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Multi-hazard risk assessment

Distance education course

RiskCity Exercise book

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www.itc.nl/unu/dgim

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Introduction

The world is confronted with a rapidly growing impact of disasters, due to many factors that cause an increase in the vulnerability of society combined with an increase in (hydrometeorological) hazard events related to climatic change. The possible impacts of hazardous events are large, especially in developing countries and governments have to incorporate risk reduction strategies in development planning at different levels. The evaluation of the expected losses due to hazardous events requires a spatial analysis, as all components of a risk assessment differ in space and time. Therefore risk assessment can only be carried out effectively when it is based on extensive, multidisciplinary studies on the basis of spatial information, derived from Remote Sensing and other sources. There is an urgent need to include the concepts of disaster geo-information management into emergency preparedness planning, spatial planning and environmental impact assessment. This requires 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.

Objectives

This course deals with the procedures to collect, analyse and evaluate spatial information for risk assessment from natural and human-induced hazards (such as geological hazards, hydrometeorological hazards, environonmetal hazards and technological hazards). The course will guide you through the entire process of risk assessment, on the basis of a case study of a city exposed to multiple hazards, in a developing country (RiskCity).

At the end of this course you will be able to:

1. understand the concepts of hazard assessment, elements at risk mapping, vulnerability assessment, and risk assessment;
2. formulate the spatial data requirements for risk assessment;
3. generate an elements at risk data base using GIS;
4. formulate the requirements of hazard data and methods;
5. apply various methods for vulnerability assessment;
6. generate risk maps using qualitative and quantitative methods;
7. have insight in how a risk assessment could be carried out in your own situation;

This course is designed for all those who have to carry out risk assessment and need knowledge and skills on the procedures to do that using a GIS. These include professionals working in NGOs and governmental organisations related with disaster risk management, but also professionals, planners, engineers, architects, geographers, environmental specialists, university teachers. Some basic background in Geographic Information Systems is desirable, although not strictly required, as the course follows a step-by-step approach which allows participants to rapidly acquire the basic skills in handling GIS software. If you lack the basic GIS skills it might be better to follow the course in a classroom environment, where more direct support on the software can be given. Courses on multi-hazard risk assessment are offered annually in the Netherlands, Mexico, Bolivia, and Thailand, and frequently also in India and China.

Course structure

The course is composed of a number of sessions. Below is a summary of the sessions and detailed content.

Session 0: Getting started

Theory: Introduction to the course, objectives, structure, and set-up. Explanation of the available materials.

Activities: Set up Blackboard account, install ILWIS software, getting to know the tutors and fellow students.

Session 1: Introduction to disaster risk management

Theory: Introduction to disaster risk management and risk assessment.

Exercise: Generation of a hazard profile using disaster databases; Introduction to ILWIS, and introduction to the RiskCity dataset. Learn the various hazard problems by evaluating high resolution images

Session 2: Obtaining spatial data for risk assessment

Theory: Presentation of data requirements for the various types of hazards. Sources of spatial data.

Exercises: Defining spatial data requirements for risk assessment; Internet search for information on risk assessment; acquiring free and low cost data; generating three dimensional image data using Google Earth; stereo image interpretation

Session 3: Hazard Assessment

Theory: Hazard types; Main concepts of hazard assessment; Frequency magnitude – relationships

Exercises: Frequency assessment; Selection of hazard assessment example (flooding, landslides, earthquakes, technological hazards, volcanic hazards etc)

Session 4: Elements at risk assessment

Theory: Types of elements at risk; classification of buildings, infrastructure, lifelines, critical facilities; population information; collection of elements at risk information.

Exercise: Generating an elements at risk database from scratch; Generating an elements at risk database using available data (building footprint map, census data and LiDAR) ; Participatory GIS

Session 5: Vulnerability assessment

Theory: Types of vulnerability; social vulnerability; physical vulnerability; methods for vulnerability assessment; participatory GIS; Spatial Multi Criteria Evaluation

Exercises: Defining vulnerability curves; Spatial Multi-criteria evaluation for vulnerability assessment

Session 6: Risk estimation

Theory: Loss estimation models; HAZUS; qualitative risk assessment; QRA; basics of flood risk, seismic risk, landslide and technological risk assessment;

Exercises: Creating risk curves; Selection of risk assessment method: flooding, earthquakes, landslides, technological. Multi-hazard risk assessment

Session 7: Risk management

Theory: Risk evaluation; risk governance; risk communication; cost benefit analysis; Using risk information for emergency planning; spatial planning, and Environmental Impact Assessment

Exercises Use risk information for disaster preparedness; Cost benefit analysis

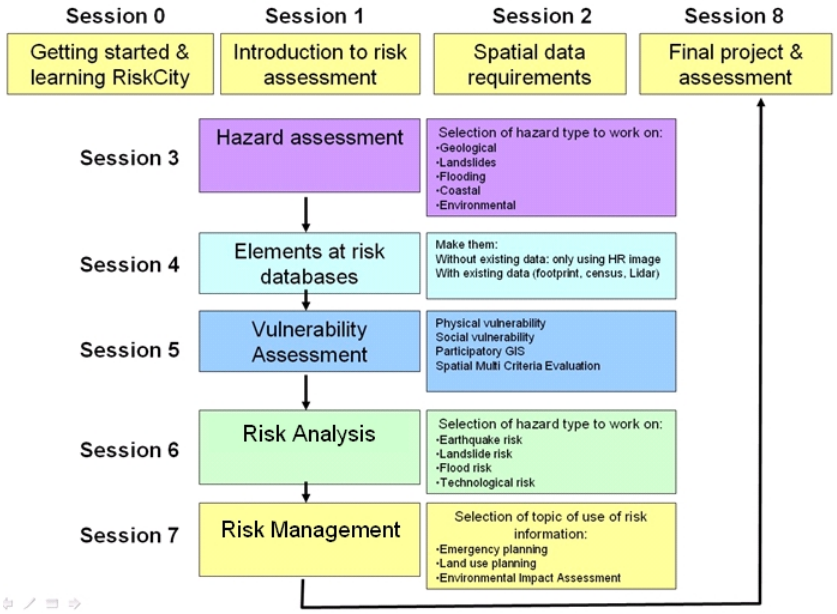
Session 8: Final project and examination

Discussion: How to do such a study in your area?

Final project: Selection of project topic related to risk assessment and its use in risk management

Examination: multiple choice exam.

The figure below illustrates the course structure:



The table below gives an overview of the sessions and related RiskCity exercises.

Session		RiskCity exercise
1. Introduction to Risk Assessment		Exercise 1: Introduction to ILWIS and the Riskcity dataset
2. Spatial data for risk assessment		Exercise 2: Creating and interpreting multi-temporal images
3. Hazard assessment		Exercise 3a: Frequency assessment
	Choice: flooding	Exercise 3F1: Flood hazard assessment using 2D flood propagation model outputs
		Exercise 3F2: Flood hazard monitoring using multi- temporal SPOT-XS imagery
	Choice landslides	Exercise 3L1. Landslide susceptibility assessment using statistical method
		Exercise 3L2. Deterministic landslide hazard assessment
	Choice: Volcanics	Exercise 3V: Modeling erosion from pyroclastic flow deposits on Mount Pinatubo
	Choice: Earthquakes	Exercise 3E: Earthquake hazard assessment
	Choice: Coastal	Exercise 3C1: Hazard analysis of cyclone flooding in Bangladesh
		Exercise 3C2: Analysis of coastal areas vulnerable to Enhanced Sea Level Rise
		Exercise 3C3: Modeling of Land Subsidence & Sea level rise in Semarang city, Indonesia
4. Elements at risk	Choice options	Exercise 4a: Generating a database of elements at risk from scratch
		Exercise 4b: Generating a database of elements at risk using existing data
		Exercise 4c: Participatory GIS for risk assessment.
5. Vulnerability assessment		Exercise 5a. Generating vulnerability curves
		Exercise 5b. Spatial Multi Criteria Evaluation for vulerability and qualitative risk assessment
6. Risk Assessment	Choice options	Exercise 6F: Flood risk assessment
		Exercise 6L: Landslide risk assessment
		Exercise 6S: Seismic risk assessment
		Exercise 6T: Technological risk assessment
		Exercise 6M : Multi-hazard risk assessment
7. Risk Management		Exercise 7b: Risk information for emergency preparedness & response
		Exercise 7a. Analysis of costs & benefits of risk reduction scenarios
8. Final project		Select a topic from a list and carry out your own analysis

Software

The course uses standard software like Adobe Acrobat Reader (Click here to download it if you don't have it yet)

The course is based on the use of Open-Source software. Open Source software has a number of criteria (http://www.opensource.org/docs/definition.php), some of which are:

- Freely distributed, downloadable from the Internet
- Access to the source code of the software
- Allows modifications or additions to the programme
- No discrimination against persons

ILWIS

The main software that will be used for all the GIS exercises that are part of this course written for the ILWIS software. ILWIS is an acronym for the Integrated Land and Water Information System. It is a Geographic Information System (GIS) with image processing capabilities. ILWIS has been developed by the International Institute for Geoinformation Science and Earth Observation (ITC), Enschede, The Netherlands.

ILWIS is a remote sensing and GIS software which integrates image, vector and thematic data in one unique and powerful package on the desktop. ILWIS delivers a wide range of features including import/export, digitizing, editing, analysis and display of data, as well as production of quality maps. ILWIS software is renowned for its functionality, and user-friendliness, and has established a wide user community over the years of its development. Even after its last commercial release in 2005, its user community has remained active, both within and outside ITC.
ILWIS is an open source software, and can be downloaded from the following web-site: http://52north.org/ilwis

ILWIS 3.4 Open is included on your course DVD in the …Software\ILWIS 3.4 Open\ folder.

To install the software, run the ILWIS34setup.exe program.

In the Software\ILWIS 3.4 Open\User's Guide folder you will find the ILWIS 3.0 Academic User's Guide in PDF format.

Installation of supporting software

The following tools are available on your CD-ROM:

Acrobat Reader:	to open PDF files. Many files of the course material are in PDF format.
MediaPlayer:	used for Video-lectures and other multimedia.
Flash Player:	used to open the animations attached to the e-lectures
ShockWave-PlugIn:	used for playing video animations related to web sites.

! Some functions of the e-lectures need Microsoft Internet Explorer. Please make it sure that you use this browser as the default when running the e-lectures.

Acknowledgements

Many people have contributed to the development of the multi-hazard risk assessment training materials. We would like to thank Gonzalo Funes from Honduras for providing the initial data sets. The Digital Surface Model and flood information was obtained from a study by the United States Geological Survey. The high resolution image was obtained from a project funded by JICA. Ruben Vargas Franco, Dinand Alkema, Lorena Montoya, Michiel Damen, Nanette Kingma, Antonio Naverette, Jean Pascal Iannacone, Marco Rusmini, Malgosia Lubczynska, Manzul Hazarika and Norman Kerle are thanked for their contributions on various aspects of this case study. Colleagues from ADPC, AIT, CDUT, ICIMOD, UNAM, CLAS, IIRS and UGM are thanked for the friendly collaboration and the testing of the training package in various training courses. Simone Frigerio has made the WebGIS version of RiskCity.

Anneke Nikijuluw has been very helpful in assisting us with the organisation of course and arrangement of course materials. Linlin Pei helped us in making the demonstrations for ILWIS. Cecille Plomp made the introduction movie. Ineke ten Dam gave us useful advice on the development of the materials. Job Duim and Benno Masselink helped in making a number of illustrations. Sabine Maresch provided a lot of project support in using the training materials in various courses.

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Session 1: N.M.S.I. Arembepola, Falak Nawaz, Simone Frigerio
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This work is part of the United Nations University – ITC School for Disaster GeoInformation Management (www.itc.nl/unu/dgim)

Disclaimer:

This book is still a draft version. It still has to go through a reviewing phase, so there may be quite some mistakes in it. We would appreciate it if you could report any mistakes to us. This can be done by sending an e-mail to **westen@itc.nl**, in which you indicate the page number and the problem.

In this book we have tried our best to indicate the sources of information. If you feel that we have omitted to indicate the source properly, please inform us.

The RiskCity case study

The RiskCity training package focuses on demonstrating the procedures of risk assessment for natural and human-induced hazardous phenomena in an urban environment within a developing country. We have selected an urban area, because the elements at risk have a much higher density, the study areas are generally smaller and the scale of analysis larger as compared to a rural setting. This allows us to demonstrate which tools can be used for generating hazard as well as elements at risk databases, even in data poor environments, and to show how qualitative and quantitative techniques for risk assessment can be used, and in which situation. Also the combined effect of different hazard on the overall risk can be better demonstrated, as well as the effect of risk reduction measures. Figure 1 gives a schematic overview of the steps that will be followed in the Riskcity exercises. We will look at four different hazards: flooding, landslides, earthquakes and technological hazards. Future flood scenarios were modelled using two different models: HEC-RAS and SOBEK. Due to time limitations we will not be working with the actual models but use GIS for input and output. Landslide hazard assessment was carried out in the RiskCity case study using two different approaches: a combined statistical/heuristic analysis and physical modeling. Earthquake hazard assessment is done using empirical attenuation curves. Technological hazards are analyzed using effect distance formulae which are empirically derived.

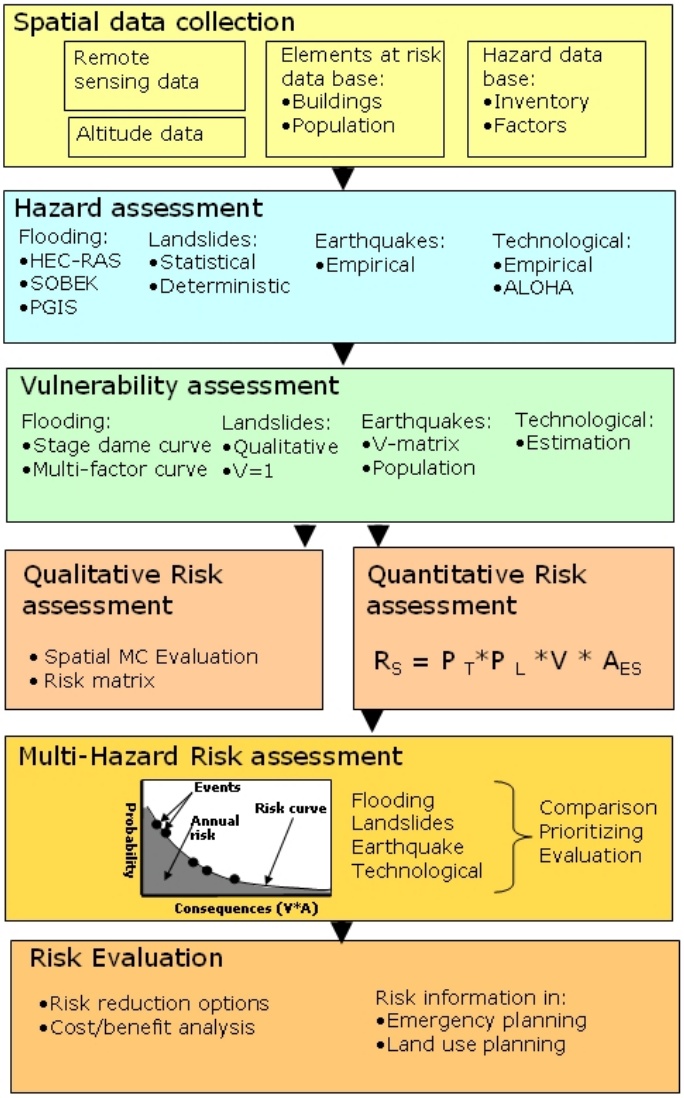


Figure 1: Overview of the steps used in the RiskCity case study for multi-hazard risk assessment. The abbreviations mentioned in the hazard assessment part are explained in session 3.

For each of the four hazard types the vulnerability will be analyzed using different approaches. Risk assessment will be done using a qualitative approach with spatial multi-criteria evaluation, and a quantiative approach using risk curves.

About the study area.

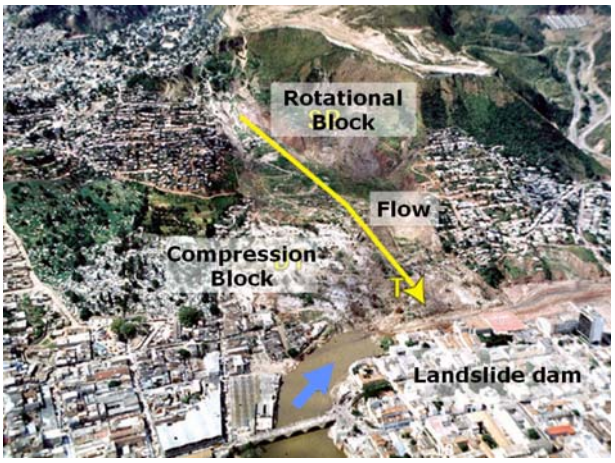


Figure 2: Overview of the hazard event with a landslide that dammed the river. Source: R. Peñalba

To illustrate some of the aspects discussed in this chapter for RiskCity, this section shows a number of examples related to landslides and flooding in RiskCity. As mentioned before the city of Tegucigalpa, Honduras was taken as the basis for RiskCity. It should be kept in mind that the material is for training purposes and has been adapted, and therefore is not a direct example for the city of Tegucigalpa. Therefore we will refer to it consistently as RiskCity from now on. Figure 2 shows an example of a large landslide, named El Berrinche, in the centre of the city of RiskCity. This landslide occurred in late October 1998, as a result of heavy rainfall and undercutting of the toe by the Choluteca River, during the passing of hurricane Mitch. RiskCity is located in a bowl shaped valley, underlain in the SE by a formation, consisting of red sandstone, siltstone and some conglomerates, and Tertiary volcanic deposits in the northwestern part. The highest parts of the area are plateaus underlain by ignimbrites with steep cliffs around their edges and a complex series of old landslides, which have not been dated till now. One of these is the El Berrinche landslide (see figure 2), which is approximately 700 meter long and 400 meter wide. The landslide has had several phases of activity over the last decades, which culminated in the massive failure on October 31 1998. The movement history can be reconstructed with the help of image interpretation, utilizing aerial photographs, satellite images and LiDAR data from different periods. On an airphoto from 1974, the paleo landslide can be clearly recognized, and a reactivation which occurred in the toe of the landslide in 1970 is evident. During this period also the houses on top of the old landslide were already constructed, road construction in the higher parts suggests that further development was planned, which was never implemented. A second reactivation took place in 1984, which produced considerable damage to roads and houses in the area. The first signs of what later would form into an earthflow can be identified on the aerial photo from 1990, as well as the depressions in the upper part of the landslide. After a geotechnical investigation the area was declared unsafe and further development was not considered appropriate. The main movement occurred in October 1998, and the aerial photo taken just after this clearly shows the different components of the landslide consisting of a rotational block in the upper part, an earthflow in the center and a compressional toe. The landslide had a volume of 6 million cubic meters, and most houses of the Colonia Soto were ruined as well as parts of the adjacent neighborhoods. The landslide dammed the Choluteca River leading to extensive flooding in the center of Tegucigalpa for a number of weeks. After the event the slope was flattened and a series of benches were constructed along the toe.

In the case of RiskCity several types of remote sensing data were used. Aerial photographs for several periods, including the period of the major disaster event in 1998, and two sets of satellite data from 2001 and 2006 were the basis for landslide mapping. High resolution satellite data was used for mapping elements-at-risk, and medium resolution Aster data for generating a land use map of the area. Figure 1.16 gives an illustration of some of the remote sensing data used in the case study of RiskCity. Elements-at-risk data can be obtained at different levels of detail. In the RiskCity case study this is done at the urban level, where information needs to be as detailed as possible, preferably at the individual building level, or at a slightly more aggregated level of mapping units or building blocks with homogenous land use and building type. In the RiskCity case study two different situations with respect to the availability of input data were simulated: a situation where the database should be constructed from scratch and a situation in which already detailed spatial and attribute information is available.

This course aims at showing you how spatial data or geo-information can be used in a multi hazard risk assessment. The definition of geoinformation is:

The tools: WebGIS and GIS

This course uses Geographical Information Systems for the multi-hazard risk assessment. During more than half of this course you will be working with GIS. However, this is not a GIS course. You also don't need to be a GIS expert in order to follow this course. Since we are using GIS tools that are easy to learn and use, we will focus entirely on what you can do with GIS for risk assessment and not on the tool as such.

If you want to get more technical information on GIS we recommend you to follow the ITC distance education course on GIS. For information and registration please visit: http://www.itc.nl/education/courses.aspx

The course is designed in such a way that even non-GIS specialist can follow the course, since the instructions are describing the steps you need to take in a cook-book manner, at least in the initial phases. In the later part of the course, when you are more used to the ILWIS software there will be also exercises where you have to evaluate yourself the steps needed for an analysis.
The course is designed in such a way that you can also follow it if you are not able or willing to use the ILWIS GIS for the exercises. This may be the case if you are not that much interested in the particular steps to follow in a risk assessment, but want to know more about the overall procedure and the things you can do with the (intermediate) results. Therefore we have made the two following options with respect to the exercise part of the course:

- **The GIS version**. This is the standard option for using the course materials. You will be working with the Open Source GIS software ILWIS, and you will learn the individual steps to make a hazard assessment, elements at risk database, vulnerability assessment, qualitative and quantitative risk assessment, and how to use the risk information for (preparedness) planning. You follow the instructions in this theory book, and when the book contains a task (indicated in a green box that refers to one of the RiskCity GIS exercises) you then go to the exercise part of the book and follow the instructions there. You will use the GIS data for that particular exercise provided on the course DVD. The duration of the course will then be 6 weeks (distance education version) or 3-4 weeks (fulltime course), depending on the option for doing the final project in session 8.
- **The WebGIS version**. The WebGIS version allows you to evaluate the individual steps of the methodology without actually doing GIS analysis. You will not use ILWIS, but will use the WebGIS version that is also included on the course DVD. The WebGIS exercises will take much less time than the GIS version. They have separate exercise descriptions.

Structure of the training materials

The training materials consist of:

A guide book,

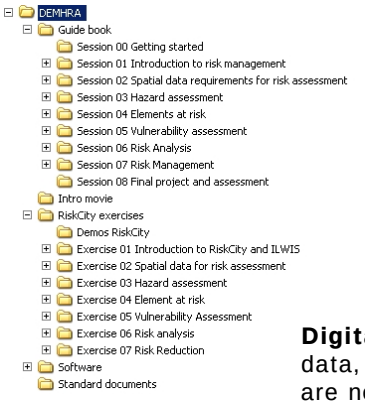
consisting of 8 chapters and an introduction, following the same structure as the sessions explained above. The guide book will contain for each session:

- **Theoretical background**, which guide you through the session and which contain theoretical parts, highlighting the main theoretical aspects, mixed with short assignments and questions, and links to relevant internet sites.
- **Tasks:** mixed with the theory of the guide book you will find a number of taks where you are asked to carry out certain small assignments, which will make you understand the theory better, and apply it to your own situation. The answers to the tasks don't have to be submitted for the course
- **Selftests:** each session has a selftest.
- **Further reading**

A RiskCity exercise book

RiskCity exercise descriptions. The exercises are written in such a way that whenever students have to carry out an action with GIS this is written in a light green box. Normally the exercise instructions are given completely (so-called "cook book style") so that it is easier to carry out the instructions also for people with no experience in ILWIS. There are also additional optional exercises which require more knowledge on the software, and which are indicated as "Optional exercise for experienced ILWIS users". These instructions are not in "cook book style", and require more knowledge on how to solve a particular problem with ILWIS. Non experienced ILWIS users might like to skip these exercises in the beginning.

A DVD



The course DVD contains the following materials:

- An introduction video for the course.
- The ILWIS software with its users guide.
- Some other generic software needed to follow the course (Acrobar reader etc.)
- The Guide Book chapters as PDF files
- The RiskCity exercise descriptions as PDF files.
- The data for the RiskCity exercises.
- Demonstration videos explaining part of the RiskCity exercises.

Digital datasets of RiskCity for each exercise. Each exercise has its own data, which are stored in a separate subdirectory. Results from one exercise that are needed for the next, are provided in the dataset of the next exercise, so you start each exercise with a "clean slate"

Blackboard (bb.itc.nl)

The course has also an internet site with educational support software (Blackboard), which can be reached through: bb.itc.nl It containing all materials and the tools for communication, and uploading of results

- All Guide book chapters, and RiskCity exercises as PDF files
- The answers to the selftests of the Guide Book
- Answer sheets for the RiskCity exercises
- Discussion board for the answers of the tasks.

How to use the RiskCity exercise descriptions

The exercise descriptions contain different parts.

Information

Information written in normal text without colours are related to the explanation on the various procedures used throughout the manual.

ILWIS instructions

The exercises are written in such a way that whenever you have to carry out an action with GIS this is written in a light green box. Normally the exercise instructions are given completely (so-called "cook book style") so that it is easier to carry out the instructions also for people with no experience in ILWIS.

☞

- This is an example of a box containing the actual instructions on using the ILWIS software

Additional information

This is a textbox that contains additional information, e.g. on the specific aspects of the software or the GIS operations that are carried out. They sometimes refer also to the ILWIS Help or to other links

This is a an example of such a text box

ILWIS instructions for advanced users.

☞

- This is an example of a box containing instruction for advanced users

There are also additional exercises which require more knowledge on the software, and which are indicated as "Optional exercise for experienced ILWIS users". These instructions are not in "cook book style", and require more knowledge on how to solve a particular problem with ILWIS. If you are not an experienced ILWIS user you might like to skip these exercises in the beginning.

Answers

In many cases you are asked to provide the answer to a specific problem, and write these down in a table, indicated in Blue colour. These are also the answers that you should submit in the small report for uploading to the Blackboard after completing the exercise.

Below is an example of such an answer table.

Which signs can you see of a recent disaster in the area?	X	Y

Watch Demo 1 for instructions

Demos

In the first RiskCity exercises you can also find demonstrations, which are explaining steps that you need to do in ILWIS and that need a certain amount of user interaction, which is more difficult to explain in the text. You can find the demo files in : **\RiskCity_exercises\Demos_RiskCity**

Answer sheets

We have made an answer sheet for each exercise. This will help you in checking the results of your work. **The answer sheets will be made available in Blackboard during the course**. The answer sheets contains:

- The answers of the questions that are asked in the text.
- Screen shots of main result maps that have to be produced as part of the exercise, together with some additional explanation
- The procedure and answers of the Optional exercises for advanced ILWIS users.

Exercise data

The GIS data for the exercises has been prepared carefully, in order to avoid confusion during your work.

IMPORTANT:

- Each exercise has its own data, which are stored in a separate subdirectory. Results from one exercise that are needed for the next, are provided in the dataset of the next exercise, so you start each exercise with a "clean slate"
- Copy the exercise data in the same directory structure to your harddisk
- Work in the same subdirectory with the data for the specific exercise
- Do not copy the data from one directory to the other.