GIS CASE STUDY

Application of GIS for multi-hazard risk assessment in an urban environment.

These exercises deal with the evaluation of multi-hazard risk in an urban environment. Three types of hazards will be evaluated, namely landslide hazards, flood hazards and earthquake hazards. Also emphasis will be given to the generation of a database of elements at risk in order to evaluate the vulnerability of buildings and population to these types of hazards.

The exercises deal with a hypothetical case study, although most the data have been obtained for one particular city (Tegucigalpa in Honduras). However, in order to be able to reach the objectives of the exercise, modifications have been made to the data, and virtual data have been added. Due to limitations of time and data the methods for hazard and vulnerability assessment have been simplified quite a bit. Nevertheless they intend to give you an understanding of the basic concepts involved, and will allow you to have an idea on how GIS can be used for analyzing the different types of hazards, assessing vulnerability and making a loss estimation.

Objectives

The objective of this exercise is to demonstrate the concepts of the use of GIS for multi-hazard risk assessment in an urban setting.

Risk is defined *as the probability of harmful consequences, or expected loss (of lives, people injured, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human induced hazards and vulnerable/capable conditions*. Risk assessment with GIS can be done on the basis of the following basic equation:

Risk = Hazard * Vulnerability * Amount of elements at risk

The hazard can be expressed as *the probability of occurrence of a potentially damaging phenomenon within a specified period of time and within a given area*. It will not always be possible to express the hazard in quantitative terms, as often we have no good information on the hazard component.

Mapping building units using screen digitizing

For the calculation of risk we are using the basic formula:

Risk = Hazard * Vulnerability * Amount of elements at risk

In this part of the exercise we will concentrate first on the last part of the formula: getting information on the elements at risk. See below

Elements at risk may be listed as follows:

- **Physical**

  Infrastructure
  - Roads
  - Railway
  - Bridges
  - Harbour
  - Airport

  Critical facilities
  - Emergency shelters
  - Schools
  - Hospitals and Nursing Homes
  - Fire Brigades
  - Police
  - Utilities
    - Power supply
    - Water supply
  - Transport
  - Communication
  - Government services

- **Economic**

  Business and trade activities
  Access to work
  Impact on work force
  Opportunity cost

- **Societal**

  Vulnerable age categories
  Low income group people
  Gender

- **Environmental**

  Loss of biodiversity
  Damaged landscape
  Physical and chemical changes in the surroundings

In this case study we only take into account two types of elements at risk: buildings and population. Building information could be obtained from existing cadastral databases, and population data from census database. However, in many cities in developing countries such data are not available, or are restricted, or are not in a digital format. When these data are not available they should be collected. However, the generation of a building database in GIS is a very time-consuming procedure. When high-resolution data sets are available, such as in this exercise, we can use them for interpretation, and the basic mapping units can be digitized on the screen.

Risk assessment could be done on a building-by-building level. However, in most cases this level of information is too detailed, as it is very difficult and time consuming to evaluate vulnerability of individual buildings. Therefore, we base the risk study on so-called mapping units, which consists of a series of buildings, with more or less the same landuse pattern. In exercise we will concentrate on the mapping of the basic units for the urban risk assessment. There are two files in the dataset that are most important for that:

- **Unit boundaries**: this contains the 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. .
- **Mapping_units**: These polygons represent 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.

Seismic building loss estimation

Depending upon the earthquake intensity and the building strength, a building may get damage during an earthquake ranging from fine cracks in plaster to the total collapse of the building. When the earthquake intensity is considered constant, the damage grade is then directly related to the strength of a building, which again is related to the material and construction type adopted in the construction. Considering the seismic vulnerability, the buildings in the case study city have been divided into the following classes.

- Stone
- Adobe (AD)
- Brick with Mud Mortar, Poorly built (BM)
- Brick with Mud Mortar, Well built (BMW)
- Brick with Cement or Lime mortar (BC)
- Reinforced Concrete Frame with Masonry having three or less stories (RCC3)
- Reinforced Concrete Frame with Masonry having more than 3 stories (RCC4)

The table **Landuse** contains an estimation of the fractions of buildings of the various types (AD, BM, BC and RCC) per landuse type.

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- Open the table **Landuse** and check the values for the different building types.

Note that we do not have separate values for RCC buildings with less or equal than 4 floors, and with more than 3 floors. This is because these percentages were already calculated earlier.

First we need to calculate the number of buildings of the different building types (AD, BM, BC and RCC). We should do this in the table **mapping_units**. However, since we will calculate quite some columns, we will make a new table linked to the map **Mapping_units**, and call it **Buildings_per_unit**.

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- Select *File / Create / Table*. Make a table with the name **Buildings_per_unit**, using the domain **Mapping_units**.
- When the empty table opens, select *Columns / Join* and join with the table **Mapping_units**, and read in the columns **Landuse, Percover3floor**, and **Nr_Buildings**
- Open the table **Buildings_per_unit** and join with the table **Landuse** and read in the columns **Perc_AD**, **Perc_BM**, **Perc_BC** and **Perc_RCC**.

Now we can calculate the number of buildings of the different types.

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- In the table **Buildings_per_unit** type the following formulas (Use a precision = 1 for all):

N_AD:=Nr_Buildings*Perc_AD

This is the number of adobe buildings per mapping unit.

N_BM:= Nr_Buildings*Perc_BM

This is the number of brick in mud buildings per mapping unit.

N_BC:= Nr_Buildings*Perc_BC

This is the number of brick in mortar buildings per mapping unit.

N_RCC3:= Nr_Buildings*Perc_RCC*(1- Percover3floor)

This is the number of RCC buildings with 1-3 floors per mapping unit.

N_RCC4:= Nr_Buildings*Perc_RCC* Percover3floor

This is the number of RCC buildings with >3 floors per mapping unit.

Generating vulnerability curves

In the table below, the damage matrix, which is the percentage of building-damage-pattern for different earthquake intensities (in MMI) for common building types in the city, is given. This relation has been derived by NSET-Nepal and JICA. In the table two types of damage grade patterns are given which were defined in the following way:

- Heavily Damage: Collapsed or un-repairable
- Partly Damage: Repairable (available for temporary evacuation)

The buildings with different heights and material types obtained as a result of this 55 procedure are grouped into the above-mentioned classes. In the damage matrix table, the damage grades are given not with a single percentage value but a range showing minimum and maximum percentage of buildings in that building material class. This intensity-damage relationship was used to estimate the vulnerability of buildings types in Lalitpur area. The following four types of columns for each type of the intensity (from VI to IX) will be created in GIS in order to calculate the number of vulnerable buildings in the mapping units.

- Partial damage min (Minimum probable number of buildings having partial damage)
- Partial damage max (Maximum probable number of buildings having partial damage)
- Collapse min (Minimum probable number of buildings having total damage)
- Collapse max (maximum probable number of buildings having total damage)

Building type: Adobe+ Field Stone Masonry Buildings

MMI		VI	VII	VIII	IX
PGA (% g)		5-10	10-20	20-35	>35
Damage Pattern (% of buildings)	Total Collapse	2-10	10-35	35-55	55-72
	Partial Damage	5-15	15-35	30	30

Building type: Brick in Mud (BM)

MMI		VI	VII	VIII	IX
PGA (% g)		5-10	10-20	20-35	>35
Damage Pattern (% of buildings)	Total Collapse	0-6	6-21	21-41	>41
	Partial Damage	3-8	8-25	25-28	<28

Building type: Brick in Mud (BMW) and Brick in Cement (BC)

MMI		VI	VII	VIII	IX
PGA (% g)		5-10	10-20	20-35	>35
Damage Pattern (% of buildings)	Total Collapse	0-1	1-5	5-18	>18
	Partial Damage	0-11	1-31	31-45	<45

Building type: R. C. Framed (≥4 storied)

MMI		VI	VII	VIII	IX
PGA (% g)		5-10	10-20	20-35	>35
Damage Pattern (% of buildings)	Total Collapse	0-2	2-8	8-19	19-35
	Partial Damage	0-4	4-16	16-38	38-65

Building type: R. C. Framed (≤3 storied)

MMI		VI	VII	VIII	IX
PGA (% g)		5-10	10-20	20-35	>35
Damage Pattern (% of buildings)	Total Collapse	0-2	2-7	7-15	15-30
	Partial Damage	0-4	4-14	14-30	30-60

In order to be able to avoid an excessive amount of columns in the table, we will convert these columns to a new table: **unit_damage**.

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- Select *File / Create / Table*. Make a table with the name **Unit_damage**, using the domain **Mapping_units**.
- When the empty table opens, select *Columns / Join* and join with the table **Buildings_per_unit**, and read in the columns **N_AD, N_BM, N_BC, N_RCC3** and **N_RCC4**.

From the vulnerability table given above there are many different possibilities for combining the information: for different Intensities (VI, VII, VIII and IX) and for partial or complete collapse minimum and maximum values are given. We will only calculate here one scenario: maximum percentage of collapsed building in an earthquake with scenario IX.

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- In the table **Unit_damage** type the following formula in the command line:

IX_collapse_max:=(N_AD*0.72)+(N_BM*0.41)+(N_BC*0.18)+(N_RCC3*0.35)+(N_RCC4*0.3)

- Make an attribute map of the column IX_Collapse_max.
- How many buildings would be maximally collapsed when the entire area is subjected to an Intensity IX earthquake?
- How many buildings would be maximally collapsed when the entire area is subjected to an Intensity IX earthquake?

Using a script for building loss estimation

This is only one scenario of intensities, and for partial or complete collapse and minimum and maximum values. This takes a long time to do manually and can be better done in a script. The script contains only two lines:

Script
Tabcalc Unit_damage %1_%2_%3:=(N_AD*%4)+(N_BM*%5)+(N_BC*%6)+(N_RCC3*%7)+(N_RCC4*%8) %1%2%3:= MapAttribute(mapping_units,Unit_damage.tbt.%1_%2_%3)
Parameters:
%1 = Intensity (VI, VII, VIII, IX) %2 = Collapse or Partial %3 = Max or Min %4 = the value of damage for Adobe building (N_AD) %5 = the value of damage for Brick in Mud buildings (N_BM) %6 = the value of damage for Brick in Cement (N_BC) %7 = the value of damage for RCC buildings with less than 4 stories %8 = the value of damage for RCC buildings with more than 4 stories

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- Use the script Damage and run it using the various parameters from the vulnerability table. For example:

Run damage `VI collapse max 0.1 0.06 0.01 0.02 0.02`

You can also create a script which serves as the input script for the script Damage and which will contain all scenarios.

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- Create a script **Damage_input** and write the input for all scenarios in the following way:

Run damage VI collapse max 0.1 0.06 0.01 0.02 0.02
Run damage VI collapse min 0.02 0 0 0 0
Run Damage VII collapse max 0.35 0.21 0.05 0.08 0.07
Run damage VII collapse min 0.1 0.06 0.01 0.02 0.1
Etc.

- Run the script **Damage_input** by typing the following command on the command line:

Run damage_input

- Display the results in a table

	VI	VII	VIII	IX
Collapse max				
Collapse min				

Earthquake Damage in Balakot city, Pakistan

Georeference the image
Digitize the damaging zone

Calculate:

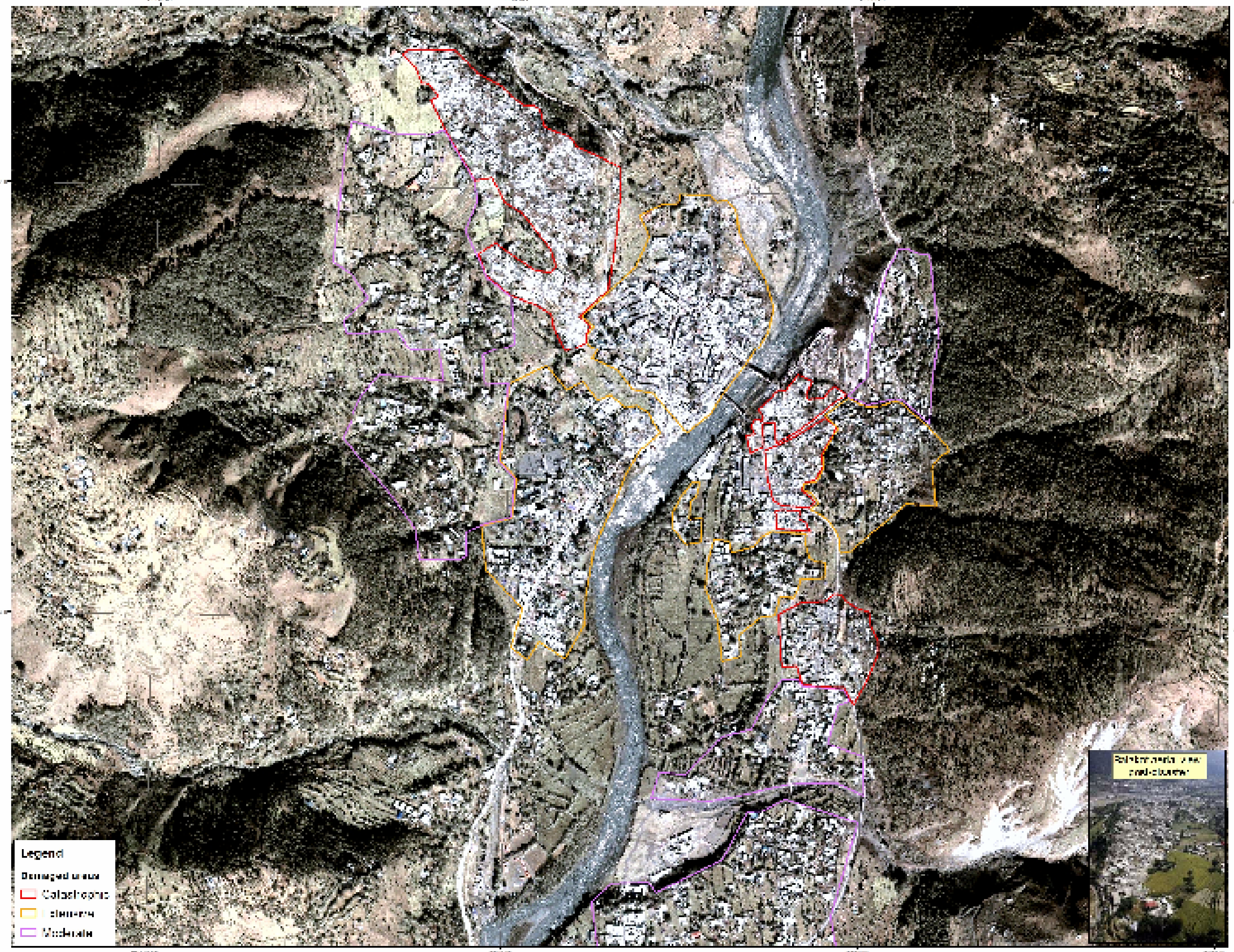
Population at Risk
Area of damaged zones
Number of houses in each damaging zones
Number of collapsed and damaged houses
Peak ground acceleration

Reference:

Building density	- /100 m^2, /200 m^2, /300 m^2
Population	- 6 people per building
Outside at daytime	- 75%

PAKISTAN - BALAKOT - Central City Area

1:4,000



Map ID: 1068
Production Date: 19 October 2005

0 125 250 500 Meters

Scale 1:4,000 for A1 printing