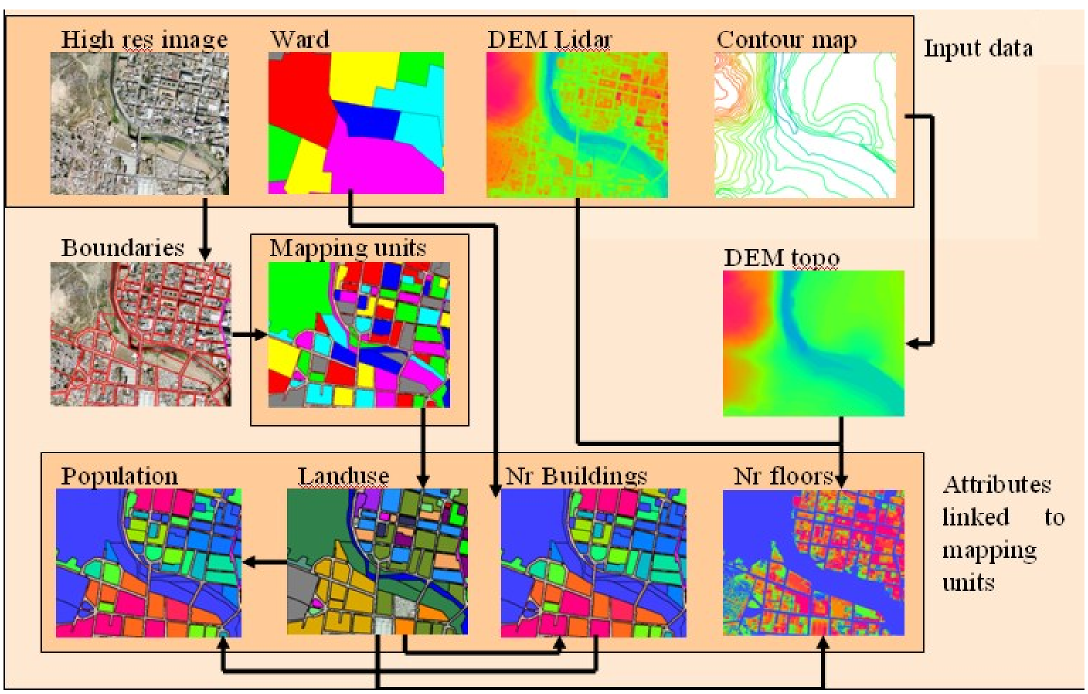

Figure 3: Simplified procedure for the generation of the elements at risk database. The mapping units are interpreted from the high-resolution image, and the urban land use is determine from the image characteristics after generation of a polygon map. Building number and height are obtained using a LiDAR image, and the combination with a DEM from contourlines.

4.2 Risk assessment for different hazard types

The risk assessment procedure follows the basic formula of risk which is indicated in figure 2. For each hazard types the hazard footprint areas of hazard scenarios with a particular hazard are derived in different ways. For the landslide hazard, this is done with the use of either statistical methods, correlating past landslides with causal factors, and with dynamic modeling. For the earthquake hazard a number of scenario earthquakes are taken from the earthquake catalog, and the Peak Ground Acceleration is computed using attenuation functions, combined with a soil amplification factor. The flood scenarios are derived from detailed flood modeling using the HEC-RAS and SOBEK models, and the technological hazard scenarios are derived from empirical formulas. Physical vulnerability assessment is done on the basis of the building characteristics, the magnitude/intensity of the hazard and the combination through empirical rules or vulnerability curves. For examples for earthquake losses vulnerability curves are used that have been derived in Nepal and India. An example of the annual loss calculation for earthquakes, taking 4 scenarios with different return periods, is given in figure 4.

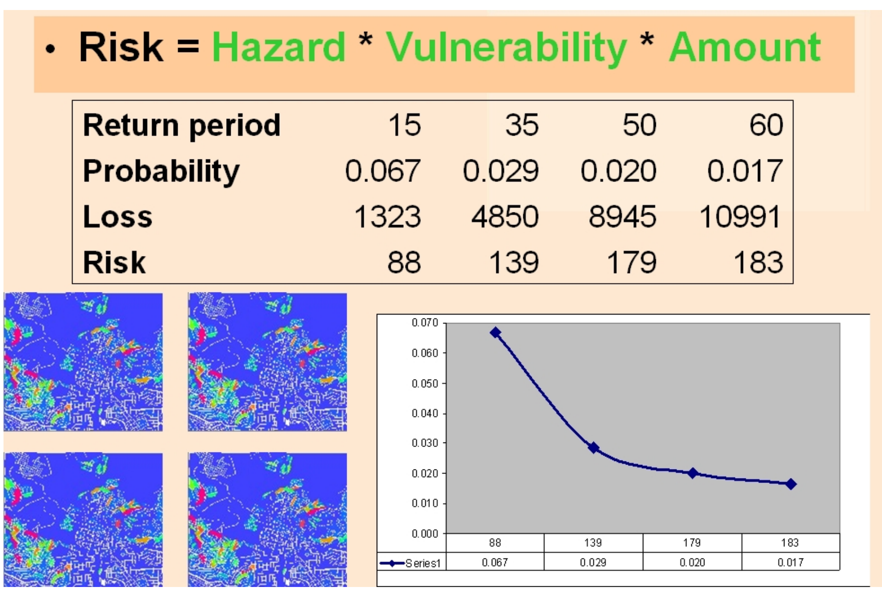

Figure 4: Example of a simplified annual risk calculation for earthquake hazard, taking 4 different scenarios with different return periods, that result in 4 different annual loss estimations, which are combined in a risk curve.

4.3 Generating Vulnerability Indicators using Spatial Multi Criteria Evaluation

The aim of this exercise is to generate a number of vulnerability indicators, based on different administrative units. The social and physical vulnerability indicators are combined into an overall vulnerability indicator using Spatial Multi Criteria Evaluation. For implementing the semi-quantitative model the spatial multi-criteria evaluation (SMCE) module of ILWIS GIS was used. SMCE application assists and guides users in doing multi-criteria evaluation in a spatial manner (ILWIS, 2005). The input is a set of maps which are the spatial representation of the criteria. They are grouped, standardized and weighted in a "criteria tree" (See figure 5). The output is one or more "composite index map(s)", which indicate the realization of the model implemented. The theoretical background for the multi-criteria evaluation is based on the analytical hierarchical process (AHP) developed by Saaty (1980).

The data for this exercise are stored in a number of tables that can be linked to the polygon maps of the three different administrative levels: mapping units, wards and districts. These three different administrative units also have different attribute information related to them. For example, demographic information from the city is only available at a generalized district level. Unemployment information is available at ward level, whereas information on poverty level and social structure is available even at building block level.

In Figure 5, below the main goal, which is indicated with the tree symbol and the text (vulnerability index), in total 4 subgoals have been defined (Generic social vulnerability indicators, hazard specific social vulnerability indicators, hazard specific physical vulnerability indicators, and capacity indicators). Each subgoal is determined by a number of indicators, which form the smallest branches in the tree structure. Each indicator is standardized in values ranging from 0 to 1, and the standardization method is indicated. The weight of each indicator is also shown in the criteria tree as well as the method of weighting that was used (mostly Pairwise comparison). The column on the right hand side shows the input data (in white) and the output data (in green). The map in the upper right of the tree is the final output map. Through this exercise the students learn how to carry out a spatial multi-criteria analysis, and how to define the problem and how to determine what the relative importance is of the vulnerability indicators.

5. CONCLUSIONS

The RiskCity training package can serve as a tool to demonstrate the utility and requirements of spatial data in urban multi-hazard risk assessment, and the problems involved. Since the preparation of such a training package takes quite some time, it is normally not possible to adapt the dataset easily to local conditions each time a course is given in another place. This is also one of the reasons why the exercise has been made as generic as possible, by excluding most of the references to the actual city where the dataset is obtained, and by substituting the original names of wards and locations with international names from different continents. The RiskCity training package is constantly being updated and further improved. There is a plan to also make a version which is focusing on rural areas in a coastal environment, where also coastal hazards (including tsunamis) will form part of the multi-hazards that are evaluated. Also the plan is to incorporate more Participatory GIS approaches in the training package.

The text of the RiskCity training package will be made available in time on the Internet page of the UNU-ITC School for Disaster Geoinformation Management (http://www.itc.nl/unu/dgim/default.asp). The training package is used regularly in courses and is available both in English and Spanish.

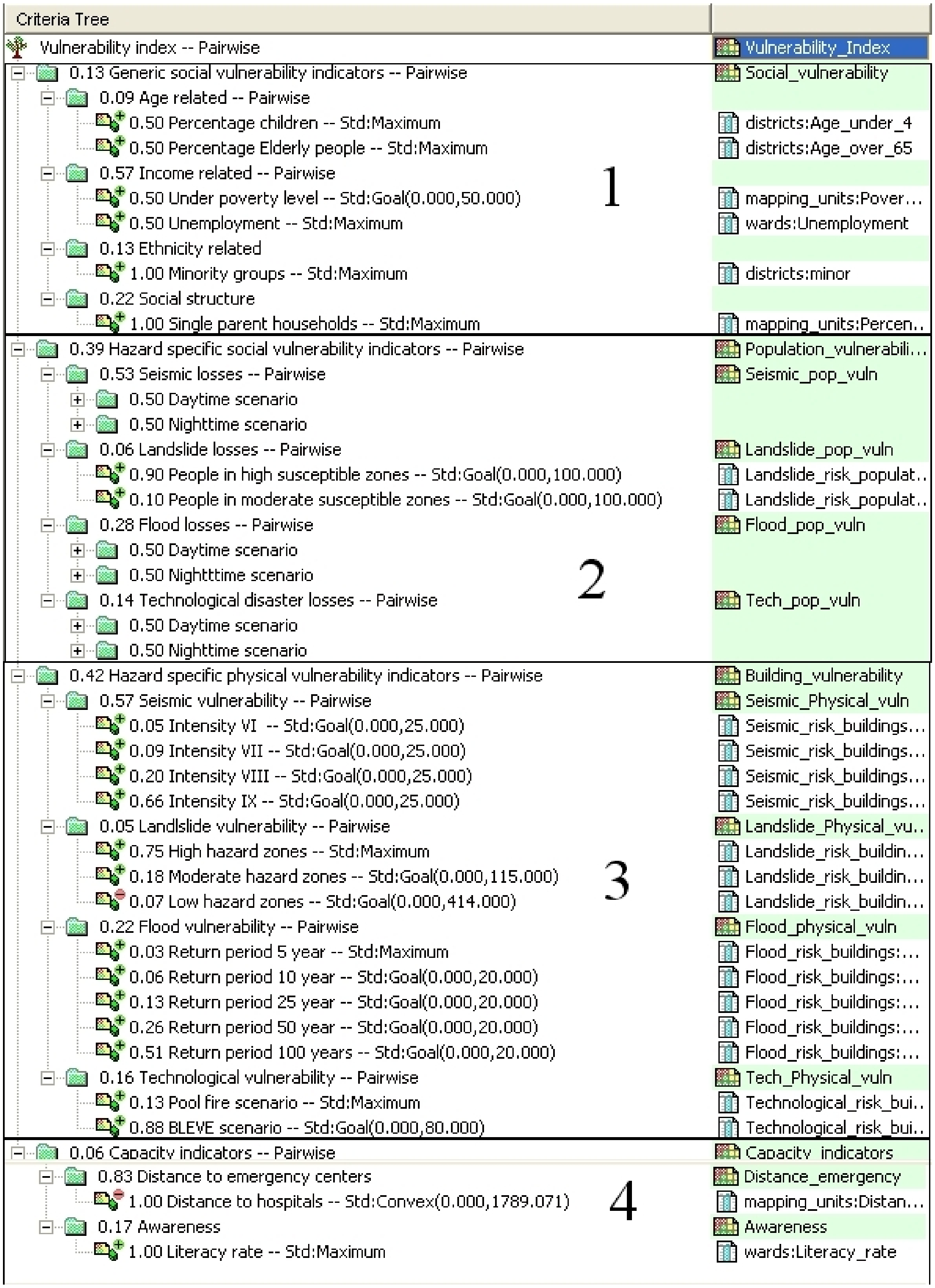

Fig. 2. Criteria tree for spatial multi-criteria evaluation based on analytical hierarchical process using the ILWIS SMCE module. The numbers 1 to 4 refer to the fours subgoals of the exercise: Generic social vulnerability indicators, hazard specific social vulnerability indicators, hazard specific physical vulnerability indicators, and capacity indicators.

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