RiskCity and WebRiskCity: Data Collection, Display and Dissemination in a Multi-Risk Training Package

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ABSTRACT: Within the activities of the United Nations University, the ITC School on Disaster Geo-Information Management (UNU-ITC DGIM) at the International Institute for Geo-Information Science and Earth Observation (ITC) has developed WebRiskCity, an Open Source WebGIS platform for multi-risk assessment. The platform is a support to the RiskCity project, a GIS distance education course for multi-hazard risk assessment. The course has a guide book which gives the theoretical background behind the spatial data requirements for risk and hazard assessment procedures, generation of elements-at-risk databases, vulnerability assessment, qualitative and quantitative risk assessment methods, and risk evaluation. The architecture of WebRiskCity is based on a hierarchic structure similar to the original RiskCity dataset. Different switches for every component of the risk assessment have been defined, and through various menus, the user can select the options for each exercise. Tools for spatial analysis are implemented to compare maps at different scales and for on-line interpretations. A complete educational database was compiled, merging original layers of local authority and simulated data. The purpose of WebRiskCity is to be a tool of knowledge and education for risk assessment, as well as to provide a means of supporting non-academic staff, and non-governmental organizations and stakeholders, whose knowledge in risk management is vital, but often lacks a scientific base.

KEYWORDS: Multi-risk assessment, distance education course, spatial analysis, WebGIS

Introduction

One of the important components of disaster risk management is building capacity for hazard response and mitigation by training planners, engineers, and architects. Part of risk management is preparedness planning, which involves expertise in social, political, and earth sciences (Gaspar-Escribano et al. 2009). The planning has to be tailored to different degrees of understanding and interest for information about natural and antrophic risks. Clear language and ontology (representation of a set of concept and relationships between them) can help to avoid misunderstanding about risk assessment and provide an efficient level of preparedness (Lutz and Klein 2006; Moreno-Sanchez 2009).

Modular applications can be published, located, and dynamically shared across the web. The web environment provides a platform for sharing, analyzing, and collecting information. A WebGIS architecture is thus different from traditional GIS packages in that it offers an open, cooperative, scalable, reliable and extensible solution (Peisheng and Yang 1999). The results of multi-risk assessment studies are extremely complex; to have tools which can translate scientific activities to a broader audience is thus of great value (Rivas-Medina et al. 2009). GIS can combine different layers, while also providing tools for spatial analysis, and supporting complex activities at every step of risk assessment (see next chapter for details of training package). A user-friendly visualization instrument should however be used to facilitate interpretation, generation of basic knowledge, and representation of

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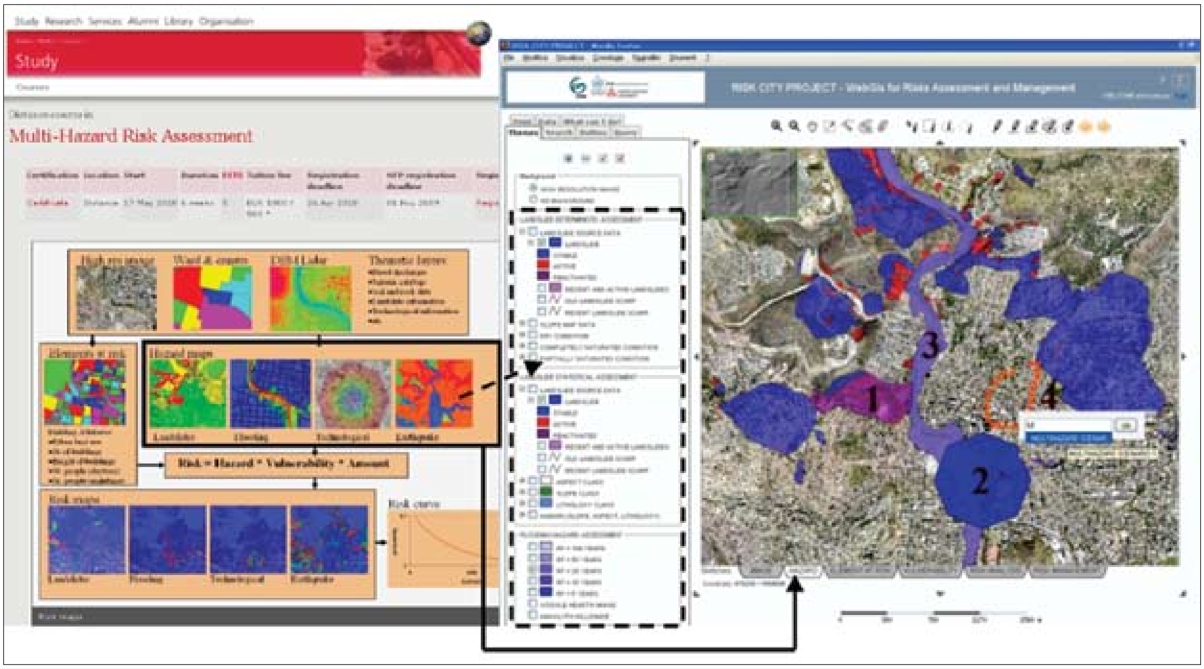

Figure 1. RiskCity distance-education course and the WebRiskCity platform. The Hazard maps activities are inside the black square in the course chapter and managed inside a switch in the web service ("Hazard" switch is select below the map). Data enclosed in the box breaks out in the layer control panel (dotted line and square).

results, both to increase the purpose of training and to define practical risk management plans (Romang et al. 2009).

WebRiskCity Training Package

Background

Worldwide, many organizations are involved in providing training in disaster risk assessment (ADPC 2005). Some organizations have focused attention on public safety and health, especially in developing countries, by introducing scientific research, technology transfer, and high-level training service (Cepeda et al. 2009; Boni 2009). Some training and scientific programs are trying to combine and evaluate the quantitative scientific analysis together with the qualitative public perception of natural hazards in different areas (Maquaire et al. 2009; Gunasekera et al. 2009; Scolobig et al. 2009).

While there are some training materials available on-line (FEMA 2008; EMA 2008; BE-SAFE-NET 2009), and literature gives basic information about the methodology of multi-hazard risk assessment (DEBRIS 2006; NAHRIS 2006), open source GIS-based training materials and textbooks are still scarce. Moreover, most of the applications are restricted to specific countries due to constrained types and quantity of data.

RiskCity distance-education course is built on the application of GIS for multi-hazard risk assessment. This course is designed for academic staff, planners, geographers, architects, and engineers, as well as for professionals working in NGOs where knowledge of disaster risk management is essential. The RiskCity distance education course is designed especially for those people from developing countries who should not be restricted in using the training package due to financial burdens of (GIS) software acquisition. It deals with procedures to collect, analyze, and evaluate spatial information for risk assessment from natural and human-induced hazards (Crozier and Glade 2005).

The aim is to use an Open Source solution (ILWIS software) as a basis (van Westen 2008a) for the RiskCity training package, so that students can interact with virtual classmates, proceed step-by-step, receive instruction and support from tutors, and submit results. The course supports the participants (van Westen 2008b) by teaching them about spatial data requirements for risk assessment, hazard assessment procedures, achievement of elements at risk databases, vulnerability assessment, qualitative and quantitative risk assessment methods, risk evaluation, and risk reduction for such hazards as earthquakes, flooding, technological hazards, and landslides.

	RiskCity	WebRiskCity
Data	Raw data on risk assessment PDF Guidebook	RiskCity analysis results Online Guidebook
Environment	Open Source GIS (ILWIS)	Open Source WebGIS (CartoWeb)
Session	Introduction to RiskCity and ILWIS	Introduction to WebRiskCity and CartoWeb
	Spatial data for risk assessment and image interpretation Hazard assessment Elements at risk Vulnerability assessment Risk analysis Risk reduction	
Activity	Image processing Spatial analysis Attribute table management Thematic map creation Import/Export	Anaglyph image analysis and interpretation Geometric querying Info export (CSV) Geometry and label creation Layout printing (PDF) Session linking (URL)

Table 1. The structures and activities of the RiskCity course (http://www.itc.nl/unu/dgim/] and the WebRiskCity platform (http://geoserver.itc.nl:8181/cartoweb3/WebRiskCity/].

In WebRiskCity, all exercises have been integrated into a parallel WebGIS platform using the Open Source software CartoWeb. See Figure 1 for structure comparison between RiskCity and WebRiskCity. The datasets and activities used in the distance education course are briefly discussed, but this work deals primarily with the web service offered—modular and customizable—and the hierarchic structure employed to manage and organize every package of information into the steps required for effective risk assessment.

The aim of WebRiskCity is to equip students and potential end-users with basic knowledge about each step in risk assessment (complete with a training dataset). The tools facilitating better technical approach to risk management, such as instruments, approaches, and scientific support, are discussed as well. Different switches for every component of the risk assessment course have been defined and, through various menus, users can select the exercise options they prefer. A simplified version of RiskCity results can thus be offered through the web. Because spatial data are available for different interactions, the user can personally evaluate the type and resolution of the data obtained during exercise session, compare different kinds of information in a multi-hazard-risk assessment environment, and prepare queries in line with the objective(s) of the exercise.

WebRiskCity allows users to learn about the different levels of risk assessment without actually executing all steps themselves. A gap between scientific community and end-user has to be addressed, in order to tailor the activities in risk assessment to the requirements of stakeholders and decision makers. Nikolaos et al. 2005, Olmedilla et al. 2005, and Lutz and Klein 2006 focus attention on the problem of semantic heterogeneity caused by the ambiguity of natural language; this issue can be resolved with a query language and graphical user interface (to intuitively formulate a query using a well known domain vocabulary is one of the main objectives of the work).

This paper describes the first step in building a distance interaction platform which will be implemented in the coming years. A comparison between RiskCity and WebRiskCity activities is given in Table 1.

WebRiskCity: The architecture

A WebGIS is a GIS platform for sharing spatial and geographical data using the web. The traditional stand-alone GIS tools are fixed and gathered to the client by the web, removing every need of software installation and setup (Brabhaharan et al. 2001; Beliën 2005; Crozi M. et al. 2006; Fan-Chieh et al. 2007; Lehto 2007; Tsou and Sun 2007; Herrmann

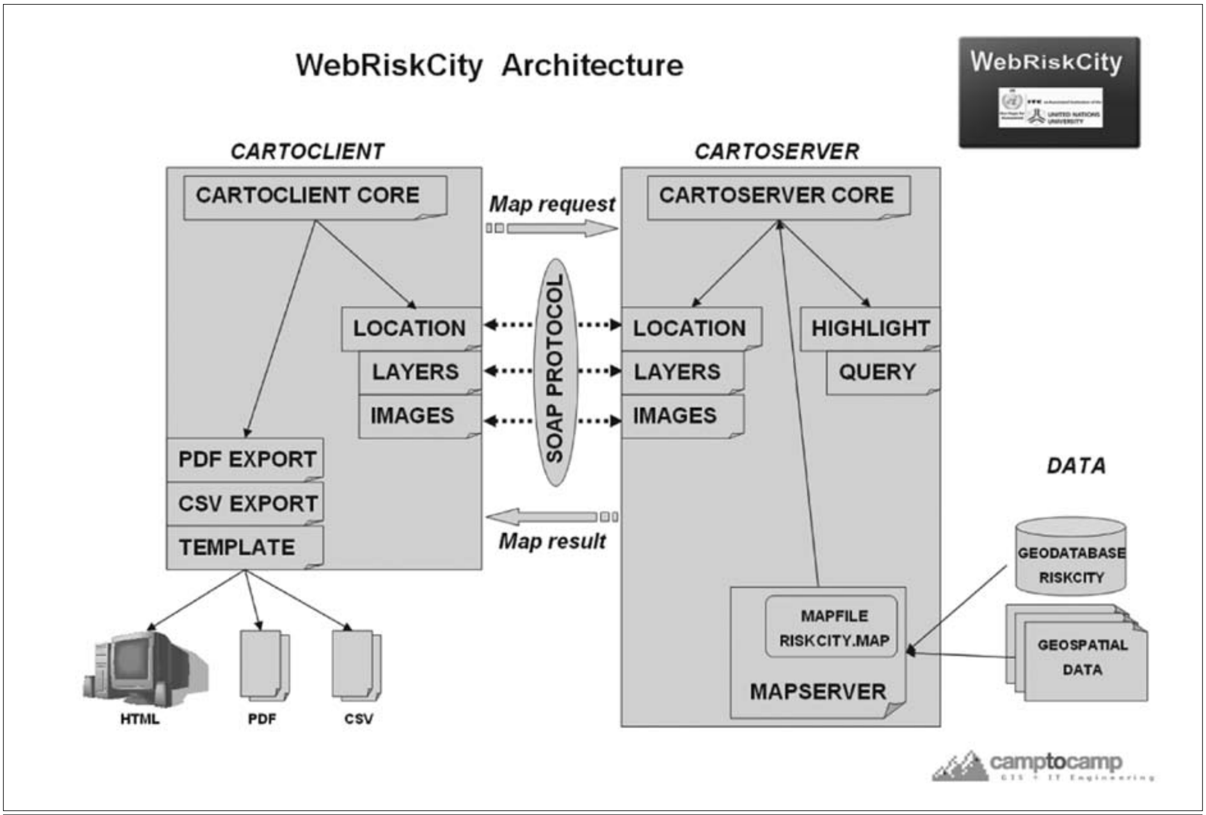

Figure 2. WebRiskCity architecture with client and server description. The SOAP protocol has been used to access remote procedures. A series of plugins allows different services in client or in server side.

2008; Balducci et al. 2004; Pierleoni et al. 2009; Rivas-Medina et al. 2009; Salvati et al. 2009).

The architecture of the system deals with components and how to combine them, the RiskCity database is the source for data while the WebGIS provides the frame. WebRiskCity network offers a series of web services at the server-side in which maps and spatial information are updated and organized to allow exploiting by users on the client-side. The WebRiskCity solution is built on Open Source CartoWeb[1], a ready-to-use WebGIS based on UMN Mapserver[2] engine and released under GNU GPL License[3]. A number of available open source engines (P.mapper, Cartonet, Geoserver, Geonetwork and others) has been considered for the aim of research. The choice of CartoWeb is a convenient framework because it is a modular and extensible solution and enables flexibility to future upgrade. A client-server model or stand-alone application is allowed; for the proposed work the second solution is performed using remote procedure based on SOAP[4] protocol (see Figure 2).

The architecture of the platform is based on a core navigation interface (map and navigation), and other tools are activated by the user (map query, annotation and labeling, measuring, creation of PDF and other export formats, online guidebook for every exercise). CartoWeb is composed of a set of standard plugins activated and adapted for the project aims. Figure 2 illustrates the interface available at the client level. The user can evaluate the type and resolution of the archived result data for every session, compare different kinds of information in a multi-hazard-risk assessment, prepare queries according to the goals, download information tables for outside elaboration, and can create personalized layouts with new shapes and labels directly drawn on the map without actually executing all steps of risk assessment.

A web-based system has to be user friendly, simple in structure and practical, based on scientific purpose but not necessarily focused on a full-blown geographic information system. Its performance could require a fast Internet connection, and it could be limited by data complexity and/or some

[1] CartoWeb application: http://www.cartweb.org/.
[2] Mapserver platform: http://mapserver.org.
[3] GNU-GPL General Public License: http://www.gnu.org/licenses/gpl.html.
[4] SOAP protocol: http://www.w3.org/TR/soap12/.

potential cumbersome editing or request activities by users. To avoid that many factors could possibly slow down the direct use of WebRiskCity, a rational compression of data (maintaining high resolution of images) is performed and a lightweight Web based map application gathers the aims of the project (Latini and Kobben 2005). An ESRI Geodatabase has been used to create a spatial database for storing the geometry and attribute data for CartoWeb. The database management system enables multi-user access and guarantees integrity to a large database. In the future, a PostGIS[5] and PostgreSQL[6] solutions will be implemented to provide better weighting in data access and management.

Arbitrarily Hierarchic Structure

The structure of the application is based on a complex hierarchy of layers which enable all users to compare different types of information and analyze a specific part of the City in several ways. All the maps are organized in switches, both to offer different data sets for risk assessment and to avoid long and unpractical sequences of layers (Figure 3a). Inside each switch, the user's activity and tasks are made easier by blocks, drop-down menus, and exclusive options.

Seven switches are used, following the different aims of the RiskCity distance course sessions, which are as follows:

- Introduction to WebRiskCity and CartoWeb;
- Spatial data for risk assessment and image interpretation;
- Hazard assessment;
- Elements at risk;
- Vulnerability assessment;
- Risk analysis;
- Risk reduction.

The aim of this structure is to provide a user-friendly instrument for the following purposes:

- Arrange results of different spatial analysis (script activities, mapping creation, image processing) in every step of risk assessment performed in RiskCity without working in a GIS environment;
- Manage every data result, following a hierarchic structure of the platform. Layers derived from different steps in risk management are considered and compared (transparency, reorder of layers, classification, legend);
- Create multiple light-weight and proof-of-concept platform view for simple way of sharing data (Latini and Kobben 2005);
- Offer a user-friendly potential instrument to understand every step of risk assessment without being a GIS expert (comparison of multi-hazard scenarios, element at risk database, vulnerability modeling);
- Train on every spatial and informative comparison of the results, to attend topics in multi-hazard risk management and to support a disaster decision support (cost-benefit, number of buildings and population involved, potential losses).

The platform is a direct user-friendly device for technical staff and decision makers who normally do not have a background in Geoinformatics for Risk Analysis and Management. The instrument identifies the multi-risk reality of the study area, presents the more "sensible" parts of the study area prone to different kinds of hazards, compares different maps, and teaches to understand the values and flaws of risk management.

The Study Area and the Spatial Database

The training package includes GIS data and support, a guide book for activities required in spatial analysis of hazard, as well as vulnerability and risk assessment for the urban environment. RiskCity is a hypothetical urban case study, but the entire database is built on the area of Tegucigalpa, Honduras.

After the Mitch Hurricane in October 1998 there was a serious river flooding caused by 281 mm of raining in 3 days (Mastin and Olsen 2002). An old landslide was reactivated, and an entire neighborhood was destroyed. As a next consequence, landslide damming on the river caused a serious flooding in large parts of Tegucigalpa for several weeks (Harp et al. 2002). To determine the degree of instability, the landslides were studied using methods described in the next section (Soeters and van Westen 1996; Castellanos Abella 2008). The database does not provide real information about the area; some exercise layers and additions have been introduced to complement an original incomplete dataset. This helped achieve the learning objective, while presenting a comprehensive view of the multi-hazard although not all the hazard types really occurred in the affected area.

Tegucigalpa encloses an area of 14 km^2; the study and the training package were thus designed on a local scale level. The hazards and vulnerability

[5] PostGIS home website: http://postgis.refractions.net/

a)

b)

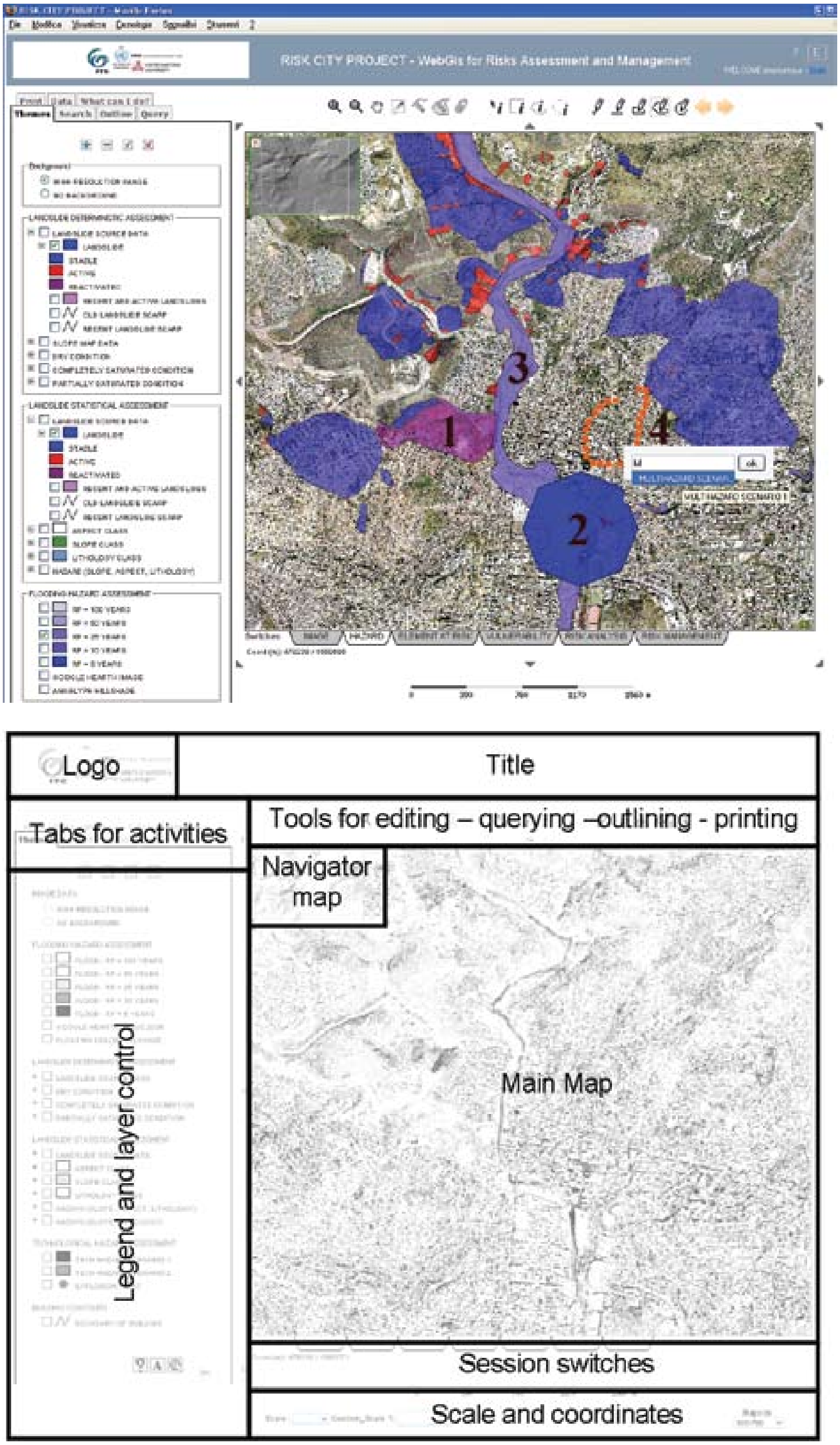

Figure 3. Framework of WebRiskCity. a. Map interface of Tegucigalpa with four numbered layers (real and added) involved in the activities (1 - reactivated landslide; 2 - potential technological scenario; 3 - flooded area in the centre of the city; 4 - new potential hazard scenario created by the user. The orange polygon is closed and marked with a label). b. Map and navigation interface. The web application layout. The Session switches are connected with the chapters of training in RiskCity.

activities are on a range scale of between 1:200 and 1:5000, and the user can select his or her own scale and make a comparison between layers at different scales. With this approach, it is possible, for example, to correlate classified hazard map evaluated in a deterministic model (Session 2 in next chapter) for the entire area and single points of interview related to response (Session 5 in next chapter), and for recovery or preparedness of population to hazard and disaster. The correlations between layers in risk assessment (for every step and for different kinds of natural hazard) are in different time frames. For instance, some flooding scenarios (marked by five return periods) can be compared with the mapped units of buildings to improve an evaluation of potential losses for the same element at risk considering a different time frame.

Multi-hazard Components

WebRiskCity is accompanied by a series of exercises allowing participants to learn about the various steps, without actually doing all the steps themselves. They get the results of the individual steps and have to use them in analyzing the problem and deriving conclusions. This has been achieved by incorporating a number of scenarios (Figure 3a), where the participants can evaluate their parameters and select the best option, or analyze a particular section of the city, using the tools window offered by the platform (Figure 3b).

For every step, the data, objective, and activities are listed, and users can follow a training path or go directly to the step that interests them. Users can interact with all the layers, already organized in switches following the steps of risk assessment. Map of different kind of hazard can be overlaid, query on multiple-layers and personalized geometry can be created. We explain each activity to be undertaken by users below.

Session 1: Introduction to WebRiskCity and CartoWeb

The first training session aims to improve the basic knowledge about the factors involved in

Name	Type	Meaning
Image Data		
High Resolution Image	Raster image	This represents a high resolution color image derived from an IKONOS image. It has been orthorectified, and the panchromatic band is fused with the color bands, and re-sampled to 1 meter.
Data Introduction		
Elevation Data		
Contours	Segment map	This file contains contour lines with 2.5 meter contour interval. These have been digitized from a series of 1:2000 scale topographical maps. (SCALE CONTROL).
LidarDEM	Raster map	Digital Elevation Model from LIDAR image in which the altitude is indicated in colors float classification.
TopoDEM	Raster map	Digital Elevation Model from contour lines interpolation in which the altitude is shown in grey tones.
Elements at Risk		
Building Map	Polygon map	Building footprint map of the city prior to the 1998 Mitch event. The map still contains the buildings that were destroyed by landslides and flooding during the Mitch event.
Mapping Units	Polygon map	Building map of the city using urban units.
Floors Estimated	Raster map	Number of floors, made using the exercise described in this ILWIS version.
Hazard Data		
Landslide	Polygon map	Landslides in the study area, with an attribute table containing information on the landslides activity.
Flood – RP=100 years	Polygon map	Flood extend map for a 100-year return period, obtained through modeling with HEC-RAs hydrological software

Note: Every session has his proper list of data, visualized on-line or on guidebook. Some layers are repeated in different step of risk assessment because of their usefulness in risk assessment. Following hierarchical structure and to avoid repetition in table only standard layers of session are embedded in the list.

Table 2. List of data used in some switches in RiskCity, grouped in image data, elevation data, and element-at-risk and hazard data.

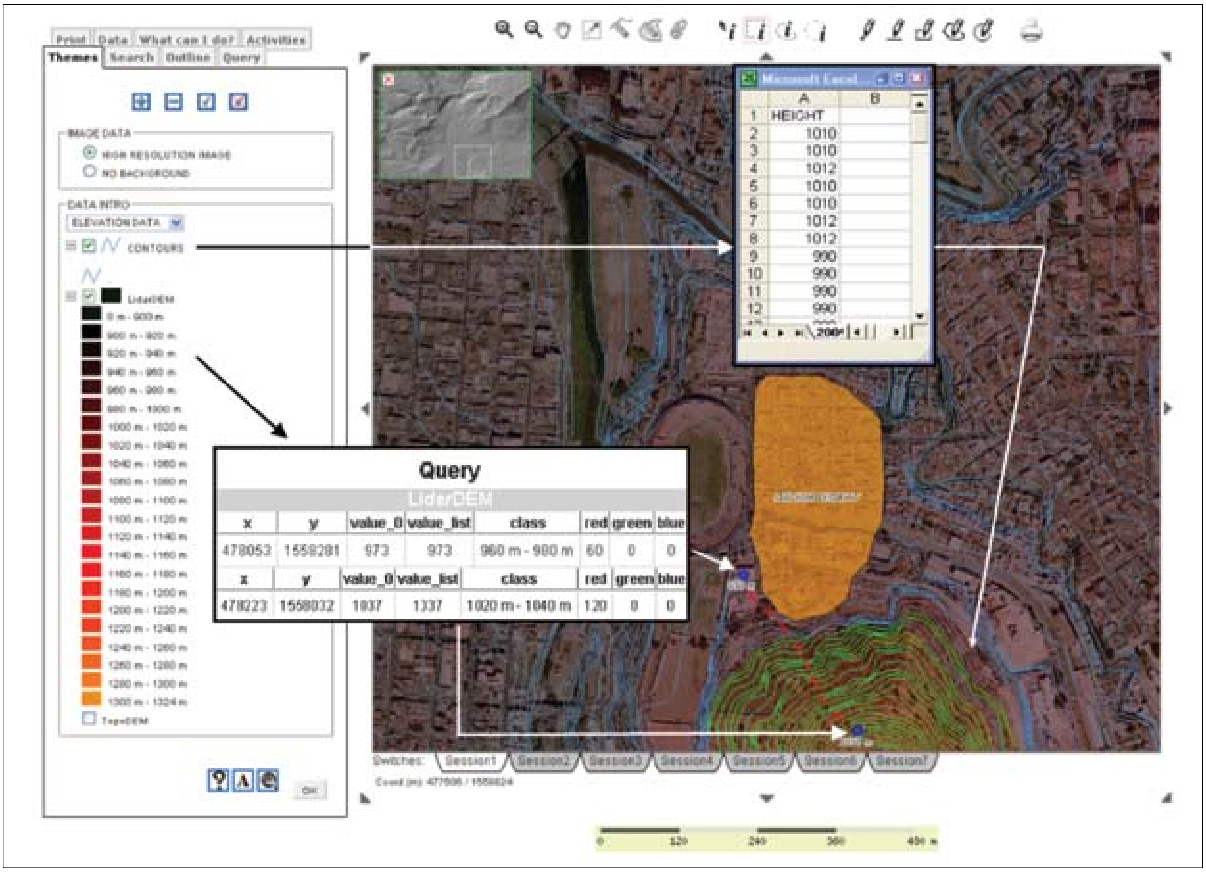

Figure 4. Area with steep slope. Maximum and minimum ranges of elevation are defined by two circle points, using LidarDEM value and contour lines (see "Themes" tab). Two query masks display the value from the two layers (one in a direct query format, the other already exported in a csv format). A dotted line connects the point following slope shape using a high-resolution background image.

risk assessment. This is achieved by presenting the situation in RiskCity in terms of hazards, elements at risks, and available data (Table 2).

First, a high resolution image (orthorectified IKONOS raster) is displayed to perform an evaluation of signs of recent disasters and visualize the most vulnerable zones (number of areas, reasons for the condition, discovery of slums on steep slopes and close to the river). The second step is to realize the significance and usefulness of the elevation data image. In this regard, users can explore the area and visualize elevation values ranging between the minimum and the maximum in order to find out areas with steep slopes (Figure 4). This requires a comparison between LidarDEM, TopoDEM, and contours lines in detailed scale, as well as a query response to visualize an example of the height of buildings in a city block. The introduction proceeds with displaying the landslides distribution map and the building map; the correlation helps find building areas developed in old landslides area and facilitates spatial queries aimed at estimating the number of buildings in the area.

Session 2: Spatial Data for Risk Assessment and Image Interpretation

Different aspect of risk can be analyzed and mapped with a variety of spatial data. In this session, we present the spatial data types supporting risk assessment and the tasks which can be performed with them.

This session is aimed at improving the understanding of the changes in hazards and vulnerability over time by means of looking at multi-temporal images. (For importance of using stereo image interpretation to recognize the geomorphologic situation and the relation between urban land use and geomorphology, see Table 3). The activities are intended to realize multi-temporal evolutions in the hazard situation and in the changes of the urban growth by looking back in time towards orthoimages and anaglyph maps (Tralli et al. 2005).

A comparison of three periods is made in this step: a Google Earth image from 2006 is used to

Name	Type	Meaning
Hazard and Building Data		
Old Landslide Scarp	Segment map	Old landslides scarp in the study area, interpreted from the available images
Boundary of Buiding	Segment map	Boundary lines of the buildings in the area. Can be used to assess the quality of the orthoimages.
Multi-temporal Image		
Orthophoto 1977	Raster	Orthorectified air photo, after generation of a georeference direct linear and resampling to the common georeference of the area.
Anaglyph 1977	Anaglyph	Stereopair generated from the Airphoto_1977 and the Lidar DEM. It can be visualized using a screen stereoscope or using anaglyphs
Orthophoto 1998	Raster	Orthorectified air photo from 1998 taken just after the landslide and flood disaster, made after generation of a gereference direct linear and resampling to the common georeference of the area.
Anaglyph 1998	Anaglyph	Stereopair generated from the Airphoto_1998 and the Lidar DEM. It can be visualized using a screen stereoscope or using anaglyphs
Google Hearth Image 2006	Raster	High resolution image downloaded from Google Earth, which can be georeferenced and resampled in order to use it for the stereo image interpretations.
Floating Color Hillshade	Raster	Hillshading image with floating colour from blue to yellow to recipe steep slopes

Table 3. Data divided into groups of high resolution images, hazards, and building data.

verify the presence of reactivated old landslides after Mitch Hurricane; a 1998 image shows the effects that the Mitch Hurricane had in Tegucigalpa, while the 1977 image enables the user to search for and draw landslides already present. For the same periods a cluster of anaglyph images is offered. Anaglyph format is a calculated stereo pair in the map window; the anaglyph is either displayed in Red-Green or in Red-Blue; user can view the 3D height differences in the stereo pair by using red-green or red-blue glasses.

Session 3: Hazard Assessment

In a multi-hazard risk assessment, this step is absolutely the most important (Table 4). It enables distinction of hazard maps for different periods, facilitates the understanding of the procedures for landslide and flood hazard assessment, aids the selection of different scenarios, and assists in the evaluation of the possible effects of flood, landslide, earthquake, and technological hazard.

The activities aim to compare landslide and flooding hazards by evaluating the flooding area after different return periods, developing a landslide map occurrence, and comparing three scenario maps resulting from a deterministic assessment in dry, wet, and saturated conditions (Demeritt et al. 2007; Faulkner et al. 2007). A concurrent comparison of three susceptibility maps with different combinations of parameters (lithology, slope, aspect) aids statistical assessment (U.S. Geological Survey 1984; Maquaire 2005; van Westen et al. 2005; van Westen et al. 2008).

Session 4: Elements at Risk

In this session, users explore the how an element at risk database is created and managed using a high resolution image and a census or cadastral information. An urban land use is compared with high resolution images as data source of identification, and with mapping units boundaries (Table 5).

The land-use classes can be compared with the number of buildings (it is possible to manage daytime and nighttime population, by available dataset). As a second step, it is possible to match different resolution data by overlaying mapping units with building maps and evaluate the number of building for every unit. The last part of this session deals with participatory mapping and Participatory GIS (PGIS) criteria for Disaster Risk Assessment (Table 6).

To generate information at the local level it is important to work together with local communities (Bankoff 2004) and learn from their local knowledge. These factors are critical in understanding the vulnerabilities and capacities of an area, but they are rarely available on maps and even less so in a format that can be entered into a GIS. This information is crucial as the local population has the best knowledge about the hazard events they have experienced (Campbell 2000; Dekens

Name	Type	Meaning
Flooding Hazard Assessment		
Flood – RP = 100 years	Polygon map	Flood extend modeled for a flood with a 100 years return period
Flood – RP = 50 years	Polygon map	Flood extend modeled for a flood with a 50 years return period
Flood – RP = 25 years	Polygon map	Flood extend modeled for a flood with a 25 years return period
Flood – RP = 10 years	Polygon map	Flood extend modeled for a flood with a 10 years return period
Flood – RP = 5 years	Polygon map	Flood extend modeled for a flood with a 5 years return period
Landslide Deterministic Assessment		
Landslide Source Data		
Landslide	Polygon map	Landslides in the study area, with an attribute table containing information on the landslides activity.
Recent & Active Landslides	Polygon map	Landslides with recent activity
Old Landslide Scarp	Segment map	Old landslides scarp in the study area, interpreted from the available images
Recent Landslide Scarp	Segment map	Recent landslides scarp in the study area, interpreted from the available images
Dry Condition		
Fdry	Raster map	Classified Factor of Safety map made using deterministic method for a dry scenario
Completely Saturated Condition		
Fsat	Raster map	Classified Factor of Safety map made using deterministic method for a saturated scenario
Partially Saturated Condition		
Fwet	Raster map	Classified Factor of Safety map made using deterministic method for a wet scenario
Landslide Statistical Assessment		
Aspect Class	Raster map	Classified aspect map
Slope Class	Raster map	Classified slope map
Lithology Class	Polygon map	Classified lithology map
Hazard (Slope, Aspect, Lithology)		
Weight Map	Raster map	Weight map for 3 variables
Landslide Hazard Map (3 Classes)	Raster map	Landslide susceptibility map, made using the weights of evidence method and classified with 3 classes
Hazard (Slope, Lithology)		
Weight Map	Raster map	Weight map for 2 variables
Landslide Hazard Map (3 Classes)	Raster map	Landslide susceptibility map, made using the weights of evidence method and classified with 3 classes
Technological Hazard Assessment		
Tech Hazard Scenario 1	Polygon map	Area exposed to an explosion of a chemical factory
Tech Hazard Scenario 2	Polygon map	Area exposed to a fire in a chemical factory
Explosion Point	Point	Explosion or fire point
Earthquake Data		
EQ_500 years	Polygon map	EQ_500 years
EQ_200 years	Polygon map	EQ_200 years
EQ_100 years	Polygon map	EQ_100 years

Table 4. Data matrix for multi-hazard assessment. Different kinds of natural and antrophic hazards, with different return periods or modeling procedures are considered.

2004), their local causes and effects, and the way their community coped with them. This information is essential for land-use planning, conflict management, and for disaster risk management. Participatory GIS is a useful tool for extracting lay (indigenous) knowledge and perceptions of environmental problems and hazards, as well as for

Name	Type	Meaning
Elements at Risk Database		
Mapping Units	Polygon map	This map represents the mapping units used for elements at risk mapping, but now as polygons. Each of the mapping units has a unique identifier, so that in the accompanying table information can be stored for each unit. The units may be individual large building or plots with a specific landuse, although they are mostly grouping a number of buildings. In the accompanying table information is given on the number of buildings and number of people
Wards	Polygon map	A polygon map representing the administrative units within the city. In the accompanying table information is given on the number of buildings and number of people based on a recent census.
Roads	Segment map	A segment map of the streets, roads and paths, made by digitizing from topographic maps.

Table 5. Element at Risk database: ILWIS image processing integrated with units information.

Name	Type	Meaning
Participatory GIS Data		
Point of Data with Interview	Point map	Point map with results of interviews from a survey in a flood and landslide affected neighborhood

Table 6. Participatory data with results of interview.

presenting and communicating this knowledge to environmental scientists and local authorities.

The course is structured around the concept that a PGIS is not only about collecting information from the local communities, but rather about collecting information with them, and interacting with them to access the local knowledge which is indispensable for reducing risk. In WebRiskCity, the student will encounter the use of PGIS as support in hazard assessment (reconstruction of historical disaster events, scenarios, and damages), as an element at risk mapping (buildings characteristics, people socioeconomic status, livelihood), basic infrastructure (sanitary facilities and water access, community services), and environmental problems (waste disposal, polluted areas). The participatory data used in the distance learning course is planned only for training and is intended to helps students understand how people can be directly involved in risk assessment, and how even not-scientific background information could provide a precious and useful input into research.

Session 5: Vulnerability Assessment

In this session, students examine vulnerability estimation results—physical, social, economic, and environmental. They are then exposed to vulnerability assessment and the different ways by which this is defined (methods, way of expression, quantification for flood, earthquake, and landslide vulnerability).

This session is one of the most "fuzzy" of the training module, as the concept of vulnerability is defined in many different ways (European Spatial Planning Observation Network 2003; Wisner et al. 2004; Birkmann 2006). Students begin by looking at the various definitions and approaches used to characterize vulnerability. Most of the session deals with methods to express and quantify physical vulnerability (procedures for creating vulnerability curves and matrices for flooding, earthquakes, and landslides are explained). A separate section deals with the analysis of population vulnerability and the methods are used to quantify the entire spectrum of vulnerability. In WebRiskCity, activities are aimed at displaying the mapping units, and evaluating building and population information (Maquaire et al. 2004), and ward maps.

In the next step, the student can display the landslide, flood, earthquake, and technological hazard maps. Once a criteria tree has been defined (outside the platform) and the relevant factors have been assigned, the indicators derived by different kind of approach can be combined (Bollin et Hidajat 2006) and the resulting qualitative risk maps can be displayed. At the end of the session the students can display point maps with interviews, query the results to obtain information about the extent of the hazard, characteristics of households and their priorities (use the information to design a risk reduction strategy for flood and landslide affected neighborhood).

Session 6: Risk Analysis

This session deals with the central theme of this course—risk analysis as part of risk assessment. Quantification of the risk in terms of losses for all the possible scenarios which might occur is based

Name	Type	Meaning
Quantitative Risk Analysis		
Building Risk Map		
Flood Risk Buildings	Raster map	Map indicating the number of buildings per mapping unit within the flood area for different return periods
Landslide Risk Building	Raster map	Map indicating the number of buildings per mapping unit within the landslide area for different return periods
Earthquake Risk Building	Raster map	Map indicating the number of buildings per mapping unit within the earthquake area for different return periods
Technological Risk Building	Raster map	Map indicating the number of buildings per mapping unit within the technological hazard scenarios for different return periods
Multi-hazard Risk Analysis		
Flood Losses	Raster map	Map indicating the potential losses for mapping units considering different return periods
Lansdlide Losses	Raster map	Map indicating the potential losses for mapping units considering different return periods
Seismic Losses	Raster map	Map indicating the potential losses for mapping units considering different return periods
Tech Losses	Raster map	Map indicating the potential losses for mapping units considering different return periods

Table 7. Comparison of a multi-hazard risk losses map with a buildings risk map.

on several approaches (Carrara 1993; IUGS 1997; Hardingham et al. 1998; Glade 2002; Bell and Glade 2004; Remondo et al. 2008). These range from calculating the hazard to evaluating vulnerability consequences.

For a number of different hazard scenarios the consequences are plotted on a graph against the temporal probability of occurrence of the hazard events. Through these points, a curve is fitted, the so-called risk curve, and the area below the curve presents the total risk. In a multi-hazard risk assessment, this procedure is carried out for all individual hazard types. Care should be taken to evaluate also the interrelations between hazards (e.g., domino effects, such as a landslide damming a river and causing a flood). Since the risk is normalized into annual risk, it is then possible to evaluate the multi-hazard risk and use the risk curves as the basis for disaster risk reduction. This is the next in line of the chain of previous steps taken to identify and assess the hazards, generate the elements-at-risk database, and assess vulnerability. Students can use previous data for an estimation of the average annual losses for buildings for all natural hazards (Peters Guarin et al. 2005; Castellanos Abella and van Western 2007) and use a simple vulnerability curve to calculate loss curves and the average annual losses for the individual risk types (comparing the results with spatial information and complete spatial and temporal information, Table 7).

In this session, students can employ various methods for risk assessment. First, the concepts of risk assessment and the different ways in which risk can be expressed are presented against a large reference background. Then three different types of approaches for risk assessment are considered: qualitative methods using risk matrices, semi quantitative methods using indices and spatial multi-criteria evaluation, and quantitative methods using a probabilistic approach. A number of parallel exercises (using external spreadsheets) are provided to learn the principles of the method, and there are several RiskCity exercises available to solidify knowledge about flood risk assessment, landslide risk assessment, earthquake risk assessment, technological risk assessment, and multi-hazard risk assessment.

The activities can be organized in WebRiskCity as follows: overlay the number of buildings on top of the various hazard maps and query for buildings affected; display the various maps with number of building affected superimposed on them (calculate the total number of buildings within each return period and each hazard type); use a simple vulnerability curve in Excel to calculate loss-exceed curves and the average annual losses for the individual risk types (map rendering of the results).

Name	Type	Meaning
Elements at Risk		
Urban Landuse	Polygon	Landuse map of the city
Risk Evaluation		
Flood Risk Buildings	Raster map	Map indicating the number of buildings per mapping unit within the flood area for different return periods
Flood Risk Population 100 - 10	Raster map	Map indicating the number of persons per mapping unit within the flood area for different return periods
Flood Risk Costs	Raster map	Map indicating the losses per mapping unit within the flood area for different return periods
Landslide Risk Buildings	Raster map	Map indicating the number of buildings per mapping unit within the landslide area for different return periods
Landslide Risk Population	Raster map	Map indicating the number of persons per mapping unit within the landslide area for different return periods
Landslide Risk Costs	Raster map	Map indicating the losses per mapping unit within the landslide area for different return periods
Earthquake Risk Buildings	Raster map	Map indicating the number of buildings per mapping unit within the earthquake area for different return periods
Earthquake Risk Population	Raster map	Map indicating the number of persons per mapping unit within the earthquake area for different return periods
Earthquake Risk Costs	Raster map	Map indicating the losses per mapping unit within the earthquake area for different return periods
Technological Risk Buildings	Raster map	Map indicating the number of buildings per mapping unit within the technological hazard scenarios for different return periods
Technological Risk Population	Raster map	Map indicating the number of persons per mapping unit within the technological hazard scenarios for different return periods
Technological Risk Costs	Raster map	Map indicating the losses per mapping unit within the technological hazard scenarios for different return periods
Hazards		
Seismic Hazard	Polygon map	Raster map indicating areas with high, moderate and low earthquake hazard

Table 8. Cost by type of hazard. The basic information for risk management.

Session 7: Risk Reduction

This session demonstrates how risk information can be used in disaster risk assessment (Guzzetti F. 2000; Moore et al. 2001; Crozier and Glade 2005). Students carry out a cost-benefit analysis (clusters of expected losses for every type of hazard in the periods used in the previous sessions) for different reduction measures (Table 8) whose results are the starting point for land-use planning and real risk management, such as identifying the areas where the need for shelters would be the greatest and determining where a future extension of the city would be most appropriate.

In this session, the aspects of Risk Perception and Risk Evaluation are determined within the framework of Disaster Risk Management (the training concentrates on the aspect of Risk Governance, with stakeholder involvement as the main issue). Next, spatial information usefulness in Risk Visualization is delineated as part of the Risk Communication. Then the focus is on the different structural and non-structural measures for risk reduction. This part of the session includes a simulation draft exercise wherein the student is a virtual end-user in a given Geoinformation Department of the RiskCity municipality and has to provide the right information to the emergency managers at the right time, using layout mapping tools, query on time information, and all the data available. The various risk reduction measures are evaluated and compared using a cost-benefit analysis.

Conclusions and Future Research

In order to conduct appropriate risk assessment and to understand the true meaning of a complete multihazard evaluation, end users require the most accurate available data as well as the easiest way to acquire this information. Moreover, people working in the field of disaster risk management with limited scientific background should be able to learn how to deal with natural and anthropogenic risk. Developing a common WebGIS tool to achieve these objectives is a suitable solution in terms of improving communication, training, and information sharing between those working in the field of disaster risk management.

The browser handling of activities provides the possibility of customizing each activity to meet the real need of end users in risk assessment. A web-based risk assessment platform does not ignore the scientific pattern of each step in the analysis. Hazard modeling, vulnerability assessment, and image interpretation require an extensive scientific background. However, the interpretation of the available results as well as the practical use of information are equally indispensable for an efficient and well-formed risk management of an area.

In this paper, we presented the WebRiskCity as a learning and training platform. It not only offers a possibility to provide concrete ideas about natural hazards, but also the steps that the scientific community has been proposing and advancing for effectively dealing with them. Future work will include the growth and expansion of the platform following the needs of risk assessment. Testing the application on new study sites, as well as fulfilling scientific and data sharing needs, is providing a key tool for managing and studying natural hazards. A direct necessity is to improve the user-friendly approach of a web service, and to boost the velocity of querying and exporting information. This is required in terms of offering a more straightforward instrument to people who want to increase their knowledge in multi-hazard assessment.

The framework has been tested in short, distance learning courses on multi-hazard risk assessment taken by ITC staff; the first course was in June 2009 and it involved 19- to 30-year-old students from developing countries who had a common background (bachelor in Geology, Geography, Geomorphology or similar). A second course provide a concrete mirror of the instruments offered in the first course, but its outcomes were not sufficiently different for statistical analysis on the usability, functional capacity, and usefulness of the course (only after a new courses has been given will it be possible to carry out a social analysis of participants with statistical criteria).

This notwithstanding, some interesting proposal and evaluation have emerged from the two courses conducted so far: the guide book, which included base theory, concepts, examples, and tips profusely complemented with graphs and tables, was positively received. The students appreciated also the theory-and-practice approach taken, and feedback suggested that this approach was very helpful in their understanding the essential concepts of risk assessment. The tasks splitting was appreciated as well, as it was seen to promote clarity in theory and practical application, with topics targeted to the special needs of risk management. Participants suggested giving longer courses so as to increase the benefits accruing from each session and provide more hands-on exercise.

The students founds the blackboard communication an effective tool to support the exercise (sometimes a loss of web synchronization or browser connection problems caused a delay in instruction), and, generally, they were satisfied with the prompt answers received from tutors. They valued the connection between the concept and mechanism of risk analysis in the distance course but felt the need to apply all the steps under local circumstances (i.e., compare "virtual" training with real, local risk case studies based on the same work plan, communication support, and research of local knowledge on past events. Some technical advice has been given following the testing of WebRiskCity's query tools for improvement, personal classification of the layers visualized and colors scheme, and advanced editing services.

The package has been developed to increase the knowledge of natural risks by presenting a complete suite of exercises, hypothetical case study datasets, and materials on the various steps required to collect and analyze relevant spatial data for risk assessment. Therefore the combination between RiskCity and WebRiskCity offers a mirror for one of the potential available methodology to explain multi-hazard risk assessment issues and user-friendly way of communication.

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