Training Package on National Scale Multi-

Hazard Risk Assessment

Theory Book

National Scale Multi-Hazard Risk Assessment

By

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Note about the PPRD-EAST project

This manual is produced in the framework of the PPRD-EAST project, which is the EU-funded Programme for the Prevention, Preparedness and Response to Man-made and Natural Disasters in the ENPI East Region (PPRD East)

The PPRD East programme focuses on natural and man-made disasters with special emphasis on the ones identified as priorities in the region. Complex emergencies are not part of this programme. The most common disasters on which the programme will focus are notably:

- Seismic risks
- Hydro-geological events (such as floods/flash floods/droughts)
- Forest and ground fires
- Urban/industrial disasters (e.g. explosions, fires, chemical accidents or toxic gas leakage, obsolete pesticides), road accidents, etc.
- Disasters caused by extreme meteorological conditions (which may or not be related to climate change)

The programme tackles these risks at the level of preparation, preparedness and mitigation and at the level of response management. It includes four sets of actions, which will result in:

- an improved knowledge base concerning the current state of play,
- strengthened prevention, preparedness capacities and response (from the administrative, operational and legislative points of view), and
- wider information and awareness. These actions must also work towards the greater goal of a progressively stronger association of the Partner Countries with the European Mechanism of Civil Protection.

The overall objectives of the Programme PPRD East:

- to contribute to the development of the Partner Countries' civil protection capacities for disaster prevention, preparedness and response
- to bring the Partner Countries progressively closer to the EU Civil Protection Mechanism and improve cooperation among themselves.

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1. INTRODUCTION TO DISASTER RISK MANAGEMENT

1.1 INTRODUCTION

Disasters are headline news almost every day. Most happen in far-away places, and are rapidly forgotten. Others keep the attention of the world media for a longer period of time. The events that receive maximum media attention are those that hit instantaneously and cause widespread losses and human suffering, such as earthquakes, tsunamis, hurricanes and floods. Recent examples are the Indian Ocean tsunami (2004), the earthquakes in Pakistan (2005), Indonesia (2006), China (2008), Haiti (2010) and Japan (2011) and the hurricanes in the Caribbean and the USA (2005, 2008). On the other hand, there are many serious geomorphologic hazards that have a slow onset, such as the recent drought in the Horn of Africa (2011), soil erosion, land degradation, desertification, glacial retreat, sea-level rise, loss of biodiversity etc. These processes and related events may cause local, regional, and global impacts in the long run, but receive generally less attention.

Disasters are defined by the United Nations International Strategy for Disaster Risk Reduction (UN-ISDR, 2004) as "***a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources***".

For a comprehensive overview of the terminology

When considering all definitions we can 'characterize' a disaster as:

- an extreme phenomenon (of different origins),
- of large intensity (e.g. a measurable quantity such as earthquake intensity, water depth)
- and limited duration (which can vary from seconds to months, but should be defined in time);
- occurring at a certain location (this spatial component will be very important in this course);

- involving a complex interplay between physical and human systems;
- causing loss of lives and threats to public health, as well as physical damage
- and disruption of livelihood systems and society;
- exceeding local capacities and resources;
- requiring outside assistance to cope with.

Although the term "natural disasters" in its' strict sense is not correct, as disasters are a consequence of the interaction between hazards and vulnerable societies, the term is used extensively in the literature and also in daily use.

A hazard is defined as "***a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation***". This event has a probability of occurrence within a specified period of time and within a given area, and has a given intensity (UN-ISDR, 2004). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterised by its location, area affected (size or magnitude), intensity, speed of onset, duration and frequency. Hazards can be classified in several ways.

Meteorological	Geomor-phological & Geological	Ecological	Technological	Global environmental	Extra terrestrial
Drought Dust storm Flood Lightning Windstorm Thunderstorm Hailstorm Tornado Cyclone Hurricane Heat wave Cold wave	Earthquake Tsunami Volcanic eruption Landslide Snow avalanche Glacial lake outburst Subsidence Coal fires Coastal erosion	Crop disease Animal disease Insect infestation Forest fire Mangrove decline Coral reef decline Pesticides	Armed conflict Land mines Major (air-, sea-, land-) Traffic accidents Nuclear / chemical accidents Oil spill Water / soil / air pollution Electrical power breakdown	Acid rain Atmospheric pollution Global warming Sealevel rise El Niňo Ozone depletion	Asteroid impact Aurora borealis

Table 1.1: Classification of disasters according to the main controlling factor.

A possible subdivision is between natural, human-induced and human-made hazards. Natural hazards are natural processes or phenomena in the Earth's system (lithosphere, hydrosphere, biosphere or atmosphere) that may constitute a damaging event (e.g., earthquakes, volcanic eruptions, hurricanes). A subdivision of natural hazards relates to the main controlling factors of the hazards leading to a disaster. They may be hydro-meteorological (including floods and wave surges, storms, droughts and related disasters such as extreme temperatures and forest/scrub fires, landslides and snow avalanches), geophysical hazards (resulting from anomalies in the Earth's surface or subsurface, such as earthquakes, tsunamis and volcanic eruptions), or biological hazards (related to epidemics and insect infestations). Human-induced hazards are those resulting from modifications of natural processes in the Earth's system caused by human activities which accelerate/aggravate the damage potential (e.g., land degradation, landslides, forest fires). Human-made hazards originate from technological or industrial accidents, dangerous procedures, infrastructure failures or certain human activities, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation (e.g., industrial pollution, nuclear activities and radioactivity, toxic wastes, dam failures; transport, industrial or technological accidents such as explosions, fires and oil spills).

The aim of a hazard assessment is to identify the various types of hazards that may threaten a territory, and to partition the landscape in zones which are characterized by different expected intensities and frequencies of hazardous processes. In a hazard assessment several aspects should be evaluated: the triggering event, the areas where hazards are likely to initiate, the areas where the hazards are likely to spread, the expected intensity of the hazard and its associated frequency or probability of occurrence. Hazards may impact vulnerable societies, and may result in physical and other types of damage to so called "elements-at-risk". With certain exceptions (e.g. ash clouds affecting air-traffic or oilspills affecting marine flora and fauna) these impacted elements-at-risk are mostly located on the earth's surface. Therefore, the relationship between the hazard events and surface processes, landforms or materials is a key component to study. Geomorphology therefore plays a key role in hazard and risk analysis. Geomorphology is the science of landforms and surface materials and of the processes that have formed or reshaped them. Geomorphologists investigate the evolution of landscapes, and study the history and the dynamics of landforms and the processes responsible for creating or modifying them, through a combination of field observations, physical experiments and numerical modelling. These processes that have shaped the Earth's surface can be potentially dangerous if they exceed a certain threshold, e.g. they may result in instability and erosion on slopes, flooding in river- or coastal areas.

The study of the endogenic (volcanic eruptions or earthquakes) or exogenic (extreme meteorological) triggering events causing hazardous processes may be outside of the scope of geomorphology, as this is the domain of seismologists, volcanologists, meteorologists etc. Nevertheless, geomorphologists contribute to the reconstruction of the frequency, extent and intensity of past events, by studying their imprints on landforms and surface materials. Geomorphologists play a key role in the analysis of how these triggering events result in hazardous processes on the earth surface. They are specialized in analyzing the possible spatial extent of future hazardous processes related to a set of environmental factors (geomorphology, topography, geology, soils, land cover etc.). Examples of this are the study of potential landslide areas, or the analysis of the effects of surface materials and landforms in the amplification of seismic waves or liquefaction. Geomorphologists are also good in modelling the extent of the spreading of hazardous processes over the topography (e.g. lahar flows, landslide runout, flood extent), based on Digital Elevation Models.

The study of hazards and risks has a very important spatial component. Certain types of hazards are restricted to certain geographical regions. Earthquakes occur along active tectonic-plate margins, and volcanos occur along subduction zones (e.g., around the margins of the Pacific plate, so-called "Ring of Fire"). Tsunamis occur in the neighborhood of active-plate margins, but their effects can be felt at considerable distances from their origin, as the waves can travel long distances. Tropical cyclones (in North America called "hurricanes" and in Asia called "typhoons") occur in particular coastal zones. Landslides occur in hilly and mountainous regions. In the analysis of hazard and risk geo-information science and earth observation plays an increasingly important role. Remote Sensing is nowadays an essential tool in monitoring changes in the earth's surface, oceans and atmosphere, and is increasingly used as the basis for early warning for hazardous events. Remote sensing provides the input for thematic information used in hazard modeling, like topography, lithology, and land cover.

The use of spatio-temporal data and geographic information technologies have now become part of an integrated approach to disaster risk management. New GIS algorithms and analysis/modelling techniques are revolutionising the potential capacity to analyse hazards, vulnerability and risks. Information technology systems are used for storage, situation analysis, modelling, and visualization (Twigg, 2004). Disaster-risk management benefits greatly from the use of geospatial technologies because spatial and temporal variation can be accounted for, and new methodologies can be developed and fully explored. One of the key advantages of using GIS-based tools for the risk decision-making process is the possibility to use 'what if' analysis by varying parameters and generating alternative scenarios in a spatial context (Longley et al., 2005). Earlier publications on this topic can be found in Wadge et al. (1993), Coppock (1995), Emani (1996), and Kaiser et al. (2003).

The objective of this chapter is to give an overview of the application of geo-information science and earth observation in the analysis of hazards and risk. The chapter starts with a background section discussing disaster trends, and the framework for disaster risk management. Subsequent sections discuss the use of GIS and remote sensing in the generation of inventories of past hazardous events, the modelling of hazards, the generation of elements-at risk databases and the integration of these data in the modeling of potential losses.

Table 1 provides a summary of the various terms that are relevant in the context of this chapter, relating to disasters, disaster risk and its various components (UN-ISDR,2004). It is important to distinguish between the terms disaster, hazard and risk. Risk results from the combination of hazards, conditions of vulnerability, and insufficient capacity or measures to reduce the potential negative consequences of risk (O'Keefe et al., 1976). When the hazard or threat becomes a reality (i.e., when it materializes), the risk becomes a disaster. For example, a certain river valley may be prone to flooding. There is risk if a vulnerable society/community or property is located within this flood prone area. If the hazard materializes, that is, if the flood actually occurs, it will cause losses to the vulnerable society or property, thus creating a disaster (Fig. 1).

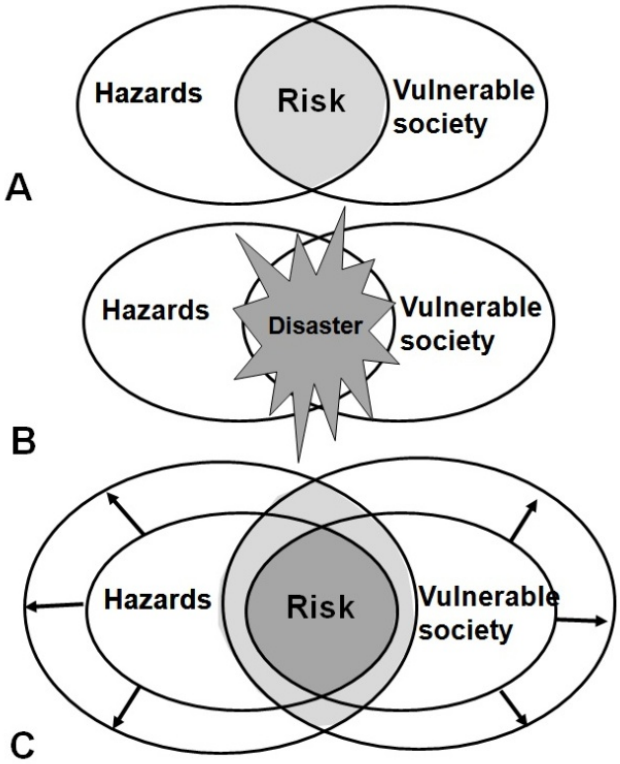


Figure 1.1: Schematic representation of the relation between hazards, vulnerable society, risk and disasters. A: risk indicates the expected losses to a vulnerable society as a result of hazards. B: A disaster occurs when the threat of a hazard become reality, and impacts on a vulnerable society. C: Future trends of increasing hazards and increasing vulnerability

Table 1.2: Summary of definitions related to disasters, hazards and vulnerability. Based on UN-ISDR (2004).

Term	Definition
Disaster	A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.
Natural hazard	A potentially damaging physical event, phenomenon or human activity that may cause loss of life or injury, property damage, social and economic disruption or environmental degradation. This event has a probability of occurrence within a specified period of time and within a given area, and has a given intensity.
Elements-at-risk	Population, properties, economic activities, including public services, or any other defined values exposed to hazards in a given area. Also referred to as "assets". The amount of elements-at-risk can be quantified either in numbers (of buildings, people etc.), in monetary value (replacement costs, market costs etc), area or perception (importance of elements-at-risk).
Exposure	Exposure indicates the degree to which the elements-at-risk are exposed to a particular hazard. The spatial interaction between the elements-at-risk and the hazard footprints are depicted in a GIS by simple map overlaying of the hazard map with the elements-at-risk map.
Vulnerability	The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. Can be subdivided in physical, social, economical and environmental vulnerability.
Capacity	The positive managerial capabilities of individuals, households and communities to confront the threat of disasters (e.g., through awareness raising, early warning and preparedness planning).
Consequence	The expected losses in a given area as a result of a given hazard scenario.
Risk	The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between (natural, human-induced or man-made) hazards and vulnerable conditions in a given area and time period.

1.2 TRENDS IN DISASTER STATISTICS

Data on disaster occurrences, their effect upon people, and their cost to countries are very important for disaster-risk management. There are now a number of organizations that collect information on disasters, at different scales and with different objectives.

Since 1988 the Centre for Research on the

Epidemiology of Disasters (CRED) has been maintaining an Emergency Events Database (EM-DAT, 2009). Disasters have to fulfill certain criteria in order to be included in the EM-DAT database: they have to cause at least 10 casualties, 100 or more should be affected, it should result in a declaration of emergency, or it should lead to a call for external assistance.

• Evaluate the disaster database from EM-DAT for the country of Georgia. Go to the website: http://www.emdat.be/database

• Select Advanced Search, and make a search for a particular type of disasters within the country of interest. Make a summary of the results, and compare your own knowledge on the events that have happened. How complete is this database?

• You can also check additional disaster data resources at: http://www.emdat.be/additional-disaster-data-resources

• We have also an older version (up to the year 2000) of the EMDAT database available as Excell file. Check out the file EMDAT_old using Excel and find out the disasters recorded for Georgia or for your own country.

Data on disaster impacts are also collected by reinsurance companies. For instance, the MunichRe database for natural catastrophes (NatCatSERVICE) includes more than 28,000 entries on material and human-loss events worldwide (MunichRe, 2010). A similar disaster-event database (SIGMA) is maintained by SwissRe. These data, however, are not publicly available.

• Check out the site of MunichRe NATHAN (unfortunately you can query the database: http://www.munichre.com/de/reinsurance/business/non-life/georisks/nathan/default.aspx

• There is a good demo for SwissRe Sigma. Although you can't access the database they have anice visualization tool: http://www.sigma-explorer.com/

The Asian Disaster Reduction Center (ADRC) has initiated a new disaster database, called Glidenumber (2010). The specific feature of this database is that each disaster receives a unique identifier and a number of relevant attributes.

- Go to the web-site: http://www.glidenumber.net/
- Check whether the GLIDENUMBER database has disaster information of the country of your interest.

At a local level, disaster data have been collected by an initiative of NGOs, called LaRed, initially in Latin America, but later on expanding also to other regions. They generated a tool called DesInventar (2010), which allows local authorities, communities and NGO's to collect disaster information. Recently, the DesInventar database has become available online.

- Go to the web-site: http://www.desinventar.net/
- Check whether the DESINVENTAR database contains any data of your country of interest.

There are also many disaster databases collected at the national level, or that are related to a specific type of hazard. The Global Risk Identification Program (GRIP) and the Centre for research in Epidemiology of Disasters (CRED) have initiated a service, called DisDAT, which brings together all publicly available disaster databases from different countries (GRIP, 2010). It contains 60 registered disaster databases, of which 13 are global.

- Go to the web-site: http://www.gripweb.org/gripweb/?q=disaster-database
- Check whether it contains any data of your country of interest

When examining the reported disasters in these databases, there is a clear increase in hazardous events over the past decades (Figure 2). The number of natural disasters in the last decade has increased by a factor of 9 compared to the decade 1950-1959 (EM-DAT, 2009), which is mainly caused by an increase in hydro-meteorological disasters. In terms of losses, earthquakes resulted in the largest amount of losses (35% of all losses), followed by floods (30%), windstorms (28%) and others (7%). Earthquakes are also the main cause of fatalities, which is estimated on the order of 1.4 million during the period 1950-2000 (47%), followed by windstorms (45%), floods (7%), and others (1%) (MunichRe, 2010; EM-DAT, 2009). It is interesting to note that human fatalities due to natural disasters shows a decreasing trend, which may be due to better warning systems and improved disaster management, but the number of people affected follows the increasing trend of the number of events (see Figure 2).

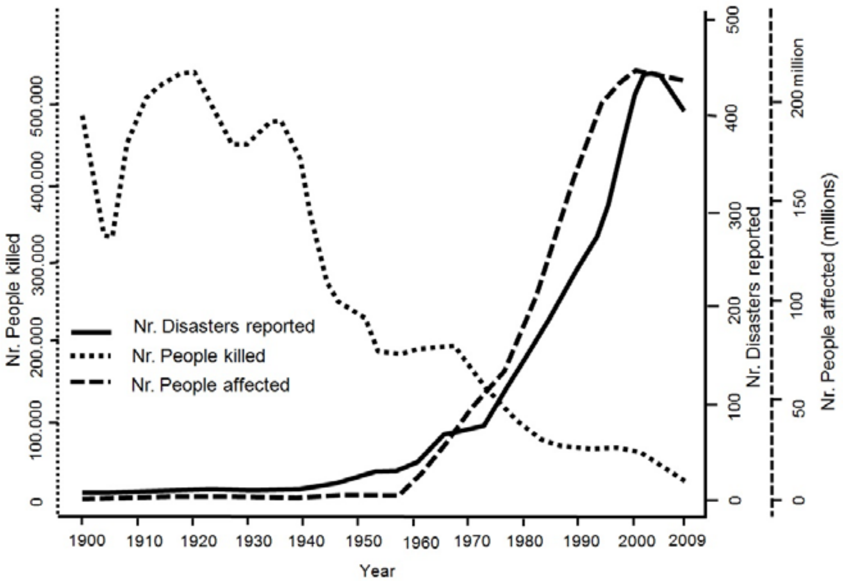


Figure 1.2: Summary of natural disasters, showing the number of reported disasters, the number of people killed and the number of people affected over the period 1900-2009. Source: EM-DAT (2009).

Disaster information collected at the local level (e.g., DesInventar) is more complete, as it includes also small-magnitude/high-frequency events, but the coverage of such databases is limited worldwide. One of the major problems with the use of disaster databases for natural hazard and risk assessment, is that they normally lack proper georeferencing of the reported events (Verelst, 1999). A comparitive study of the EM-DAT, Sigma and NATCAT databases carried out for four countries showed that these databases differed significantly (Guha-Sapir and Below, 2002).

The increase in the number of disasters, the losses and people affected cannot be explained only by better reporting methods and media coverage of disasters, lack of which probably made the number too low for the first part of the last century. There are a number of factors that influence the increase in the number of disasters which can be subdived as those leading to a larger vulnerability, and those leading to a higher occurrence of hazardous events.

The increased vulnerability is due to a number of reasons. The rapid increase of the world population, which has doubled in size from 3 billion in the 1960s to 7 billion in 2011 (World Bank, 2011). Depending on the expected growth rates, world population is estimated to be between 7.9 and 11.0 billion by the year 2050 (UNPD, 2010a). The increase in disaster impact, however, is higher than the increase in population, which indicates that there are other important factors involved that increase the overall vulnerability of the world population. One of the main factors is the large urbanization rate. According to UN figures (UNPD, 2010b), the worldwide urbanization percentage has increased from 29% in 1950 to 50% in 2010, and is expected to rise to 69% in 2050. Another factor related to the population growth is that areas become settled, that were previously avoided due to their susceptibility to natural hazards. Many of the largest cities in the world, the so-called "Megacities" are located in hazardous regions, either in coastal zones, or in seismically active regions (Smith and Petley, 2008; Kraas, 2008).

The increasing impact of natural disasters is also related with the development of highly sensitive technologies, and the growing susceptibility of modern industrial societies to breakdowns in their infrastructure. Data from MunichRe (2010) show that the economic losses have increased by a factor of 8 over the past 50 years, and insured losses by a factor of 15. There is a rapid increase in the insured losses, which are mainly related to losses occurring in developed countries. Windstorms clearly dominate the category of insured losses (US $90 billion), followed by earthquakes (US $ 25 billion). Insured losses to flooding are remarkably less (US $ 10 billion), due to the fact that they are most severe in developing countries with lower insurance coverage (MunichRe, 2010).

It is not only the increased exposure of the population to hazards, however, that can explain the increase in natural disasters. The frequency of destructive events related to atmospheric extremes (such as floods, drought, cyclones, and landslides) is also increasing (EM-DAT, 2009). During the last 10 years a total of 3,750 windstorms and floods were recorded, accounting for two-thirds of all events. The number of catastrophes due to earthquakes and volcanic activity (about 100 per year) has remained constant (MunichRe, 2010). Although the time-span is still not long enough to indicate it with certainty, these data suggest that climate change is related to the increased occurrence of natural disasters.

There is an inverse relationship between the level of development and loss of human lives in the case of disasters. About 85 percent of the disaster related casualties occur in less developed countries, where more than 4.7 billion people live. The greater loss of lives is due to the lower quality of buildings, lack of building codes or lack of enforcement, construction of buildings in hazardous areas due to lack of land-use planning, lower awareness and disaster preparedness, less accurate or missing early-warning systems, lack of evacuation planning, lack of facilities for search-and-rescues and medical attention. Although 65% of the overall losses occur in high-income countries (with GNI US$ >12,000 per capita) (World Bank, 2010), and only 3% in low-income countries (GNI US$ < 1000 per capita), the effect in the latter group is devastating, as they may represent as much as 100% of their Gross National Income (UN-ISDR, 2009). Economic losses in absolute terms (billions of dollars) show an increase with the level of development, as the absolute value of elements-at-risk that might be damaged during a disaster increases with increasing level of development. In relative terms, however, the trend is reverse, showing a decrease in the losses expressed as percentage of GDP with increasing level of development (MunichRe, 2010).

1.3 DISASTER RISK-MANAGEMENT FRAMEWORK

Disaster-Risk Management (DRM) is defined as "the systematic process of using administrative decisions, organization, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters". This comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards (UN-ISDR, 2004). Disaster-risk management is aimed at disaster-risk reduction, which refers to the conceptual framework of elements considered with the possibilities to minimize vulnerabilities and disaster risks within the broad context of sustainable development (UN-ISDR, 2004).

The past decades have witnessed a shift in focus from disaster recovery and response to risk management and mitigation. This change was also from an approach that focused primarily on the hazard as the main causal factor for risk, and the reduction of the risk by physical-protection measures, to a focus on vulnerability of communities and ways to reduce those through preparedness and early warning. Later more focus was given to the strengthening of the capacity of local communities and the development of community-based coping strategies (Blaikie et al., 1994; Lavel, 2000, Pelling, 2003). The Yokohama conference in 1994 put into perspective the socio-economic aspects as a component of effective disaster prevention. It was recognized that social factors, such as cultural tradition, religious values, economic standing, and trust in political accountability are essential in the determination of societal vulnerability. In order to reduce societal vulnerability, and therewith decrease the consequences of natural disasters, these factors need to be addressed (Hillhorst, 2004). The ability to address socio-economic factors requires knowledge and understanding of local conditions, which can, in most cases, only be provided by local participants.

The decade from 1990 to 2000 was declared by the United Nations as the International Decade for Natural Disaster Reduction (IDNDR). As the impact of disasters increased dramatically during this decade the international community decided to continue this effort after 2000 in the form of an International Strategy for Disaster Reduction (ISDR). The ISDR stressed the need to move from a top-down management of disasters and a cycle that focuses on reconstruction and preparedness, towards a more comprehensive approach that tries to avoid or mitigate the risk before disasters occur, and at the same time fosters more awareness, public commitment, knowledge sharing and partnerships to implement various risk reduction strategies at all levels (UN-ISDR, 2005b).

This more positive concept has been referred to as the "risk-management cycle", or better "spiral", in which learning from a disaster can stimulate adaptation and modification in development planning, rather than a simple reconstruction of pre-existing social and physical conditions. This is illustrated in Figure 3, by showing the disaster cycle and various components (relief, recovery, reconstruction, prevention and preparedness), and how these changed through time. Initially (Figure 3A) most emphasis was given to disaster relief, recovery and reconstruction, thereby getting into a cycle where the next disaster was going to cause the same effects or worse. Later on (Figure 3B) more attention was given to disaster preparedness by developing warning systems and disaster awareness programs. Eventually (Figure 3C) the efforts are focusing on disaster prevention and preparedness, thus enlarging the time between individual disasters, and reducing their effects, requiring less emphasis in relief, recovery and reconstruction. The eventual aim of disaster-risk management is to enlarge this cycle, and only reach the response phase for extreme events with very low frequency.

Disaster prevention is achieved through risk management. Figure 4 presents the general risk-management framework which is composed of a risk-assessment block and a block in which risk-reduction strategies are defined. A summary of the terminology used in risk management is given in Table 2. Central in the procedure is risk analysis, in which the available information is used to estimate the risk to individuals or populations, property or the environment, from various hazards. Risk analysis generally contains the following steps: 1) hazard identification; 2) hazard assessment; 3) elements-at-risk/exposure analysis; 4) vulnerability assessment and 5) risk estimation. Risk evaluation is the stage at which values and judgments enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental, and economic consequences, in order to identify a range of alternatives for

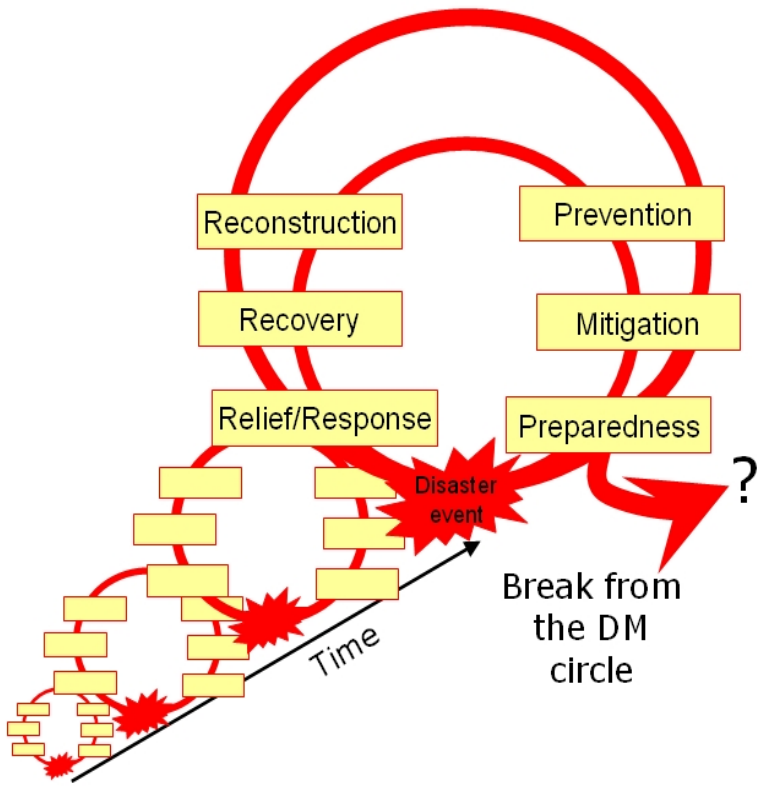


Figure 1.3: Disaster cycle and its development through time.

reducing the risks (UN-ISDR, 2004).

Risk assessment is the combination of risk analysis and risk evaluation. It is more than a purely scientific enterprise and should be seen as a collaborative activity that brings professionals, authorized disaster managers, local authorities and the people living in the exposed areas together (O'Brien, 2000; Plapp, 2001; Montague, 2004;). Risk governance is therefore an integral component. The final goal, reduction of disaster risk, should be achieved by combining structural and non-structural measures that focuses on emergency preparedness (e.g., awareness raising, early-warning systems, etc.), inclusion of risk information in long term land-use planning, and evaluation of the most cost-effective risk-reduction measures (see Figure 4). In the entire risk-management framework, spatial information plays a crucial role, as the hazards are spatially distributed, as well as the vulnerable elements-at-risk.

1.4 RISK-ANALYSIS FRAMEWORK

As illustrated in Figure 1.4, there are three important components in risk analysis: 1) hazards; 2) vulnerability; and 3) elements-at-risk (Van Westen et al., 2008). They are characterized by both spatial and non-spatial attributes. Hazards are characterized by their temporal probability and intensity, derived from frequency-magnitude analysis. Intensity expresses the severity of the hazard, for example water depth, flow velocity, and duration in the case of flooding. The hazard component in the equation actually refers to the probability of occurrence of a hazardous phenomenon with a given intensity within a specified period of time (e.g., annual probability).

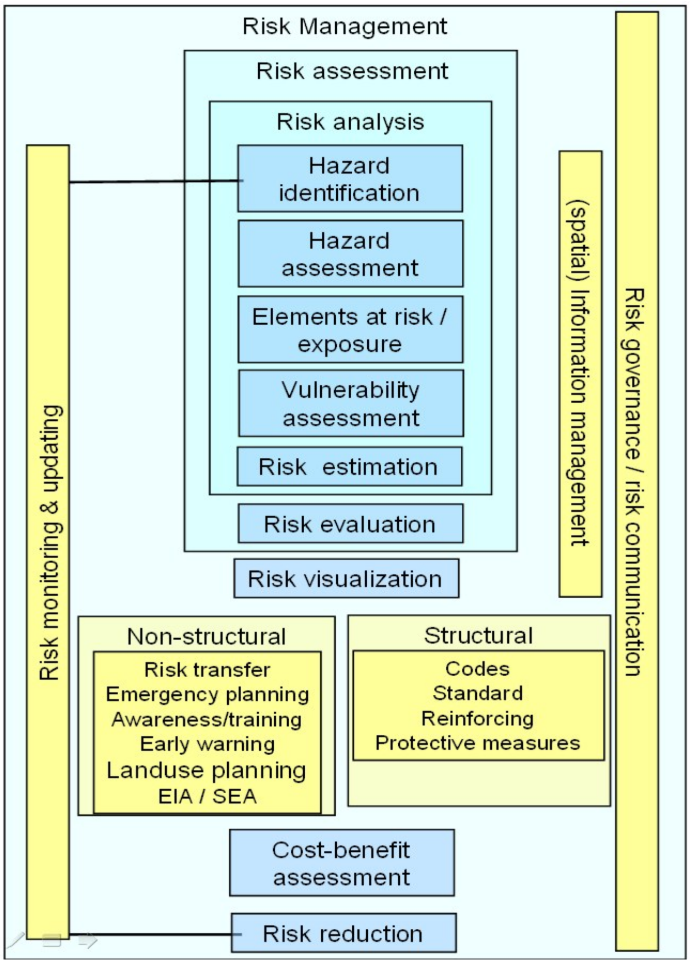


Figure 1.4: Risk Management framework

Hazards also have an important spatial component, both related to the initiation of the hazard (e.g., a volcano) and the spreading of the hazardous phenomena (e.g., the areas affected by volcanic products such as lava flows) (Van Westen, 2009).
lements-at-risk or "assets" are the population, properties, economic activities, including public services, or any other defined values exposed to hazards in a given area (UN-ISDR, 2004). Elements-at-risk also have spatial and non-spatial characteristics. There are many different types of elements-at-risk and they can be classified in various ways (see Section 4.1). The way in which the amount of the elements-at-risk is characterized (e.g., as number of buildings, number of people, economic value, or qualitative rating according to their importance) also defines the way in which the risk is presented. The interaction of elements-at-risk and hazard defines the exposure and the vulnerability of the elements-at-risk. Exposure indicates the degree to which the elements-at-risk are actually located in an area affected by a particular hazard. The spatial interaction between the elements-at-risk and the hazard footprints are depicted in a GIS by map overlaying of the hazard map with the elements-at-risk map (Van Westen, 2009).

Table 1.2: Summary of definitions related to risk management. Based on UN-ISDR (2004).

Term	Definition
Risk analysis	The use of available information to estimate the risk to individuals or populations, property, or the environment, from hazards. Risk analysis generally contains the following steps: hazard identification, hazard assessment, elements-at-risk/exposure analysis, vulnerability assessment and risk estimation.
Risk evaluation	The stage at which values and judgements enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental, and economic consequences, in order to identify a range of alternatives for managing the risks.
Risk assessment	The process of risk analysis and risks evaluation.
Risk control or risk treatment	The process of decision making for managing risks, and the implementation, or enforcement of risk-mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.
Risk management	The complete process of risk assessment and risk control (or risk treatment).

Vulnerability refers to the conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards (UN-ISDR, 2004). The vulnerability of communities and households can be analyzed in a holistic qualitative manner using a large number of criteria, that characterize the physical, social, economic and environmental vulnerability. The importance of each of these indicators is evaluated by assigning weights and combining them using spatial multi-criteria evaluation. Physical vulnerability is evaluated as the interaction between the intensity of the hazard and the type of element-at-risk, making use of so-called vulnerability curves (see Section 4.2). For further explanations on hazard and risk assessment, see Alexander (1993), Okuyama and Chang (2004), Smith and Petley (2008) and Alcantara-Ayala and Goudie (2010).

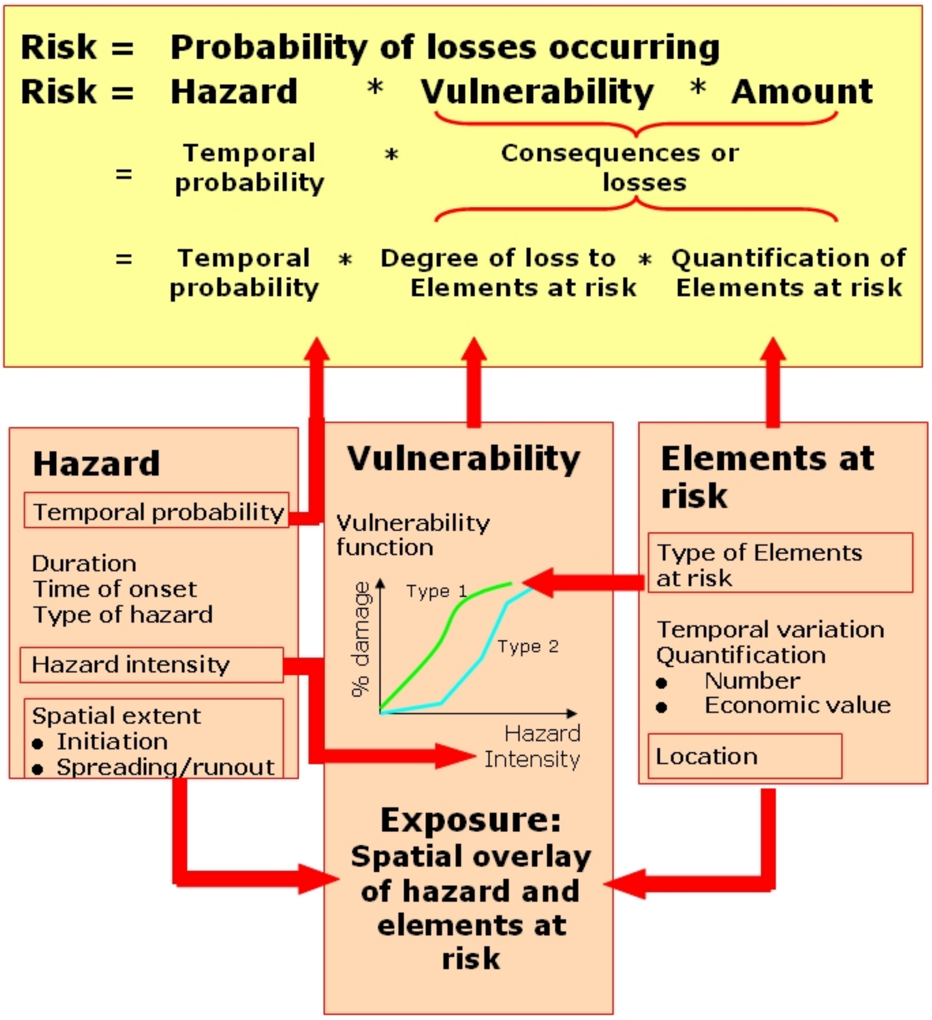


Figure 1.5: Risk analysis and its components

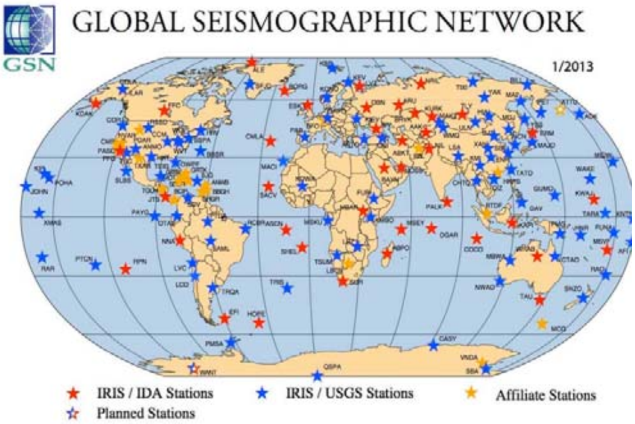
2.OBTAINING SPATIAL DATA FOR RISK ASSESSMENT

The assessment of multi-hazards and the subsequent risk assessment is a very data intensive procedure. The availability of certain types of spatio-temporal data can be one of the main limitations for carrying out specific types of analysis. Table 2.1 gives a schematic overview of the main GIS data layers required for hazard and risk assessment, for different hazard types. These can be subdivided into three groups: 1) hazard inventory data; 2) environmental factors; and 3) triggering factors.

2.1HAZARD INVENTORIES AND TRIGGERING EVENTS

The hazard-inventory data are by far the most important, as they should give insight into the distribution of past hazardous phenomena, their types, mechanisms, causal factors, frequency of occurrence, intensities and the damage that has been caused.

The most straightforward way of generating hazard inventories is through direct measurements of the phenomena. These measurements can be collected by networks of stations (e.g., earthquake strong-motion data, flood-discharge stations, meteorological stations, coastal-tide gauging stations, or wave-measurement buoys). Seismic networks have been formed globally (NERIES, 2009; ANSS, 2009; GSN, 2009), and the data is managed centrally, for instance by the United States Geological Survey (USGS) using web-mapping applications. In the US, a similar network has been established for recording stream-discharge data for nearly 10,000 sites in a central database linked with a web-mapping service (NWIS, 2010). Although a tsunami warning system has been operational in the Pacific Ocean for a number of decades, the 2004 Indian Ocean tsunami has urged the international community to implement such systems worldwide. For these monitoring networks, the spatial coverage is important so that potentially hazardous areas are monitored. The density of observations required for the monitoring networks differs strongly for various hazard types. This is more problematic for flood-discharge stations, as each potential hazardous river needs to be monitored, whereas for seismic stations, the required density can be much less. Also the spacing between the individual stations is of importance given the variability of the measured characteristics (e.g., rainfall measurements vary strongly over mountainous regions). The period



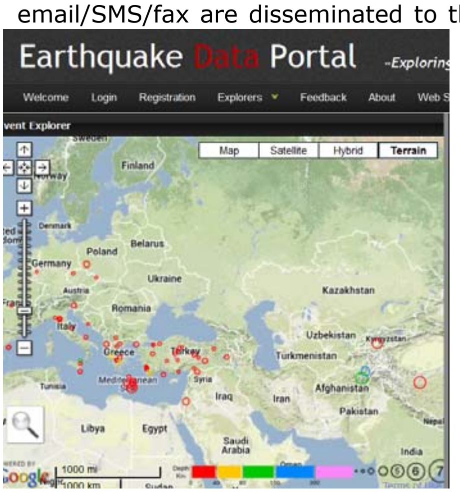
http://www.iris.edu/hq/programs/gsn

The ***Global Seismographic Network (GSN)*** is a 150+ station, globally distributed, state-of-the-art digital seismic network providing free, real time, open access data through the IRIS DMS. The map shows the distribution of the current 150 station network with respect to network operations. This includes 4 planned stations to be installed in the near future.

The Global Seismographic Network is a cooperative partnership between IRIS and the *U.S. Geological Survey (USGS)*, coordinated with the international community, to install and operate a global, multi-use scientific facility as a societal resource for Earth observations, monitoring, research, and education. GSN instrumentation is capable of measuring and recording with high fidelity all seismic vibrations from high-frequency, strong ground motions near an earthquake to the slowest global Earth oscillations excited by great earthquakes. The primary focus in creating the GSN has been seismology, but the infrastructure is inherently multi-use and can be extended to other disciplines.

http://www.emsc-csem.org/Earthquake/Map/

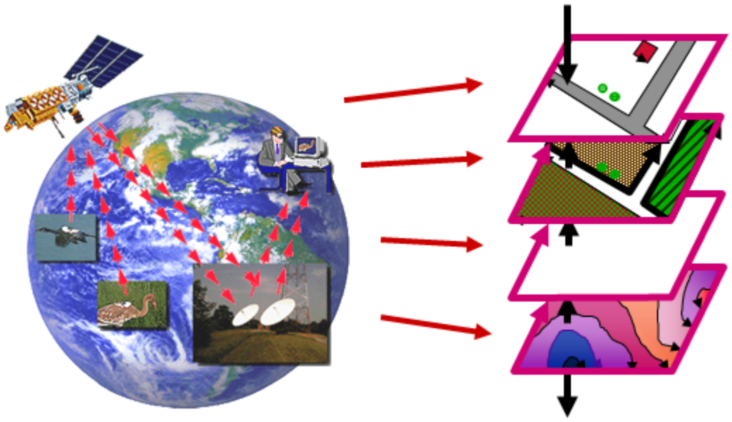
The ***European – Mediterranean Seismological Centre*** collects real time parametric data (source parmaters and phase pickings) provided by 65 seismological networks of the Euro-Med region. These data are provided to the EMSC either by email or via QWIDS (Quake Watch Information Distribution System, developed by ISTI). The collected data are automatically archived in a database, made available via an autoDRM, and displayed on the web site. The collected data are automatically merged to produce automatic locations which are sent to several seismological institutes in order to perform quick moment tensors determination. For potentially destructive earthquakes, the EMSC operates an Earthquake Notification Service in which email/SMS/fax are disseminated to the registered end-users within 20-30 minutes on average after the earthquake occurrence.



http://www.seismicportal.eu/jetspeed/portal/

The **Earthquake Data Portal** was developed under the European Commission-funded NERIES project.

The Portal provides a single point of access to diverse, distributed European earthquake data provided in a unique joint initiative by observatories and research institutes in and around Europe. Based on internet-standard portlet and web services technologies, it enables the scientists/users to integrate and combine different data services.



for which measurements are available, and the continuity of the measurements also play an important role, as often the period for which measurements are available is not sufficiently large to capture major events from the past. Catalogues from the measurement networks should be carefully analysed before being used in a hazard assessment. The monitoring networks located on the ground or in the oceans are supported by a number of satellite systems that are used for transmitting information to central data centres. There are also a large variety of satellite-based monitoring systems that can measure characteristics of hazards over larger areas on a regular basis, such as sea-surface temperature, rainfall, altitude, clouds, vegetation indices, etc.

For larger areas, if no data are available from meteorological stations, general rainfall estimates from satellite imagery can be used, such as from the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA), which is used to issue landslide and flood warnings based on a threshold value derived from earlier published intensity-duration-frequency relationships for different countries (Hong et al., 2007b). As another example, GEONETCast is a global network of satellite-based data dissemination systems providing environmental data to a world-wide user community for which the ITC developed a Toolbox. Products include meteorological satellites (Meteosat, GOES, FengYun), and vegetation monitoring using SPOT-Vegetation data. This information is made available to many users, with low cost receiving station and open-source software (Mannaerts et al., 2009). Another example is the Sentinel Asia programme which is an initiative supported by JAXA and the APRSAF (Asia-Pacific Regional Space Agency Forum) to share disaster information in the Asia-Pacific region on the Digital Asia (Web-GIS) platform and to make the best use of earth observation satellites data for disaster management in the Asia-Pacific region (Sentinel Asia, 2010).

An important initiative that is focused on the provision of space-based information for disaster response is the international charter "Space and Major Disasters" (Disaster Charter, 2010). A number of organizations and programmes are involved in rapid mapping activities after major disasters, such as UNOSAT (2010), DLR-ZKI (2010), SERTIT (2010), GDACS (2010) and Dartmouth Flood Observatory (2010).

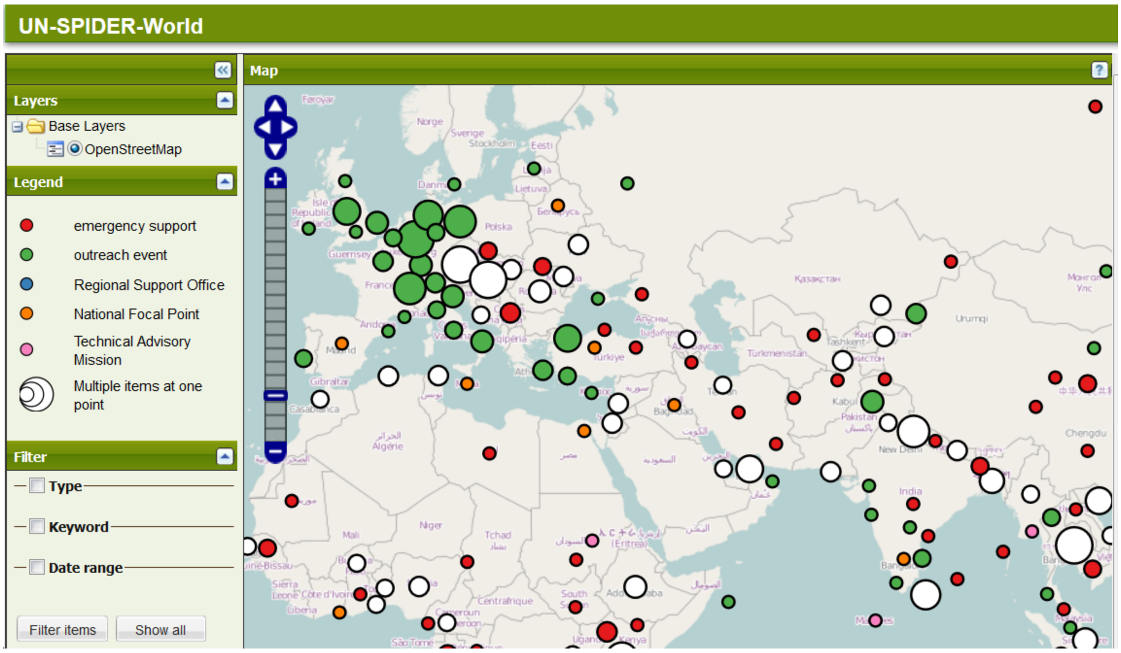
GeoNetcast & ITC : ***http://www.itc.nl/pub/WRS/WRS-GEONETCast***

In Europe the Global Monitoring for Environment and Security (GMES) initiative of the European Commission and the European Space Agency (ESA) is actively supporting the use of satellite technology in disaster management, with projects such as PREVIEW (Prevention, Information and Early Warning pre-operational services to support the management of risks), LIMES (Land and Sea Integrated Monitoring for Environment and Security), GMOSS (Global Monitoring for Security and Stability), SAFER (Services and Applications For Emergency Response), and G-MOSAIC (GMES services for Management of Operations, Situation Awareness and Intelligence for regional Crises) (GMES, 2010). The United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER, 2010) has been established by the UN to ensure that all countries have access to and develop the capacity to use space-based information to support the disaster management cycle.

They are working on a space application matrix that will provide the satellite-based approaches for each type of hazard and each phase of the disaster management cycle. Overviews on the use of space-based information in hazard inventory assessment can be found in CEOS (2003), Tralli et al. (2005), IGOS (2007) and Joyce et al. (2009).

http://www.un-spider.org/un-spider-world

UN-SPIDER *aims at providing universal access to all types of space based information services relevant to disaster management being a gateway to space information for disaster manage-ment support; serving as a bridge to connect the disaster management and space communities; and being a facilitator of capacity-building and institutional strengthening*

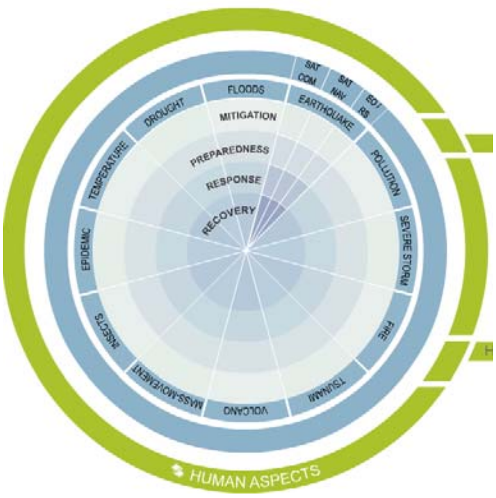


Search Case Studies by Space Application Matrix

http://www.un-spider.org/space-application-matrix

The Space Application Matrix allows you to explore the possibilities of using space technologies for disaster management in all phases of the disaster management cycle: mitigation, preparedness, response and recovery.

With this tool you can access case studies, the Space Application Guides, authored by experts and practitioners. They describe experiences from the application of space technology, and address benefits, lessons learned, and further potential, as the case may be.



International Charter
Space & Major Disasters

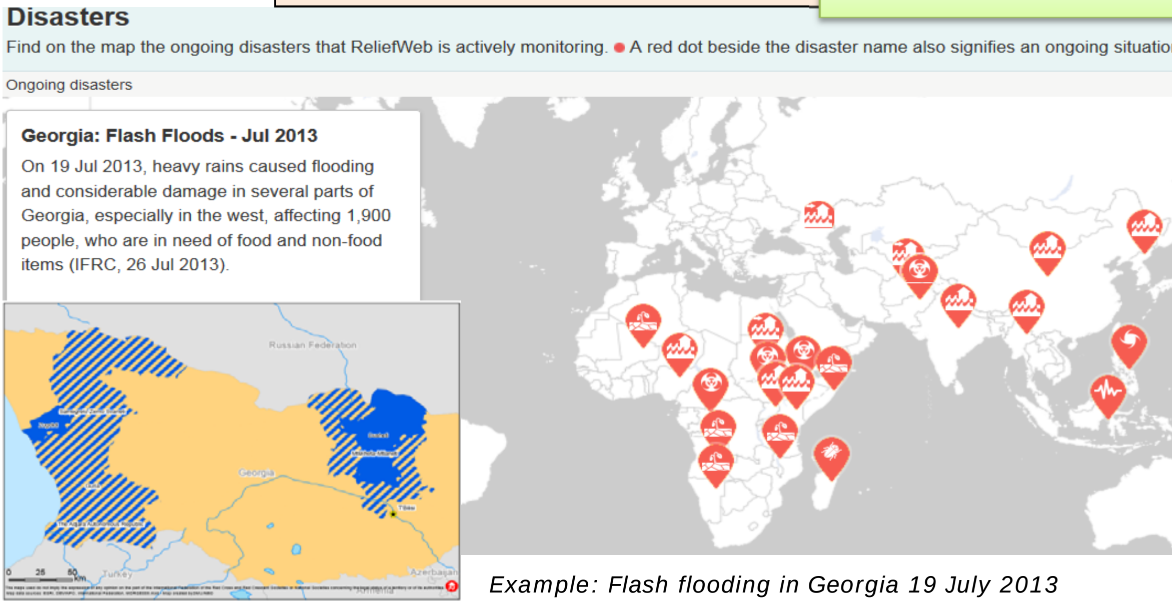
[***http://www.disasterscharter.org/***](http://www.disasterscharter.org/)

The ***International Charter*** *is a system of space data acquisition and delivery activated by participating space agencies in case of major natural and man-made disasters.*

UNOSAT acts as a user intermediary for requests emanating from UN agencies responding to natural disasters. In such cases, the Space Charter provides free satellite imagery and data that are used in UNOSAT Rapid Mapping Service to generate information and publish maps for the use of the UN Disaster Assessment Coordination (UNDAC) teams and other field teams. Please note that for before using the maps in a GIS they have to be geo-referenced first.

United Nations website providing information to humanitarian relief organizations

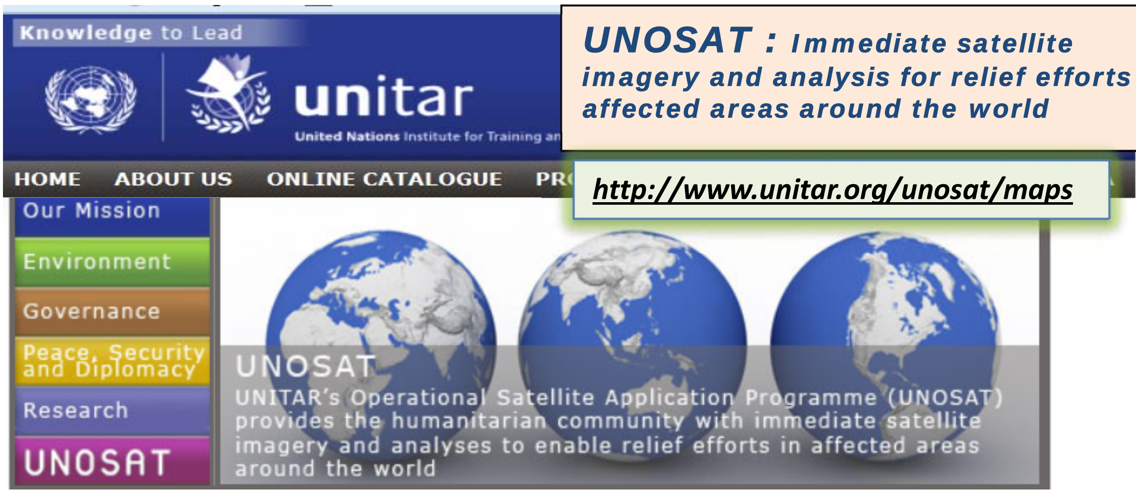
[***http://reliefweb.int/***](http://reliefweb.int/)



Example: Flash flooding in Georgia 19 July 2013

UNOSAT : Immediate satellite imagery and analysis for relief efforts in affected areas around the world

[***http://www.unitar.org/unosat/maps***](http://www.unitar.org/unosat/maps)



European satellite-borne earth observation, in-situ data and services for monitoring the earth's environment.

Information on land cover/land use & vegetation and the water cycle.

Landsat ETM mosaic of 2000
http://land.copernicus.eu/pan-european/high-resolution-image-mosaic/image-2000/view

French web portal
Expert teams 24 hours a day, 365 days a year, produce in near real time factual geo-information integrated by decision support systems.

Rapid Mapping Access:
http://sertit.u-strasbg.fr/SITE_RMS/RMS/RMS_accueil_2012.html

Global Disaster Alert and Coordination System

GDACS is a cooperation framework between the **United Nations, the European Commission and** disaster managers worldwide to improve alerts, information exchange and coordination in the first phase after major sudden-onset disasters.

http://www.gdacs.org

Example

Satellite-Detected Flood Waters Along the Prut River, Cahul and Vulcanesti Districts, Republic of Moldova (as of 29 Jul 2010)

This map illustrates (see next page) probable standing flood waters along the eastern bank of the Prut River in the Cantemir District of the Republic of Moldova, as well as the western bank of the river in Romania. This flood analysis is based on Formosat-2 satellite imagery recorded on 31 July 2010. Areas of potential / probable flooding within towns and road / bridge obstacles have been identified and marked in the overview and inset focus maps.

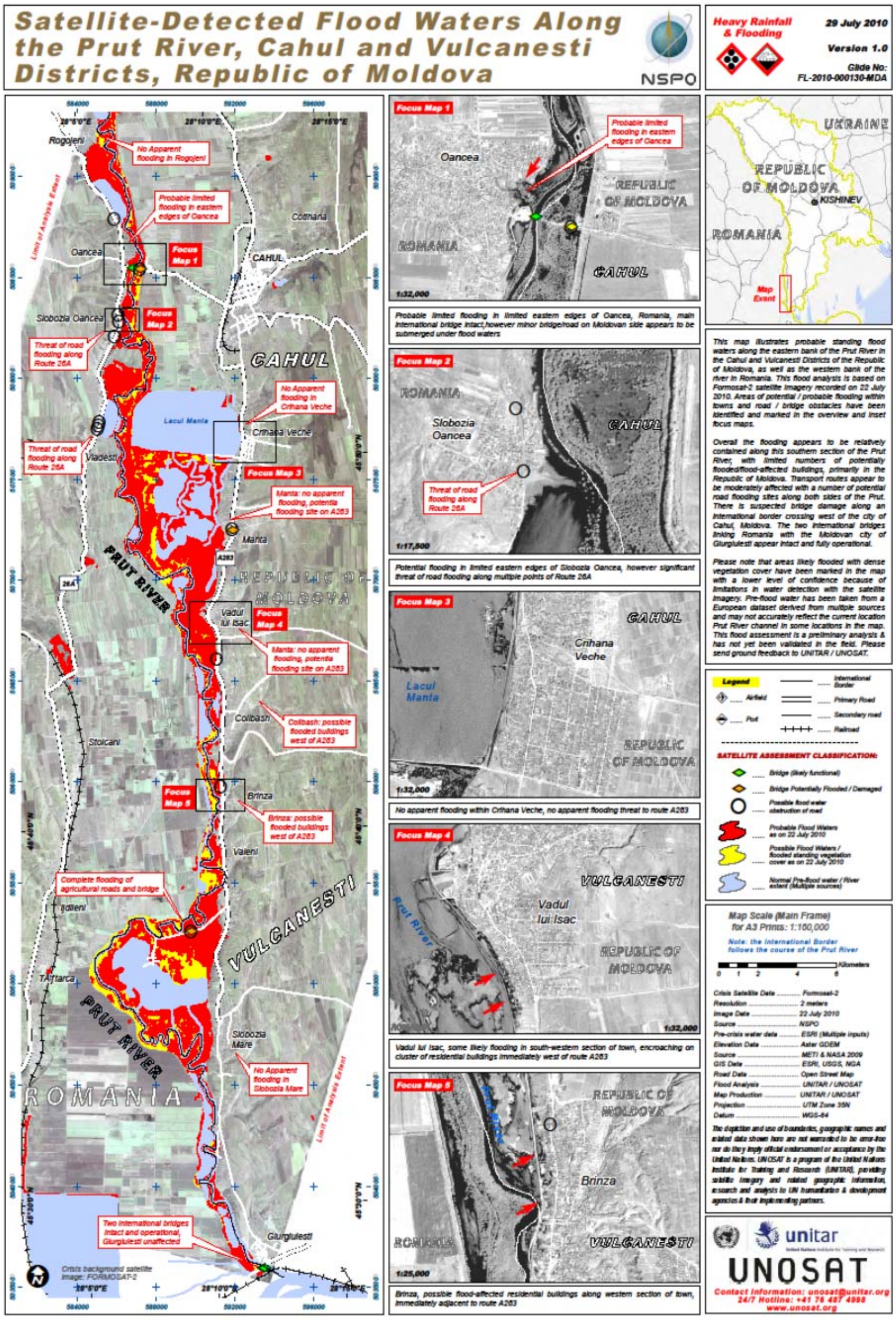


Table 2.1: Overview of spatial data for hazard assessment, and their relevance for different types of hazards. (••• = highly relevant, •• = moderately relevant, and • = Less relevant). EQ= Earthquakes, VO= Volcanic hazards, DR= Drought, WS= Windstorms, FL= Floods, CO= Coastal, LS = Landslides, WF = Wildfire.

Group	Data layer and types	EQ	VO	DR	WS	FL	CO	LS	WF
Hazard inventories	Satellite based monitoring	•	•••	•••	•••	•	•	•	•••
	Ground-based networks	•••	•••	•••	•	•••	•	•	•
	Archive studies	•••	•••	•••	•••	•••	•••	•••	•••
	Visual image interpretation	••	••	•	•	••	••	•••	••
	Field mapping	••	•••	•	•	•••	•	•••	•
	Participatory approaches	•••	•••	•••	•••	•••	•••	•••	•••
	Dating methods	•••	•••	•	•	•	•	•••	•
Topography	Relief	•••	•••	•	••	•••	•••	•••	••
	Altitude difference (in time)	•••	•••	•	•	•••	•••	•••	•
	Slope steepness	•••	•••	•	••	••	•••	•••	•
	Slope direction	•••	•••	•	•••	••	••	••	••
	Flow accumulation	•	••	•	•	•••	•	••	•
Geology	Rock types	•••	•••	•	•	•	••	•••	•
	Weathering	•••	•	•	•	•	••	•••	•
	Faults	•••	••	•	•	•	•	•••	•
	Structural geology	•••	•	•	•	•	•	•••	•
Soils	Soil types	•••	•	•••	•	••	••	•••	••
	Soil depth	•••	•	•••	•	•	•	•••	•
	Geotechnical properties	•••	•	•	•	•	••	•••	•
	Hydrological properties	••	•	•••	•	••	••	•••	••
Hydrology	Discharge	•	•••	••	••	•••	••	•	•
	Ground water tables	•••	•	•••	•	••	•	•••	•••
	Soil moisture	••	•	•••	•	•••	•	•••	•••
	Run off	•	•••	•••	•	•••	•	••	••
Geomorphology	Physiographic units	••	••	••	••	••	••	•••	•••
	Origin/genesis	•••	•••	•	•	•••	•••	•••	••
	Landforms	•••	•••	••	••	•••	•••	•••	••
	Active processes	•••	•••	••	•	•••	•••	•••	••
Landuse	Natural vegetation	•	•	•••	•••	•••	••	••	•••
	Land use	••	••	•••	••	•••	••	•••	•••
	Vegetation changes	•	••	•••	•••	•••	••	••	•••
	Land use changes	•	••	•••	•••	•••	••	•••	•••
	Linear infrastructures	•	•••	••	•	•••	••	•••	•••
	Built-up areas	•••	•••	•••	•••	•••	•••	•••	•••
Triggering factors	Rainfall	••	•••	•••	•••	•••	••	•••	•••
	Temperature	•	•	•••	•••	•	••	•	•••
	Wind speed & direction	•	•••	•	•••	•	•••	•	•••
	Wave height	•	•	•	•	••	•••	•	•
	Tides	•	•	•	•	•••	•••	•	•
	Earthquakes	•••	•••	•	•	••	•••	•••	•
	Volcanic eruptions	•	•••	•	•••	••	•••	•••	•••

For a number of hazards, satellite-based information is the major source for generating hazard inventories, and hazard monitoring (e.g., tropical cyclones, forest fires, and drought). For others it supports ground-based measurements (e.g., earthquakes, volcanic eruptions, coastal hazards). There are hazard types that cannot be recorded by a network of measurement stations, as these do not have specific measurable characteristics (such as landslides, forest fires and snow avalanches). There are also many areas where recorded information is not available. Thus the identification of hazardous phenomena may require techniques such as automatic classification or expert visual interpretation of remotely sensed data.

Automatic classification methods make use of reflectance variations in different parts of the electromagnetic spectrum, and by active microwave and LiDAR sensors. For instance for flooding, Earth-observation satellites can be used in mapping historical events and sequential inundation phases, including duration, depth of inundation, and direction of current (Smith, 1997). Geomorphological information can be obtained using optical (LANDSAT, SPOT, IRS, ASTER) and microwave (ERS, RADARSAT, ENVISAT, PALSAR) data (Marcus and Fonstad, 2008). The use of optical satellite data is often hampered by the presence of clouds, and hazard mapping is also hampered in areas with vegetation cover. Synthetic Aperture Radar (SAR) is therefore a better tool for mapping hazard events, such as floods (Schumann et al., 2007).

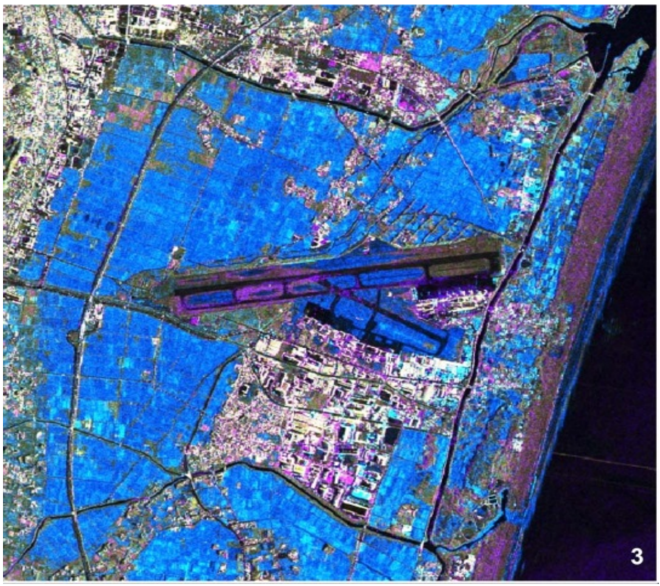
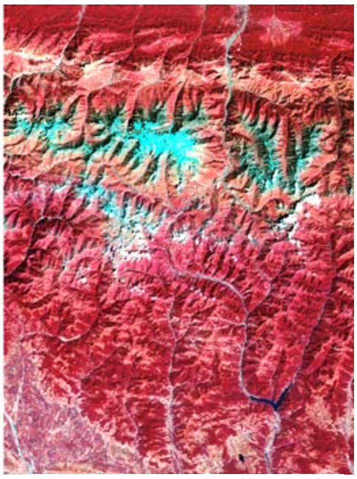


Figure 2.1 Terra-SAR-X radar satellite image of tsunami inundation in blue – Sendai, Japan

Mapping of forest fires with satellite information is done by mapping the fires themselves using thermal sensors (Giglio and Kendall, 2001), or through the mapping of burnt areas (e.g., using MODIS or AVHRR which have a high temporal resolution (Trigg et al., 2005), or with SAR (Bourgeau-Chavez and Kasischke, 2002)).

For visual interpretation of hazard phenomena that cannot be automatically obtained from satellite images (such as landslides) and for geomorphological interpretation of hilly and mountainous areas, stereoscopic imagery with a high to very high resolution is required (Metternicht et al., 2005).


Landsat TM - False color Mt. Kazbegi, Georgia

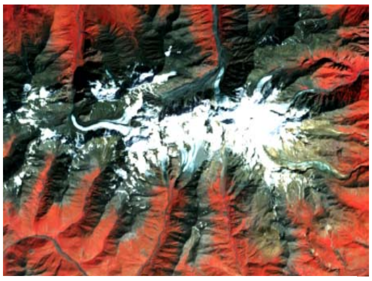
One of the oldest and best known satellites missions is ***Landsat***, **MSS** and **(Enhanced) Thematic Mapper** which has been providing Earth surface data since 1972. Initially the data had a resolution of approximately 60 m, which was later improved to 30m for multi-spectral data and even 15 m for panchromatic band. Despite its pioneering qualities, there have also been setbacks, with Landsat 6 failing to reach orbit in 1993, and Landsat 7, suffering from some image quality problems.

The US government decided to make all Landsat data, including the entire archive, available free of charge. Data can be searched using the GLOVIS tool: ***http://glovis.usgs.gov/***

There is also a source for free ortho-rectified Landsat data at the Global Landcover Facility (GLCF) and also at ***http://earthexplorer.usgs.gov.*** Be aware that Landsat datasets, even when compressed, can easily reach several hundred MB in size, which can make their download difficult. As with the other datasets mentioned above though, the files have geographic reference information and can easily be imported into a GIS or similar program (ILWIS for instance). Older Landsat images can be useful to compare the land surface with a more recent situation. Landsat images from all dates can be browsed at the Landsat Look Viewer: ***http://landsatlook.usgs.gov/***

Landsat 8 is NASA's eighth satellite in the Landsat series has been launched February 2013 and continues the Landsat program's. Landsat 8 measures Earth's surfaces in the visible, near-infrared, short wave infrared and thermal infrared, with a moderate-resolution of 15 to 100 meters, depending on spectral frequency.

More information: ***http://landsat.usgs.gov/LDCM_Landsat8.php***


ASTER VNIR - Mt. Kazbegi, Georgia

Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) has become a very widely used satellite image source. Launched in 1999, the sensor carries a spectacular 15 channels, with 4 bands at 15 m resolution, 6 at 60m., and 5 at 90m. The spatial and spectral details are thus excellent, and, in addition, the data can be used to create DEMs, as explained before. The best way to search for ASTER data is via NASA's Earth Observing System Data and Information System. Visit for this the **Reverb Portal**: ***reverb.echo.nasa.gov/reverb/*** where also other satellites can be found such as MODIS. You can register (for free), or search as a guest. Be aware that there are many different data products and that Aster Level 1B or higher can only be downloaded by special registered users. It is advisable to read up on how these products were generated and what they are useful for (see: **http://asterweb.jpl.nasa.gov/**). An even quicker way to check for available data is via the USGS'S Global Visualization Viewer (GLOVIS)'s (***http://glovis.usgs.gov/***), which gives a nice graphical overview. Download is however easier from the Reverb Portal.


SPOT-5 Reno, Nevado - 5m.

The ***SPOT*** satellites were initiated by the French Space Agency, but are now operated by Spot Imaging, a commercial company. The regular images are expensive, but the latest SPOT satellite includes resolutions from 20 m. up to 1.50 m. With an imaging swath of 60 km SPOT products provide an ideal basemap at local and regional scales from 1:100 000 to 1:15 000. A 26-year archive from SPOT 1 through to SPOT 5 contains more than 30 million images at resolutions of 20 to 2.5 m. and is therefore ideal for environmental monitoring studies.

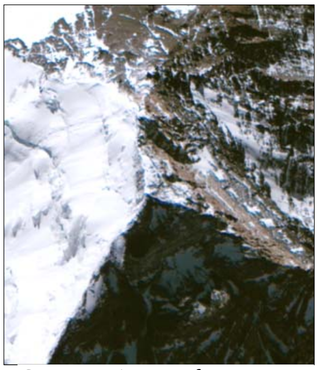
Information about the SPOT satellite: ***http://www.astrium-geo.com/en/11-products-services***

FORMOSAT-2 Island of Mauritius

High resolution optical satellite sensors

Commercial satellite data quickly reach costs in the thousands of dollars. Hence the wellknown commercial data types, such as ***IKONOS*** or ***Quickbird***, are often not affordable, and are only briefly mentioned here. However, a few points must be noted.

The mentioned commercial satellite operators have managed to increase the spatial resolution by a very impressive margin, for the first time reaching 50 cm with ***GeoEye*** starting in 2008. The ***WorldView-3*** sensor to be launched in 2014 which will have a resolution in panchromatic mode of 31 cm.



GeoEye-1 image of Mt. Everest – 0.5m. resolution

These data are of a resolution comparable with many aerial photographs, but are already digital and usually include several spectral bands as well. These multispectral channels are of a lower resolution, usually at 4 times the resolution of the pan-chromatic band. With so called "pan-sharpening" it is however with the help of image processing software possible to fuse the multi-spectral and panchromatic bands into one image with a resolution the same as the panchromatic channel.
The good news is that many of the images used by ***Google Earth*** derived from *IKONOS* and *Quickbird* and even at places from colour aerial photographs. This means that with proper geo-referencing it is still possible to get an very useful high resolution satellite "picture", which can be combined with other spatial data layers.
For those who require high resolution commercial data, good search engines exist, such as DigitalGlobe website: ***http://geofuse.geoeye.com/landing/Default.aspx*** for GeoEye, IKONOS and WorldView imagery. Technical information at: ***http://www.digitalglobe.com/resources/satellite-information***

There are many more countries with their own space technology. In addition to the traditional space powers – the US, Canada, Europe, Russia, and Japan – we now find many countries building and operating their own satellites instruments. The ***CBERS Program*** was born from a partnership between Brazil and China in the space technical scientific segment. The satellite images have a 20 m. resolution and also 260 m. Wide **Field Imager).** See also: ***https://earth.esa.int/web/guest/missions/3rd-party-missions/potential-missions/cbers***

Another example of this is the Taiwanese *FORMOSAT* satellite. The ***FORMOSAT-2*** is a high-resolution optical satellite able to revisit the same point on the globe every day in the same viewing conditions. Its unique orbit and 2-m. Panchromatic resolution are well suited to change detection and rapid coverage of large areas. Further info:***http://www.astrium-geo.com/en/160-formosat-2***

The Japanese ***ALOS*** satellite has three remote sensing instruments on board: the *PRISM* panchromatic sensor for stereo mapping, comprised of three optical systems to obtain 3-D data with a resolution of 2.5m. The Advanced Visible and Near Infra-red Radiometer (AVNIR-2) has a 10 m. spatial resolution. Finally it has a radar system named *PALSAR* working in the L-band. More information on the *AIOS* satellite system and instruments: ***http://www.eorc.jaxa.jp/ALOS/en/index.htm***

ALOS - St. Petersburg – pan sharp.

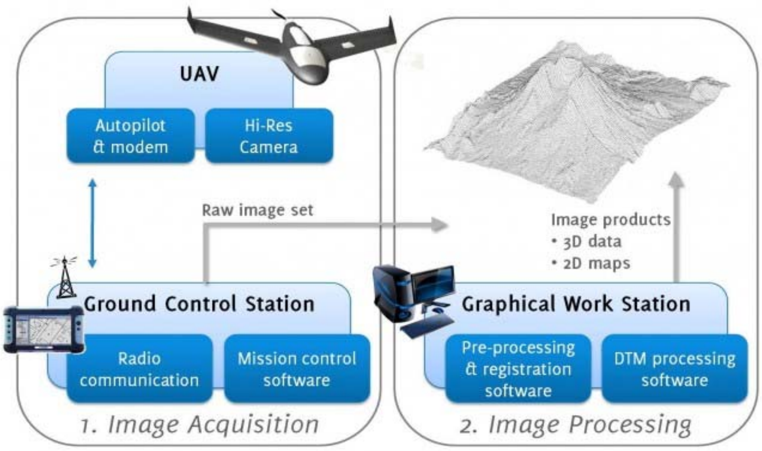
The ***Pléiades 1A*** and ***Pléiades 1B*** satellite system operate as a constellation in the same orbit, phased 180° apart. The identical twin satellites deliver optical data products in record time with 50 cm. resolution and offer a daily revisit capability to any point on the globe in less than 24 hrs. for instance in response to a crisis or natural disaster. Information about the SPOT satellite and Pléiades 1A & 1B can be found on the ASTRIUM website: ***http://www.astrium-geo.com/en/11-products-services*** and also Satellite Image Corporation: ***http://www.satimagingcorp.com/satellite-sensors/spot-5.html***

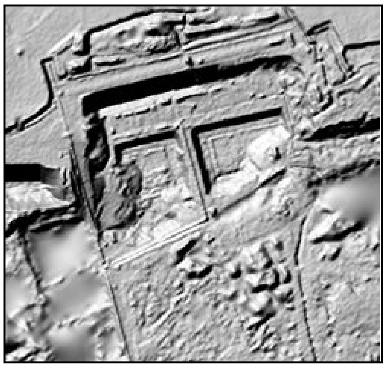
CARTOSAT Ardana, Turkey - 1m.

Countries that deserve special mention are India, which is operating one of the largest fleet of earth observation satellites. The ***Cartosat-2*** satellite sensor for instance has a resolution of only 1 m. in the panchromatic part of the EM spectrum. The multi-spectral sensors have a lower resolution, comparable to Landsat Unfortunately large parts of these data are classified and can therefore not be accessed by civilian users. More information of the Indian Space Research Organisation (ISRO): ***http://www.isro.org/***

Unmanned Air borne Vehicles

Unmanned air-borne vehicles can be of use in disaster situations in which one cannot wait long for satellite images to be acquired and where for instance clouds are covering the surface. Various systems are nowadays on the market which can take very high resolution ortho-photographs and even generate digital elevation models. Most of the systems are small, so that they can be transported in the trunk of a car for access "on the spot". The limitation is the relative small surface area to be covered compared to satellite images.





Example: UAV X 100 Trimble
http://uas.trimble.com/trimble-uas

Very high resolution imagery (QuickBird, IKONOS, WorldView, GeoEye, SPOT-5&6, Resourcesat, Cartosat, Formosat and ALOS-PRISM) have become the best option now for visual mapping from satellite images, and the number of operational sensors with similar characteristics is growing year by year, as more countries are launching earth observation satellites with stereo capabilities and spatial resolution of 3 meters or better.

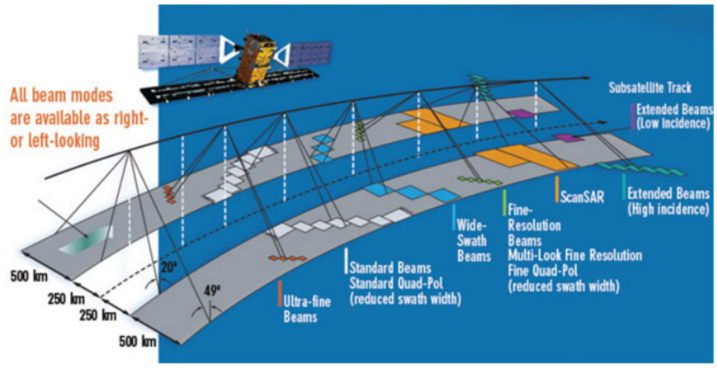
The high costs may still be a limitation for obtaining these very high resolution images for particular study areas, especially for multiple dates after the occurrence of main triggering events such as tropical storms or cyclones. Automatic classification of landslides using digital airphotos and very high resolution satellite images has been applied successfully by Hervas et al., (2003), Barlow et al. (2006) and Martha et al. (2010).

Hazard inventory databases should contain information for extended periods of time so that magnitude/frequency relationships can be analyzed. This requires the inclusion of both high frequency/low magnitude events for estimating hazards with a high probability of occurrence, but should also contain sufficient low frequency/high magnitude events to evaluate the hazard for extreme events as well. Therefore, apart from measuring, observing and mapping recent hazard events, it is of large importance to carry out extensive archive studies. For example, one of the most comprehensive projects for landslide and flood inventory mapping has been the AVI project in Italy (Guzzetti et al., 1994). Another example is from China where an analysis was made on extreme precipitation events based on datasets derived from Chinese historical documents over eastern China for the past 1500 years (Zheng et al., 2006). Hazard inventories can also be produced using participatory mapping and participatory GIS (PGIS). Participatory GIS involves communities in the production of spatial data and spatial decision-making. Local people could interpret the outputs from a GIS or contribute to it, for example by integrating participatory mapping of hazardous events to modify or update information in a GIS. Capturing local knowledge and combining it with other spatial information is a central objective. This process may assist communities to look at their environment and explore alternative scenarios based on understanding of their own goals, constraints and preferences (McCall, 2003; Peters Guarin et al., 2005).

The techniques described above are intended to support the generation of hazard inventory databases. Such databases may have a very large degree of uncertainty, which can be related to the incompleteness of historical information with respect to the exact location, time of occurrence, and type of hazard. Table 5 lists a number of sources for global hazard inventories that have been used in the PREVIEW project (Peduzzi et al., 2009).

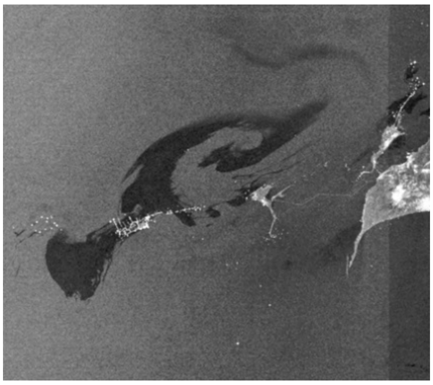
Active spaceborne sensors

RADARSAT-2



Various remote sensor platforms have also **radar sensors** "on board", such as for instance the **ALOS** satellite and some of the Indian Remote Sensing satellite systems. Other imaging radar systems to be mentioned are ***Radarsat*** of the Canadian Space Agency and the European Remote Sensing satellites ***ERS-1* and *2*** (retired since 2011). All these systems had many options, which can be useful for the monitoring of hazard processes using older imagery. For more information one have to visit the websites. ***Radarsat***: ***http://www.asc-csa.gc.ca/eng/satellites/radarsat2/default.asp*** and sites of ***ERS-1*** and ***ERS-2*** : ***https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/ers***

The European Environmental satellite ***ENVISAT*** in not operational since 2012. It provided measurements of the atmosphere, ocean, land, and ice. The satellite was launched in 2002 and is out of service since 2012. ENVISAT had among others the *MERIS* optical and *ASAR* radar sensors on board which had various different image modes and resolutions. The ASAR image mode can be useful for the detection and monitoring of oil spills and sea ice. More information can be found on : ***https://earth.esa.int/***



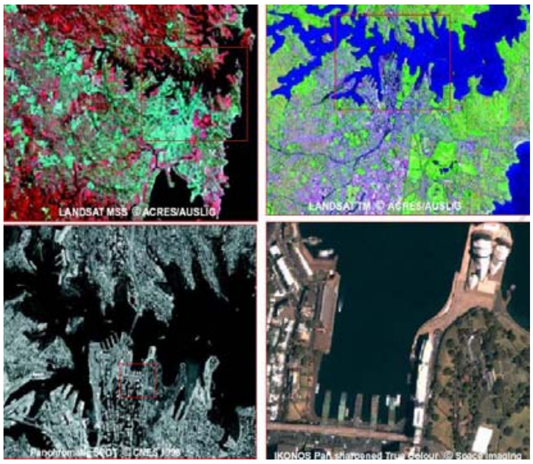
ENVISAT-ASAR - x-band Oil spill

A very useful imaging radar satellite to be mentioned for hazard and disaster risk studies is the German ***Terra SAR-X*** system with a flexible resolution of 1, 3 and 18,5 m. and a high geometric and radiometric accuracy. It can access any point on earth inside 2.5 days. The constellation consist of an almost identical twin satellite designed to fly in a close formation with TerraSAR-X: Together, the two satellites can collect high resolution data for the generation of global Digital Elevation Model. Info: ***http://www.astrium-geo.com/terrasar-x/***

How to select satellite imagery for risk assessment?

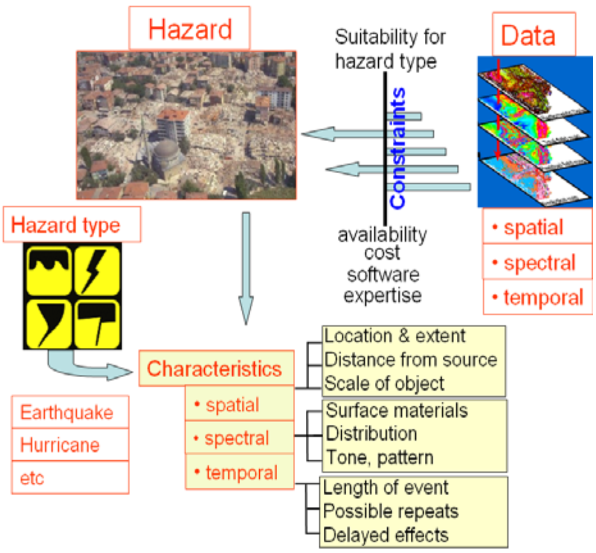
The selection of the most suitable satellite imagery for risk assessment depends to a large extend on the type of hazard and elements at risk to be studied. Different hazard types, such as earthquakes or landslides have different (i) spatial, (ii) spectral and (iii) temporal characteristics. A hazard can be very local and spatially confined (e.g. an unstable slope), it can be very extensive (e.g. flooding or drought), or there can be a large distance between the actual source of the hazard and the area in question. Examples of that can be earthquakes, where the responsible fault may be a long distance away from areas that may still experience strong shaking during an event, or flooding by the river caused by snowmelt in the upper part of the catchment or even dam break. We also have to consider the dimensions of the hazard: a hill slope is quite small in extent, while an area possibly exposed to flooding may be vast. The data we choose in the analysis need to reflect those dimensions and the details we need to see. For the analysis of the elements at risk such as buildings, infrastructural facilities etc. we have to use in most cases high resolution imagery.

Optical imagery derived from passive satellite sensors, are well suited to map vegetation, flooding by the river and the sea and at high resolution detailed surface processes such as landslides or the different types of elements at risk. In areas or situations where clouds, smoke, or night-time conditions prevent, we can have to rely on active sensors, such as radar.



Different spatial resolutions (pixel sizes)

(N. Kerle, ITC)

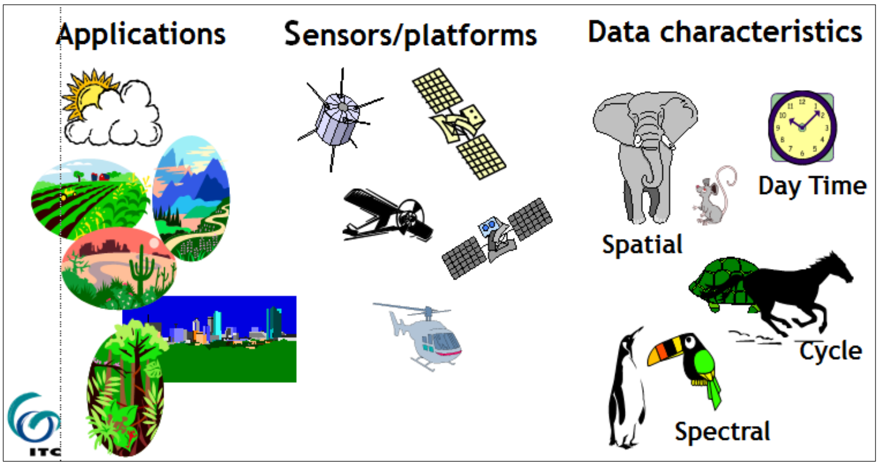


The hazard type dependency of spatial data

(N. Kerle, ITC)

Thus we see that we need to have a good understanding of the spatial, spectral and temporal characteristics of the hazard(s) under consideration, before deciding on a specific analysis type and data requirements. The figure illustrates that also our spatial data sources have spatial and temporal characteristics, in case of image data also in the spectral domain. Those need to be matched with the hazard characteristics, but, for risk assessment, also with those of the elements at risk. For example, while we may use a satellite image that shows a large area, such as the catchment from which a flood might originate, we may need very detailed imagery to map buildings and other structural elements that may be affected by a flood. This is difficult, as there is a largely inverse relationship between coverage and detail.

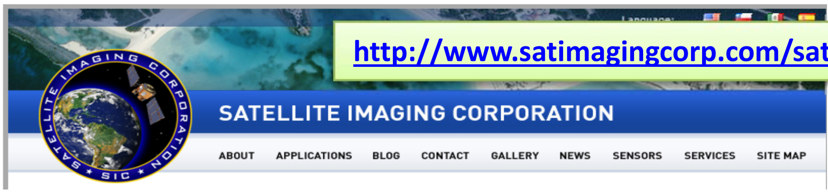
Once we have clarified the suitability of a given data type, or combination of types, there are a few other important considerations that typically act as constraints: availability, cost, software, expertise. There can be a large difference between suitable and actually available data.



Check list data selection (after N. Kerle, ITC)

- ✓ *Consider the type of event and its characteristics*
- ✓ *Define clearly what you need to map*
- ✓ *Based on that, define what data characteristics you require*
- ✓ *What data are available? How quickly?*
- ✓ *How quickly are results needed?*
- ✓ *Do pre-event images exist & are they useful?*
- ✓ *What are the cost constraints?*
- ✓ *Are the technological and expert requirements met?*

Web portals with an overview of most satellite sensor data



http://www.satimagingcorp.com/satellite-sensors.html

NLR Satellite information database

http://gdsc.nlr.nl/FlexCatalog/catalog.html

2.2 ENVIRONMENTAL FACTORS

The environmental factors are a collection of GIS data layers that are expected to have an effect on the occurrence of the hazardous phenomena, and can be utilized as causal factors in the prediction of future events (given numerous assumptions). The list of environmental factors in Table 4 is not exhaustive, and it is important to select those factors that are related to a specific type of hazard in each particular environment. They represent, however, an example of data types related to topography, geology, soils, hydrology, geomorphology and land use. The basic data can be subdivided into those that are more or less static, and those that are dynamic and need to be updated regularly. Examples of static data sets are related to geology, soil types, geomorphology and topography. The time frame for the updating of dynamic data may range from hours to days (e.g., meteorological data and its effect on hydrology), to months and years for land-cover and land-use data. Land-use information should be evaluated with care, as this is both an environmental factor, which determines the occurrence of new events (such as forest fires, landslides and soil erosion), as well as an element-at-risk, which may be affected by the hazards. Table 2.2 provides an indication on the relevance of these factors for hazard assessment for different types of hazards (Van Westen, 2009).

Table 2.2: Global data sources for inventory of hazardous events, and hazard assessment used in the PREVIEW project (UNEP/DEWA/GRID, 2010)

Hazard type	Historic events	Hazards
Cyclones	UNEP/GRID-Europe, based on various raw data sources	UNEP/GRID-Europe
Cyclones storm surges:	UNEP/GRID-Europe, based on Cyclones - winds data	UNEP/GRID-Europe
Droughts	UNEP/GRID-Europe based on Climate Research Unit (CRU) precipitation data	International Research Institute for Climate Prediction (IRI), Columbia University
Earthquakes	United States Geological Survey (USGS) ShakeMap Atlas	UNEP/GRID-Europe, USGS, and GSHAP (Global Seismic Hazard Assessment Project)
Fires	European Space Agency (ESA-ESRIN) and World Fires Atlas Program (ATSR).	IONA Fire Atlas
Floods	Dartmouth Flood Observatory (DFO).	UNEP/GRID-Europe
Tsunamis	National Geophysical Data Center (NGDC) Tsunami database, NOAA	Norwegian Geotechnical Institute (NGI),
Volcanoes	Smithsonian Institution Volcanoes of the world	
Landslides	Not available	Hotspots project, International Centre for Geohazards (ICG/NGI)

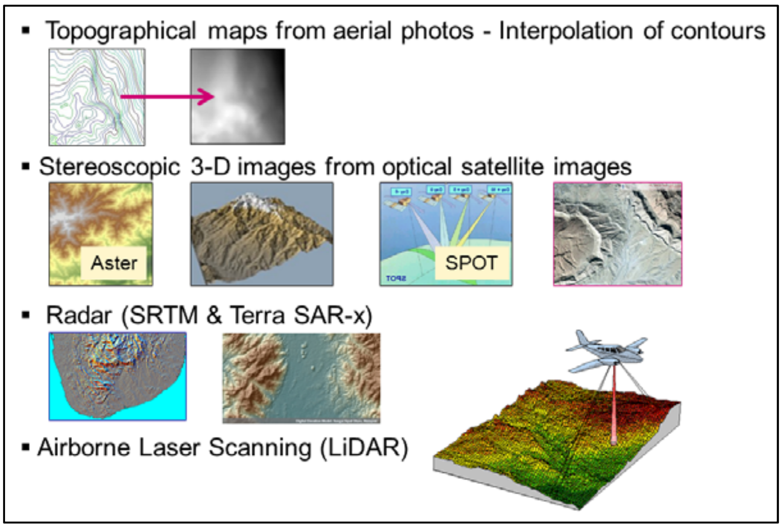
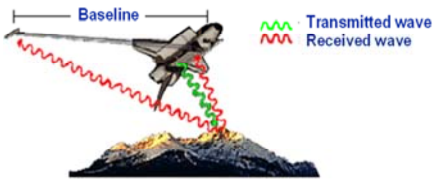


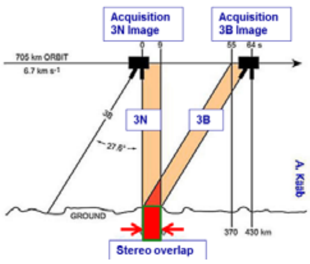
Figure 2.2 – Different types of aerospace data for the creation of Digital Elevation Models

As topography is one of the major factors in most types of hazard analysis, the generation of a Digital Elevation Model (DEM) and geomorphometric analysis plays a critical role. Elevation data can be obtained through a variety of techniques, such as digitizing contours from existing topographic maps, topographic levelling, EDM (Electronic Distance Measurement), differential Global Positioning Systems (GPS) measurements, digital photogrammetry, Interferometric Synthetic Aperture Radar (InSAR), and Light Detection and Ranging (LiDAR). Data source selection depends upon a variety of factors that include data availability, price and application. Many topographic parameters can be produced from DEMs using fairly simple GIS operations.

The radar signal of ***Shuttle Radar Topography Mission*** data (SRTM) is recorded with antennas at two slightly different positions: one in the centre of the Space shuttle itself and another at the end of a 60 m long mast.



Using the information about the distance between the two antennas and the differences in the reflected radar wave signals, elevation data of the Earth's surface can be generated at a relative accuracy. The pixel resolution of the data is approximately 90 m; the vertical (Z) resolution 1 m. with an absolute accuracy of approximately 10 – 15 m. This means that SRTM is not suitable for the measurement of accurate elevations. However, for medium of low terrain studies of large areas it can be very good.



The three dimensional terrain model of ***ASTER (GDEM)*** is created by combining the nadir looking and "back-ward" looking image bands of the VNIR sensor. The pixel resolution is 30 m. and the vertical resolution 1 m.

Although the pixel size of the GDEM is smaller compared to SRTM, is the absolute elevation accuracy by far not as good. The data is however useful to generate 3-D imagery for visual inspection at a relative small scale.

The main sources for global DEMs used in hazard and risk analysis are GTOPO30 (USGS, 1997; Hastings and Dunbar, 1998), and Shuttle Radar Topographic Mission (SRTM) (Farr and Kobrick, 2000). The relatively low

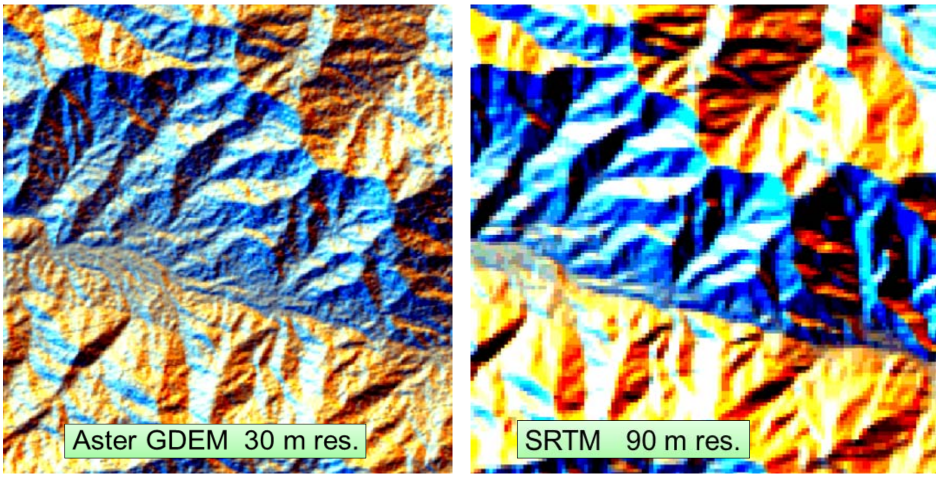
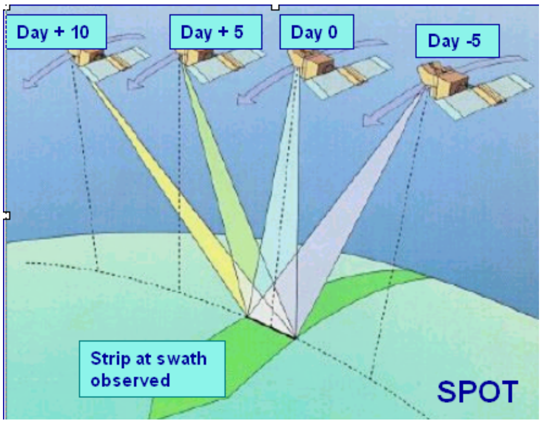


Figure 2.3 - Comparison ASTER GDEM and SRTM - color hill-shade Structurally controlled hills, Vietnam

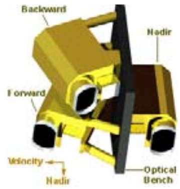
vertical accuracy of SRTM data (Falorni et al., 2005) doesn't make it suitable for large scale hazard assessments. However it is extensively used for many small scale applications in areas where other sources of DEM are not available, such as in tsunami hazard assessment (Blumberg et al., 2005). ASTER derived DEMs (GDEM) are also frequently used in hazard assessments for (parts of) countries, in the absence of more detailed data (Fujisada et al., 2005). For smaller areas the best option is to derived DEMs from very high resolution images (e.g. Quickbird, IKONOS, ALOS PRISM, Cartosat and SPOT 6&7). The Terra SAR-X radar satellite has the advantage that it is independent of the presence of clouds and therefore very suitable for hazard monitoring.



The commercial ***SPOT satellite*** has a different system compared to *ASTER* to generate 3-D data and has a very good global coverage. The sensor has a steerable mirror by which it can detect terrain across track to the "right" or to the "left" of the satellite overpass. By combining this images– which are taken under an angle - from different overpasses, a three dimensional model can be generated. An advantage is also that the revisits time is enhanced. The newest *SPOT-6 & 7* satellite provides a daily revisit everywhere on Earth.

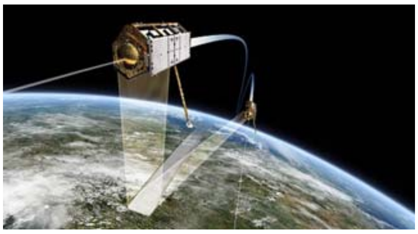
A ***SPOT DEM*** is a digital elevation model by stereo-pairs acquired by SPOT-5. The resampled resolution is 20 m; the absolute vertical accuracy between 10 and 20 m. The newest SPOT 6 and SPOT 7 satellites form a constellation in the same orbit as the Pléiades constellation. They provides a daily revisit everywhere on Earth. The SPOT-6/7 has also stereo capability with an every higher accuracy.

Information about the SPOT satellite can be found on the ASTRIUM website: *http://www.astrium-geo.com/en/11-products-services* and also Satellite Image Corporation: *http://www.satimagingcorp.com/satellite-sensors/spot-5.html*

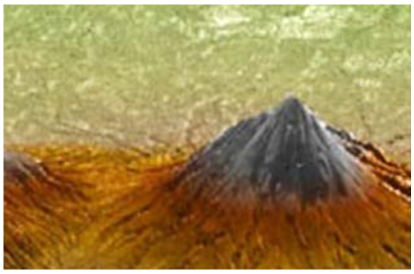


The Japanese ***ALOS satellite*** has the ***PRISM*** panchromatic radiometer on board with 2.5 m. spatial resolution at nadir. It provides an accurate digital surface model (DSM). PRISM has three independent optical systems for viewing nadir, forward and backward. More information on the ALOS satellite: *http://www.eorc.jaxa.jp/ALOS/en/index.htm*

The ***Terra-SAR-X radar satellite constellation*** consist of an almost identical twin satellite designed to fly in a close formation with TerraSAR-X: Together, the two satellites can collect high resolution data for the generation of global Digital Elevation Model. The spatial resolution is up to 10 m. with an absolute height accuracy of 5 m. Info: *http://www.astrium-geo.com/terrasar-x/*



The ***WorldDEM™*** is a global elevation dataset of high quality, accuracy, and coverage. It will be available from 2014 for the Earth's entire land surface - pole to pole. The accuracy of the WorldDEM™ will surpass that of any satellite-based global elevation model available today. The data source is Terra SAR-X. Vertical accuracy: 2m (relative) / 10m (absolute) and pixels of 12m x 12m. Info: *http://www.astrium-geo.com/terrasar-x/*

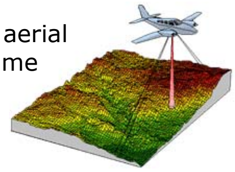


Terra SAR-X DEM - Merapi vocano, Java, Indonesia

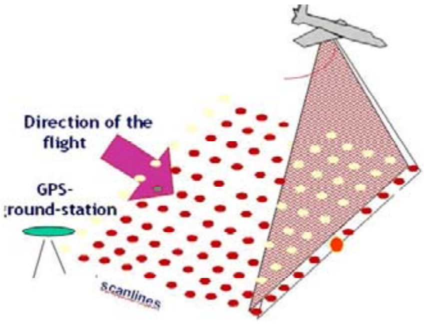
Synthetic Aperture Radar Interferometry (InSAR) can be used for the generation of Digital Elevation Models, but in practice it is mostly used for detecting changes in topographic heights, related to different hazardous geological processes, such as land subsidence, slow moving landslides, tectonic motions, ice movement and volcanic activity (Massonnet & Feigl, 1998; Ferretti et al. 2001; Hilley et al. 2004; Salvi et al. 2004; Bürgmann et al. 2006). Multi-temporal InSAR analyses using techniques such as the Permanent Scatterers (PSInSAR; Ferretti et al. 2001) can be used to measure displacement of permanent scatterers such as buildings with millimetre accuracy, and allow the reconstruction of the deformation history (Farina et al. 2008).

For detailed measurement of displacements networks of Differential Global Positioning Systems (DGPS) at fixed points are used extensively, e.g. for mapping strain rates and tectonic plate movements (Vigni et al., 2005), volcanic movements (Bonforte and Puglisi (2003), and landslides (Gili et al, 2000).

More detailed DEMs derived using LiDAR are used extensively for geomorphologic mapping and terrain classification (Asselen and Seijmonsbergen, 2006). Airborne LIDAR data can be applied to glacial hazards (Favey et al., 2002) coastal hazards (Miller et al., 2008), flood modelling (Cobby et al., 2001; French, 2003), and landslide hazard assessment (Haugerud et al., 2003). Multi-temporal LIDAR can also be used



With ***Light Detection and Ranging (LiDAR)*** it is possible to create with aerial sensors very high resolution elevation models of the terrain, and at the same time also from objects near the surface such as buildings and even vegetation. A laser scanner mounted in an aircraft emits laser beams with a high frequency to record the reflections together with the time difference between the emission and reflection.



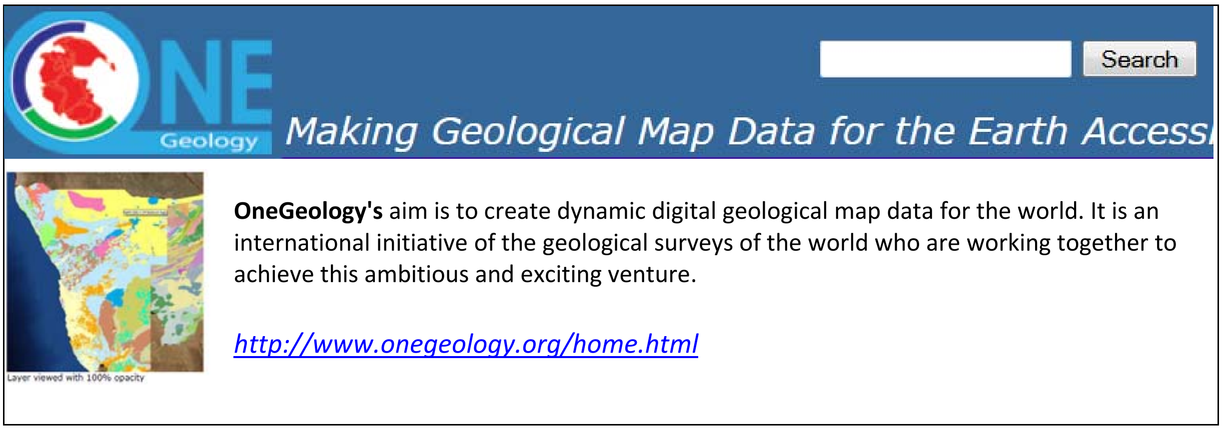
With detailed information about the internal and external orientation using GPS and other devices, the elevation of the 'scanned' area can be measured in centimetre accuracy. LiDAR differs from RADAR mainly in its ability to resolve very small targets and penetrate vegetation.

The reflection strength depends on the wave length and the terrain type. All terrain features are scanned, not only the terrain itself but also trees, buildings, cars on the street, etc To create a 3-D terrain model all this data has to be filtered out from this original surface 3-D model. The multiple reflections from the same surface feature can also be used for, for instance 3-D vegetation mapping and biomass estimation.

to model the changes and quantify rates of active fluvial processes, for instance river bank erosion (Thoma et al., 2005).

Derivatives from DEMs can be used in heuristic hazard analysis at small scales (e.g. hillshading images for display as backdrop image, physiographic classification, internal relief, drainage density), in statistical analysis at regional scales (e.g. altitude zones, slope gradient, slope direction, contributing area, plan curvature, profile curvature, slope length), in physically-based modelling at local scales (local drain direction, flow path, slope gradient) and in spread modelling (detailed slope morphology, flow path) (Moore et al., 2001). The use of slope gradient maps in hazard assessment is greatly affected by the resolution of the DEM (Zhou and Liu, 2004). As a general rule of thumb the use of slope gradient maps is not advisable for small scale studies (Van Westen et al., 2008), although some have used 1 km resolution DEMs to calculate slope angle distribution (Hong and Adler, 2007a). In larger scale studies slope maps, and other DEM derivatives such as aspect, slope length, slope shape etc. can be used as input factors for heuristic or statistical analysis. In local and site investigation scale hazard assessment, DEMs are used in slope hydrology modelling and slope maps are used for physically-based modelling (Kuriakose et al., 2009a).

Geological maps represent a standard information component in the hazard assessment of many hazard types (seismic, volcanic, landslides, soil erosion). A geological map of the world (CGMW) was developed in 2009 with maps at scale 1:5 million and 1:25 million. OneGeology is an international initiative of the geological surveys of the world, launched in 2007 as a contribution to the International Year of Planet Earth, with the aim to create a web-based geological map of the world (OneGeology, 2010). Digital geological maps of chronostratigraphy, lithostratigraphy, faults, tectonic



lineaments, tectonic units and other themes are available on-line with scales ranging from 1:250,000 (for certain countries) to 1:50 million.

For individual countries, geological information is often digitally available at much larger scales. For example, through the web-portal of the USGS, scanned geological maps, as well as GIS data can be downloaded (USGS, 2010). The subdivision of geological formations into meaningful units for hazard assessment is often problematic at small scales of analysis. In detailed hazard studies, specific engineering geological maps are collected and rock types are characterized using field tests and laboratory measurements. For detailed analysis, 3-D geological maps have also been used, although the amount of outcrop and borehole information collected will make it difficult to use this information on a scale smaller than 1:5000, and its use is restricted mostly to a site investigation level (e.g., Xie et al., 2003). Apart from lithological information, structural information is very important for hazard assessment (e.g., earthquakes, landslides, volcanic eruptions). At medium and large scales, attempts have been made to generate maps indicating dip direction and dip amount, based on field measurements, but the success of this depends very strongly on the amount of measurements and the complexity of the geological structure (Günther, 2003).

Soil information is also required for hazard assessment. This includes soil types, with associated geotechnical and hydrological properties, and soil sequences, with depth information. These data layers are essential components for any physically-based modelling approach (e.g., for earthquake amplification studies, landslides and soil erosion). Pedologic soil maps usually portray soil classes based on the upper soil horizons, with rather complicated legends, and are relevant for soil erosion, drought and forest-fire hazard assessment. Engineering soil maps describe all loose materials on top of the bedrock, and portray classes according to geotechnical characteristics. They are based on outcrops, borehole information and geophysical studies. The soil depth is very difficult to map over large areas, as it may significantly vary over a relatively small area. Soil thickness can be modelled using an interpolation technique which incorporates factors such as land use and slope (Kuriakose et al., 2009b). Digital soil information is available worldwide from the FAO Digital Soil map of the World Information (FAO, 1981), and include soil-type classification, clay mineralogy, soil depth, soil-moisture capacity, bulk density, soil compaction, etc. This product is not based on satellite information directly, but is based primarily on ground surveys and national databases.

Geomorphological maps are made at various scales to show land units based on their shape, material, processes and genesis (e.g., Klimaszewski, 1982). There is no generally accepted legend for geomorphological maps, and there may be a large variation in contents based on the experience of the geomorphologist. An Applied Geomorphological Mapping Working Group has been formed as part of the International Association of Geomomorphologists (IAG) to set guidelines for geomorphological mapping and develop a digital atlas of geomorphological maps. Detailed geomorphological maps contain a wealth of information, but require extensive field mapping, and are very difficult to convert into digital format (Gustavson et al., 2006). Unfortunately, traditional geomorphological mapping seems to have nearly disappeared with the developments of digital techniques, and relatively few publications on hazard and risk still focus on it (Carton et al., 2005; Castellanos and Van Westen, 2007), or replace it by using morphometric information. An important new field within geomorphology is the quantitative analysis of the topography, called geomorphometry or digital terrain analysis, which combines elements of the earth sciences, engineering, mathematics, statistics and computer science (Pike, 2000; Drăguţ and Blaschke, 2006). Part of the work focuses on the segmentation of the topography into land-surface objects or geomorphological land units based on morphometric characteristics at multiple scales (Giles and Franklin, 1998; Miliaresis, 2001), and on the extraction of landform elements (Carrara et al., 1995). Digital geomorphological maps are available only for some parts of the world, for example for Germany (GMK, 2010), Austria (Geomorphology.at, 2010) and New Zealand (GNS, 2010).

Land cover can be considered as a static factor in some hazard studies, although most types of hazard assessments actually focus on the detection of land-cover changes in relation to hazard phenomena. Changes in land cover and land use resulting from human activities, such as deforestation, forest logging, road construction, fire, drought and cultivation on steep slopes can have an important impact on hazards. An example is the evaluation of the effect of logging and deforestation on landslides (e.g., Furbish and Rice, 1983). Land use maps are made on a routine basis from medium resolution satellite imagery such as LANDSAT, SPOT, ASTER, IRS1-D etc. Another source for land-cover data with higher temporal and lower spatial resolution are MODIS (Moderate Resolution Imaging Spectroradiometer) (Friedl et al. 2002), MERIS (Medium Resolution Imaging

MODIS low resolution satellite data are often considered together with the ASTER sensor, as the sensor is also NASA operated. There are actually MODIS sensors on two different satellites, acquiring data at moderate resolution in a remarkable 36 channels. The resolution is variable, with some bands at 250 m., some at 500, and others at 1,000 m. The coverage of MODIS is 2,230 km, thus very large regions can be monitored daily. The data are particularly suited for studies of which information on a regular basis is needed of the atmosphere, the land (MODIS TERRA) or the ocean (MODIS AQUA) . The data are free, but it is important to be careful in the product selection.

MODIS TERRA Natural color image - Caspian sea

As MODIS also contains image bands that record information in the infrared and thermal parts of the spectrum, it is very sensitive to strong thermal emission, such as originating from wild fires or magmatic activity at volcanoes.

MODIS AQUA Fires and smoke in Indonesia

More information on the sensor can be found on MODIS WEB: ***http://modis.gsfc.nasa.gov/***

Spectrometer), NOAA-AVHRR, Global Imager (GLI), and SPOT-Vegetation imagery with varying resolutions (250 m - 1 km) which are used on a routine basis for monitoring the global distribution of land-cover types (e.g. 10-day basis) (Cihlar, 2000). Algorithms for bi-temporal change detection (between two images) and temporal-trajectory analysis (between a whole series of images covering a certain period) for land-cover change detection are reviewed by Coppin et al. (2004). Seasonal and inter-annual variations in land cover that may be caused by natural disasters, and land-use changes can be detected using high temporal frequency satellite data.

Several initiatives have produced global land-cover maps for different time periods. For example, the CORINE Land Cover 2000 dataset (CLC2000) has been produced using remotely sensed imagery to produce a land-cover database at a scale of 1:100,000, a positional accuracy of 150m and a minimum mapping unit of 25ha in Europe and a resolution of 1 km globally. A more recent map is the ESA Globcover global land-cover map based on MERIS fine resolution (300 m) mode data acquired between mid 2005 and mid 2006 (Arino et al., 2007). For individual continents, more detailed land-cover information is available (e.g., the Africover (2010) database for Africa).

Hazard and risk assessments require a multitude of data from different sources. Therefore, it is important to have a strategy for data availability.

Important information concerns include data quality, metadata and multi-user databases. Many project-specific data sets can be used for various purposes (e.g., for resource management was well as risk assessment). This requires that the potential users know what data exist, and have ready access to them. Spatial-risk information requires the use of a Spatial Data Infrastructure, where through the internet, basic GIS data can be shared among different technical and scientific organizations involved in hazard and risk assessment. A spatial data infrastructure is the foundation or basic framework (e.g., a system or organizational scheme) with policies, resources and structures to make spatial information available to decision makers when they need it, where they need it, and in a form where they can use it (almost) immediately. The website where the data is actually exchanged is called a clearinghouse. A good example of that is the European ORCHESTRA project (ORCHESTRA, 2009), which designed and implemented the specifications for a service oriented spatial data infrastructure for improved interoperability among risk management authorities in Europe. In the framework of the CAPRA project of the World Bank (CAPRA, 2009), the GeoNode was developed as an open-source platform that facilitates the creation, sharing and collaborative use of geospatial data for risk assessment (GeoNode, 2010). Examples of initiatives that focus on spatial-data infrastructure for disaster relief are Reliefweb (2010), Alernet (2010), HEWSweb (2010), and GDACS (2010).

3.HAZARD ASSESSMENT

Figure 3.1 presents a schematic overview of a set of natural hazards and their cause-effect relationships. The upper row in the figure consists of the triggering events, which are the endogenic or exogenic events that precipitate other events. They may cause direct effects, such as ground shaking resulting from an earthquake (Jimenez et al., 2000), drought caused by deficiency in precipitation (Karnieli and Dall'Olmo, 2003), pyroclastic flows and ash fall following a volcanic eruption (Zuccaro et al., 2008), or wind speeds caused by tropical cyclones (Holland, 1980; Emanuel et al., 2006). The direct effects may trigger indirect effect, or secondary hazards, such as landslides caused by ground shaking in mountainous areas (Jibson et al., 1998), landslides and floods occurring in recently burned areas (Cannon et al., 2008) or tsunamis caused by earthquake-induced surface displacement in the sea (Priest et al., 2001; Ioualalen et al., 2007). Secondary hazards that are caused by other hazards are also referred to as concatenated hazards or cascading hazards. Figure 6 aims to depict the interrelationships between the triggering factors, the primary hazards and secondary hazards.

There are relatively few examples in literature on such complete multi-hazard assessments, and mos

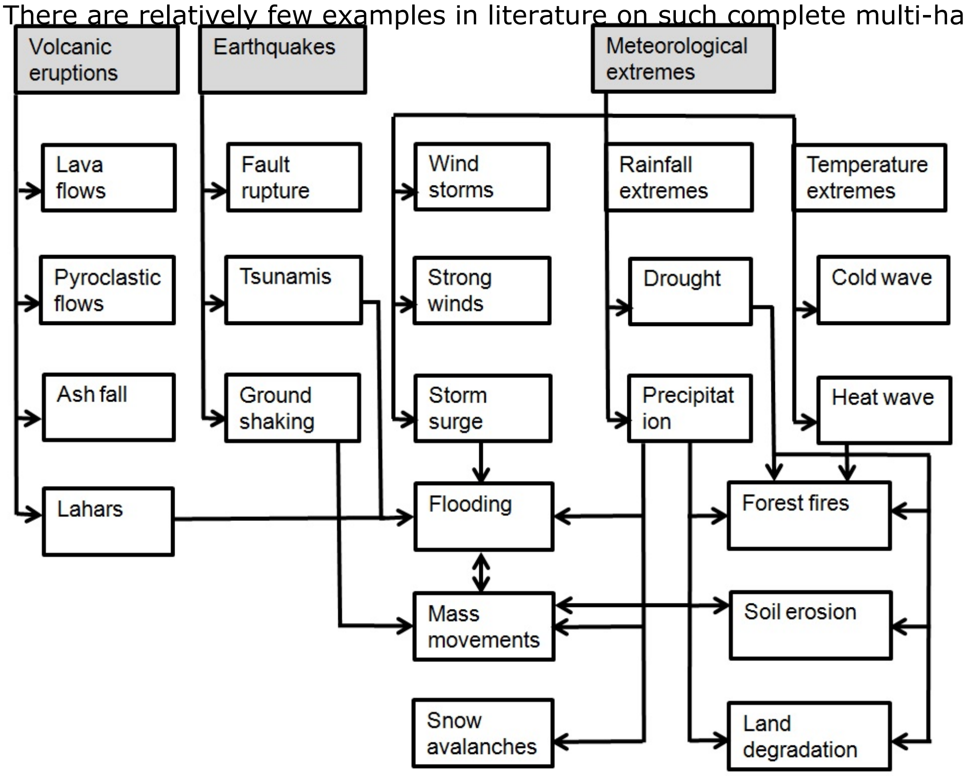


Figure 3.1: Examples of multi-hazards and their interactions required for multi-hazard risk assessment. Partly based on CAPRA (2009).

These relationships can be very complex, for instance the occurrence of floods as a result of the breaking of earthquake-induced landslide dams (Korup, 2002). Given this complexity a multi-hazard assessment, which forms the basis for subsequent risk assessment, should always lead to some sort of simplification in terms of the cause-effect relationships.

3.1 SCALE AND HAZARD ASSESSMENT

Hazard assessment using GIS can be carried out at different geographical scales. Although it is possible to use a range of spatial resolutions of the input data for GIS analysis (computational scale), in practice the geographic scale determines the size of the study area that is analyzed. This in turn restricts the scale of the input data and the resolution of the data used in the computations. The geographical scale also determines the scale of representation of the end products (cartographic scale). There are a number of factors that play a role in deciding what scale of hazard and risk assessment should be selected (Fell et al., 2008, Van Westen et al., 2008). These are related first of all to the aim of the hazard assessment, the type of hazard, and the operational scale at which these hazard processes are triggered and manifest themselves. They also relate to the size and characteristics of the study area, the available data and resources, and the required accuracy. Table 3 provides an overview of scales and levels for different hazard types.

Hazard assessments that are carried out for the entire earth (global scale) are focusing on global problems, such as climate change, or are aimed at displaying the distributions of a particular hazard worldwide (e.g. land degradation). Risk assessment at this scale is mainly intended to generate risk indices for individual countries, to link them to indices related to socio-economic development, and to make prioritizations for support by international organisations, such as the World Bank, ADB, WHO, UNDP, FAO etc. (Cardona, 2005; Peduzzi et al., 2009). The input data have a scale less than 1:10 million, and spatial resolutions on the order of 1-5 km. Under the umbrella of the ProVention Consortium staff from the Hazard Management Unit of the World Bank, the Development Economics Research Group (DECRG) and the Columbia University carried out a global-scale multihazard risk analysis which focused on identifying key "hotspots" where the risks of natural disasters are particularly high (Dilley et al., 2005). The project resulted in a series of global hazard and risk maps which can be downloaded from the CIESIN website (CIESIN, 2005).

Table 3.1: Scales/levels for hazard assessment, with indication of basic mapping units and the optimal scale for displaying different types of hazards (EQ= Earthquakes, VO= Volcanic hazards, DR= Drought, WS= Windstorms, FL= Floods, CO= Coastal, LS = Landslides, WF = Wildfire). Indicated is the applicability: (••• = highly applicable, •• = moderately applicable, and •= Less applicable).

Scale	Level	Cartogrpahic scale (million)	Spatial resolution	Area covered (km^2)	EQ	VO	DR	WS	FL	CO	LS	WF
Global	Global	< 1:5	1-5 km	148 million	•	•	••	••	•	•	•	•
Very small	Continental / large countries	1 – 5	1	5-20 million	••	•	•••	•••	••	••	•	•
Small	National	0.1 – 1	0.1-1 km	30– 600 thousand	•••	•	•••	•••	•••	•••	•	••
Regional	Provincial	0.05 – 0.1	100 m	1000 - 10000	•••	••	••	•••	•••	•••	••	•••
Medium	Municipal	0.025 – 0.05	10 m	100	••	•••	••	••	•••	••	•••	••
Large	Community	> 0.025	1-5 m	10	••	•••	•	•	•••	•	•••	•

For individual continents or regions covering several countries, hazard applications are either focused on analysing the triggering mechanism(s) of hazards that cover vast areas of various millions of km^2, such as tropical cyclones, earthquakes or drought. They are also used for analysing hazards that cross national boundaries (e.g., flood hazard in large catchments like the Rhine, Ganges etc.), or that are related to natural hazard reduction policies at international level (e.g., for the entire European Union). The hazard maps are generated using standardized methodologies, and are aimed both at risk assessment, early warning (De Roo et al., 2007) and post-disaster damage assessment. The areas that are evaluated vary in size, as some countries like China, India or the USA are as large as continents like Europe, under one administrative setup. The scale of the input maps can range between 1:100.000 and 1:5 million, and spatial resolutions may vary from 90 meters to 1 km, depending on the application.

Hazard and risk assessment at the national scale covers areas ranging from tens to several hundred thousand km^2, depending on the size of the country. Hazard assessment is carried out at a national scale for national planning purposes, implementation of national disaster-risk reduction policies, early-warning systems, disaster preparedness and insurance. The applications in planning become more concrete when zooming in on larger scales such as the provincial level. For instance, hazard and risk assessment become an integral component of regional development plans and Environmental Impact Assessments for infrastructure developments. At municipal level, hazard and risk assessment are carried out as a basis for land-use zoning, and for the design of non-structural risk-reduction measures. At a community level, hazard and risk assessment are carried out in participation with local communities and local authorities, as a means to obtain commitment for disaster-risk reduction programmes.

3.2 GLOBAL HAZARD ASSESSMENT

As indicated in Table 3, hazard assessment is carried out at various scales, and the methods for hazard assessment are determined by the type of hazard and by the availability of input data (See table 4). This section will discuss the main approaches for hazard assessment used at the various geographic scales indicated in Table 3.

It is evident from Table 3 that there are hazardous events that encompass large areas such as windstorms, drought, earthquakes, and tsunamis. Therefore, the hazard assessments must utilize a global or international mapping scale. For instance, the Global Seismic Hazard Mapping Project (GSHAP, 1999), a demonstration project of the UN/International Decade of Natural Disaster Reduction, was conducted in the 1992-1998 period with the goal of improving global standards in seismic-hazard assessment. The GSHAP produced regional seismic-hazard maps for most parts of the world, that display the global seismic hazard as peak ground acceleration (PGA) with a 10% chance of exceedance in 50 years, corresponding to a return period of 475 years. The procedure involved the identification of seismo-tectonic zones in which earthquake characteristics were analyzed from historic earthquake databases. For each point, seismic hazard is then analyzed using modules, such as SEISRISK (Arnold, 1989).

For windstorms international databases exist for tropical cyclones, in different parts of the world. For the North Atlantic region for example, the HURDAT database (Jarvinen et al., 1984) contains all historic Hurricane tracks. Windstorm-hazard models generate a set of stochastic events based on historical and modelled windstorm tracks, with parameters on intensity, size and shape. For each simulated track, data is calculated for wind velocity together with associated levels of storm surge, and rainfall intensities using empirical relations (Mouton and Nordbeck, 2003). Areas that may inundate due to tidal changes are mapped using a DEM in coastal zones (Lavelle et al., 2003). Drought-hazard assessment at an international level is carried out using monthly average precipitation data (e.g., the Weighted Anomaly of Standardized Precipitation (WASP) developed by the International Research Institute for Climate and Society (IRI), computed on a 2.5° x 2.5° grid (Lyon and Barnston, 2005)).

For other hazards, such as floods and landslides, information at international levels is too general for the estimation of hazards, as the hazard events are too localized, and require more detailed information. Nadim et al. (2006, 2009) made an attempt to generate a global landslide-hazard map, making use of general spatial data sets with global coverage, such as an SRTM-derived DEM with 1 km spatial resolution, the geological map of the world at 1:25 million scale, a soil-moisture index, monthly precipitation data, and the Global Seismic Hazard Mapping Programme (GSHAP) results. Given the poor resolution of the data as compared to the specific conditions in which landslides occur, however, the results are only a general indication of landslide susceptibility. Hong et al. (2007a) present a qualitative method for a global landslide-susceptibility map using GIS-based map overlay techniques, combining several layers of different parameters (e.g., elevation, slope, land use, etc.). Recently, an attempt to provide global scale landslide early warnings in near real time using stochastic models combining a global landslide database, TMPA rainfall estimates, SRTM DEM and MODIS land-cover products was conducted at Columbia University, the success of which was mainly limited by the lack of completeness of the landslide database and the quality of the rainfall estimates from TRMM (Tropical Rainfall Measuring Mission) Multi-satellite Precipitation Analysis (TMPA) (Kirschbaum et al., 2009). Global flood-hazard studies are difficult to carry out, as the DEMs available at global scale are generally not of sufficient detail for flood modelling applications. One example of an approach used for flood-hazard mapping over very large areas is based on an inventory of past flood events (e.g., from Dartmouth Flood Observatory), coupled with a very simple flood model based on the HYDRO1k Elevation Derivative Database (USGS, 1996; Verdin and Greenlee, 1996). HYDRO1k is a geographic database developed to provide comprehensive and consistent global coverage of topographically-derived data sets, including streams, drainage basins and ancillary layers derived from the USGS 30 arc-second DEM of the world.

At the global scale, few approaches have been carried out for multi-hazard assessment, which aims at providing general indicators or risk indices for countries, or for parts of countries, mainly for comparison of risk levels between countries. Dilley et al. (2005) have developed a methodology for global hazard and risk assessment for the main hazard types of hazards in Table 3. Peduzzi et al. (2009) present a model designed for the United Nations Development Programme as a component of the Disaster Risk Index (DRI), which aims at monitoring the evolution of risk. Four hazards (droughts, floods, cyclones and earthquakes) were modelled using GIS based on the datasets shown in Table 5.

Examples of International hazard and risk initiatives.

World Bank Hot Spots project

In 2005 International Bank of Reconstruction, World Bank and Columbia University compiled the set of global disaster risk maps for several types of hazards called Natural Disaster Hotspot Map. (http://www.ldeo.colimbia.edu/chrr/research/hotspots/).

Comments on the applicability of the HotSpots method for the southern Caucasus
It seems that there are serious problems related to correctness of assessments of Hotspot Maps in Caucasian region. According to the Hotspot Map, the Southern Caucasus is prone only to hydro-meteorological hazards when the northern Caucasus in subject to Geophysical and Hydro-hazards. Geophysical hazards include earthquakes, volcanoes and landslides. If it can be accepted that the hydro-hazards for the both regions are the same, the relative assessment of geophysical hazards, namely earthquakes and landslide risk for these two parts of Caucasus is wrong. The landslide risk for the both parts of Caucasus is approximately the same and the seismic activity of Southern Caucasus is larger than in the North. The infrastructure exposure, population density and vulnerability in Southern Caucasus are larder or at least equal to that in the North, so the difference cannot be prescribed to this component of risk. The sources of Hotspot Map assessments were GSHAP maps for Peak Ground Acceleration (PGA) and database of EQ of M>4.5 occurred in 1976-2002 from the Advanced National System Earthquake Catalog (USA). It is easy to see that GSHAP map gives for the PGA in the North mainly in the range 0.2-0.3 g and for the South – in the range 0.2-0.4 g. The number of EQ of M>4.5 is three times larger in Southern compared to Northern Caucasus. Besides, recurrence times of M>4.5 EQ-s in the North and South is approximately the same. By the way, the Hotspot Map contradicts also the version of World Disaster Map, compiled by Munich Re Group (http://www.munichre), where the seismic hazard of Northern Caucasus is much less than in the Southern part of the Caucasus. The mortality assessment is entirely wrong: only the Spitak EQ (1988) victims number (25 000) exceeds may times the human losses of all other kinds of disasters in the North Caucasus for centuries. The EQ in Georgia (Racha, 1991) was the strongest in Caucasus and causes 6 bn $ in losses and around 200 victims.
Thus we conclude that during compilation of the Hotspot map the input data were not analyzed correctly and the map needs serious revision in Caucasus region. Namely, both North and South Caucasus should be considered as prone to Geophysical and Hydro-disasters. Unfortunately, the Hotspot map still is used without corrections. For example, at present the map is placed on the home page of GRIP and is included in many other publications. The errors in the Hotspot map on mortality rate can be revealed not only for Caucasus: the disastrous Ashgabat EQ (Turkmenistan) with 100 000 victims as well as Shemakha EQ in Azerbaijan with 80 000 victims are not taken into account
(comments From T. Chelidze, M.Nodia Institute of Geophysics. Georgia, 2009).

Global Risk Data platform

Figure 3.2: Global Risk Data Platform, PREVIEW (UNEP/DEWA/GRID, 2010).

3.3 (INTER)NATIONAL HAZARD ASSESSMENT

Hazard assessment is often carried out for individual continents or countries, as they are related to the same administrative area, and controlled by national or international governments (e.g. EU, USA, China). The methodology for hazard and risk assessment is standardized and mostly follows established guidelines that are requested by governments (e.g., the European Floods Directive). The applications at (inter)national level are more refined than those carried out globally, and require higher-resolution data. For example, the European Flood Directive (EFD) indicated that preliminary flood-risk assessments in Europe should be completed by 2011, flood hazard and risk maps should be available by 2013, and flood-management plans should be completed by 2015 (EFD, 2007). In order to accomplish these goals, standardized methods, datasets and GIS-based tools are used for the assessment and monitoring of flood risk for the whole of Europe. Flood-hazard maps are generated based on DEMs with a resolution ranging between 100 m and 1 km. The hazard factor is estimated by using hydrological modeling (e.g., LISFLOOD) at different scales and for many return periods (Barredo, 2007; van der Knijff et al., 2010). Modelling of extreme precipitation and resulting river discharge is calculated in real time, and flood forecasts are made for the whole of Europe. In the USA, the Federal Emergency Management Agency (FEMA) has established a national flood-hazard mapping project with the Federal Insurance and Mitigation Administration's Hazard Mapping Division, through their national Flood Insurance Program (FEMA, 2010).

Similar initiatives in Europe are in the field of forest fires. The European Forest Fire Information System (EFFIS) makes a rapid assessment of the burned areas through a series of daily images from the MODIS instruments on board of TERRA and AQUA satellites, and displays fires with burned area of approximately 40 ha or larger from a web-GIS (Ayanza et al., 2003). A third example that is implemented at both the European level as well as globally is the MARSOP-3 project on Crop Yield Forecasting, carried out by the Joint Research Centre (JRC) of the EC, with other partners. This system includes the management of a meteorological database, an agro-meteorological model and database, low-resolution satellite information, statistical analyses of data and crop-yield forecasting and publishing of bulletins containing analysis, forecasts and thematic maps on crop-yield expectations using a Web-GIS application (Reidsma et al., 2009). An overview on the use of satellite data for drought monitoring and hazard assessment can be found in Henricksen and Durkin (1986), Peters et al. (2002) and White and Walcott (2009). The aforementioned software tools are used for early warning as well as for hazard assessment for the whole of Europe.

In the USA a GIS-based tool for earthquake hazard assessment, ShakeMaps, was developed by the USGS in cooperation with regional seismic-network operators. ShakeMaps provides near-real-time maps of ground motion and shaking intensity after important earthquakes. It can also be used to generate hazard maps using scenario earthquakes (Wald et al., 1999). Later a methodology was developed for modelling of seismic site conditions using topographic slope as a proxy, using the SRTM30 database, which provided the average shear-velocity down to 30 m. (Wald et al., 2004). Initiatives to incorporate open-source software in seismic-hazard assessment have been taken by OpenSHA (2010) and by the Global Earthquake Model (GEM, 2010), an international initiative to develop uniform and open standards and platforms for calculating earthquake risk worldwide. The GEM brings together all major players in the earthquake risk assessment field, including partners from the insurance sector, international organisations, public organisations and research centres from all over the world.

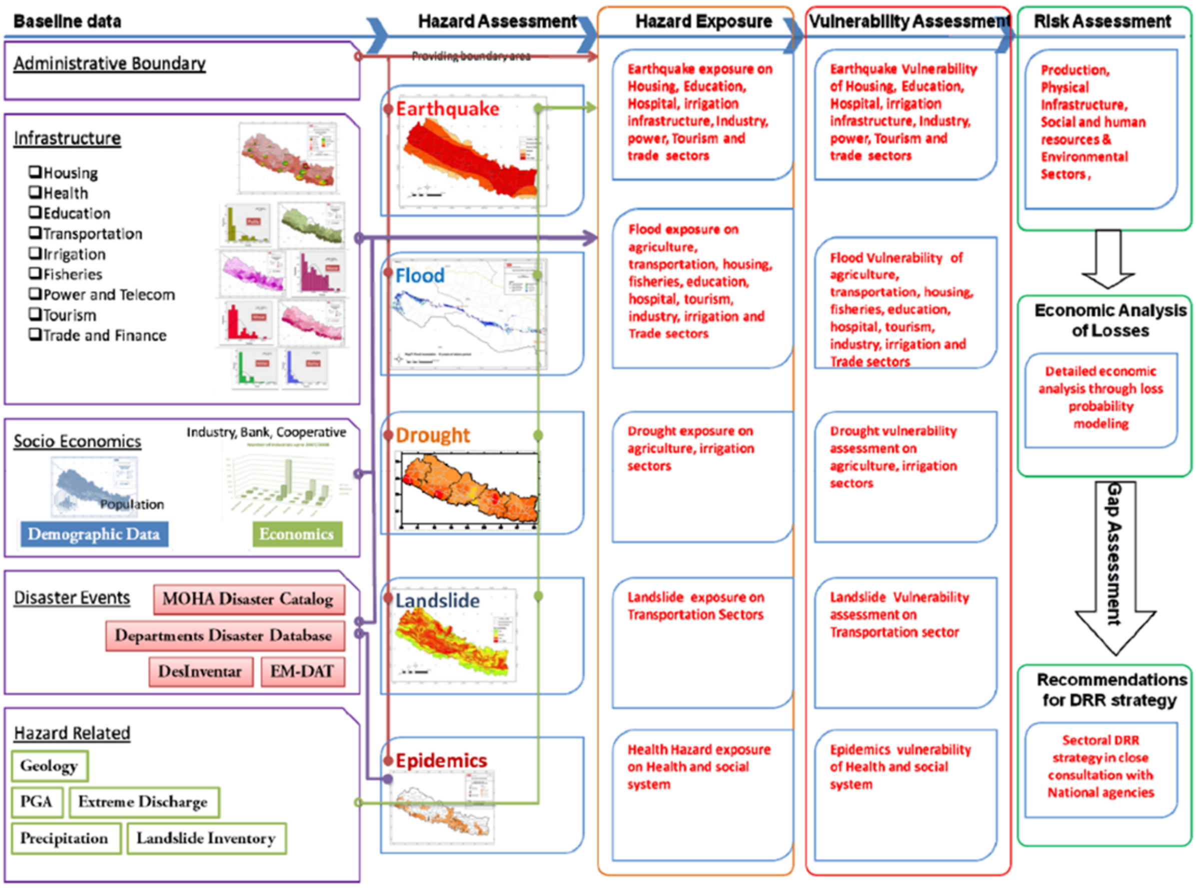
In terms of landslide-hazard assessment, this scale is still too general to be able to map individual landslide phenomena. The analysis of landslide hazards at this scale is still done by weighting a number of input maps (e.g., Malet et al., 2009; Castellanos and Van Westen, 2007).

3.4 EXAMPLES OF NATIONAL SCALE HAZARD ASSESSMENTS

In this section we present a number of examples of national scale hazard and risk assessment approaches for different countries, with a focus on countries that have generally a limitation in terms of available data. The examples are also accompanied by actual risk atlases which can be consulted in the classroom exercises.

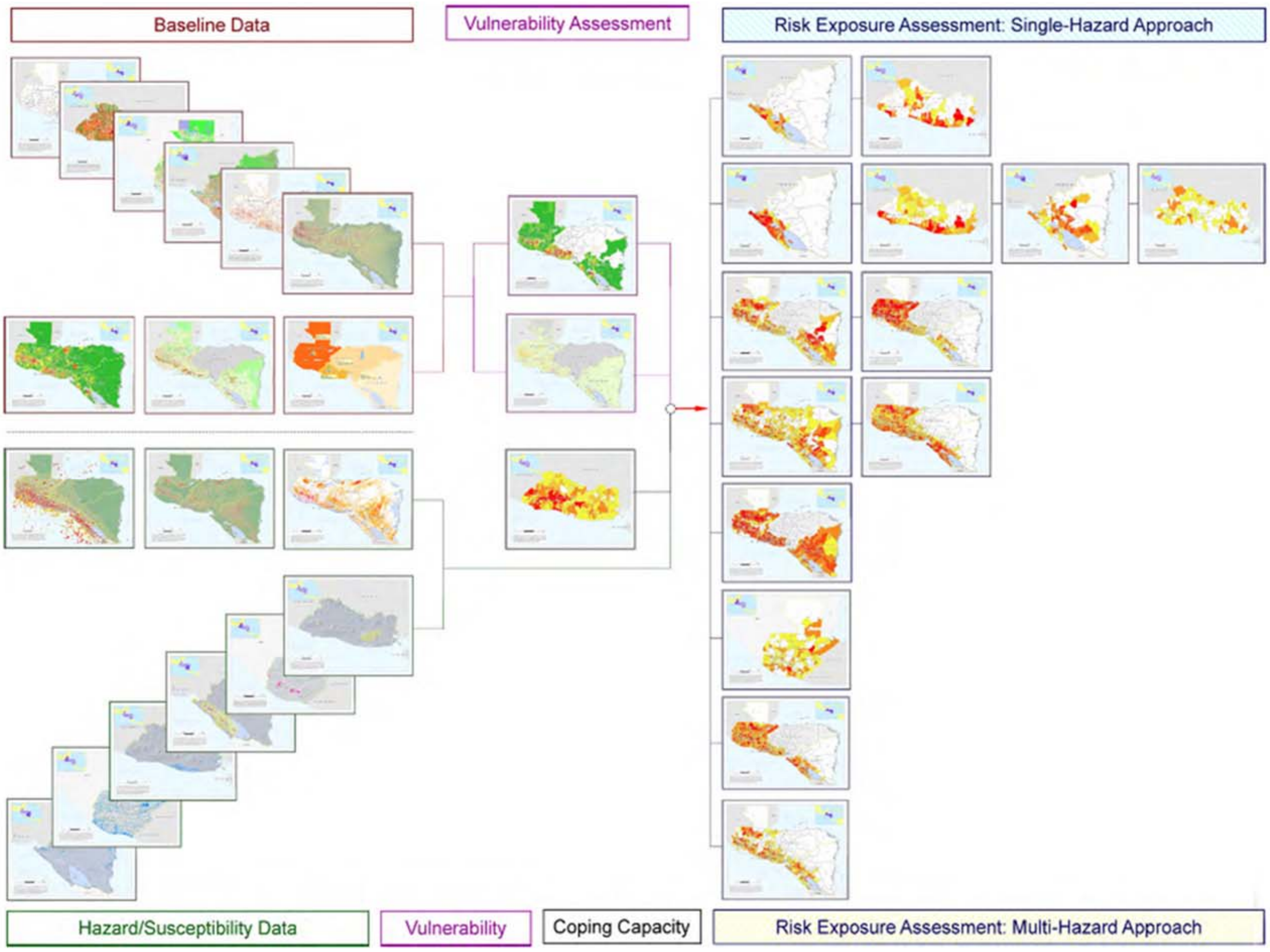
3.4.1 Nepal

The Asian Disaster Preparedness Center (ADPC), in association with Center for International Studies and Cooperation (CECI), Nepal and Norwegian Geotechnical Institute (NGI) carried out a multi-hazard risk assessment for Nepal. The study covered five hazard types (earthquakes, Floods, Drought, Landslides and Epidemics). The methodology is primarily includes collection of baseline data, hazard and susceptibility assessment and mapping, Exposure and vulnerability assessment, economic risk assessment with various national sectors. The end result of hazard and risk assessment will form the genesis for national level disaster risk mitigation strategy.

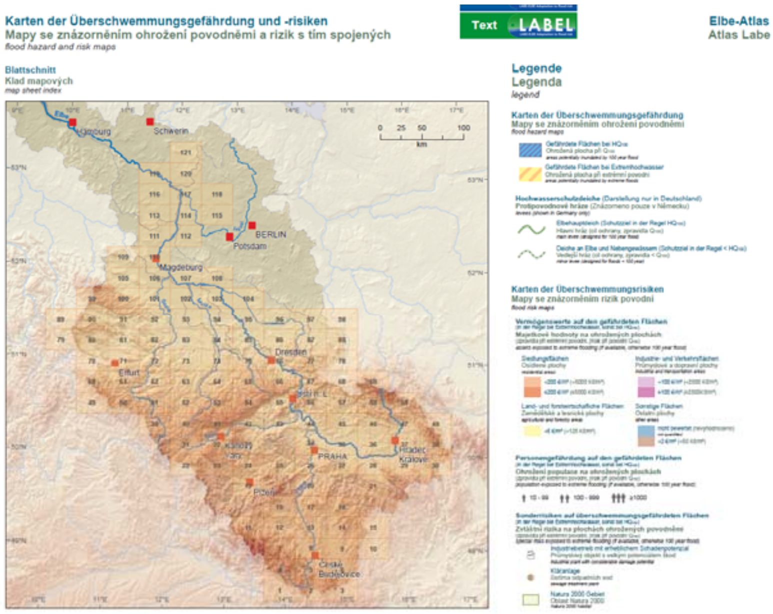


3.4.2 Central America

To mitigate the impact of natural disasters in Central America caused by geological and associated hydro-meteorological events like hurricanes both a national and a supra-regional risk analysis and a corresponding mapping are imperative. The risk analysis comprises integrating knowledge of topographic and demographic conditions, infrastructure, economic and social aspects, such as the availability of healthcare facilities. The incorporation of this information results in the assessment of risk exposure whose findings can be implemented in spatial development planning processes afterwards.

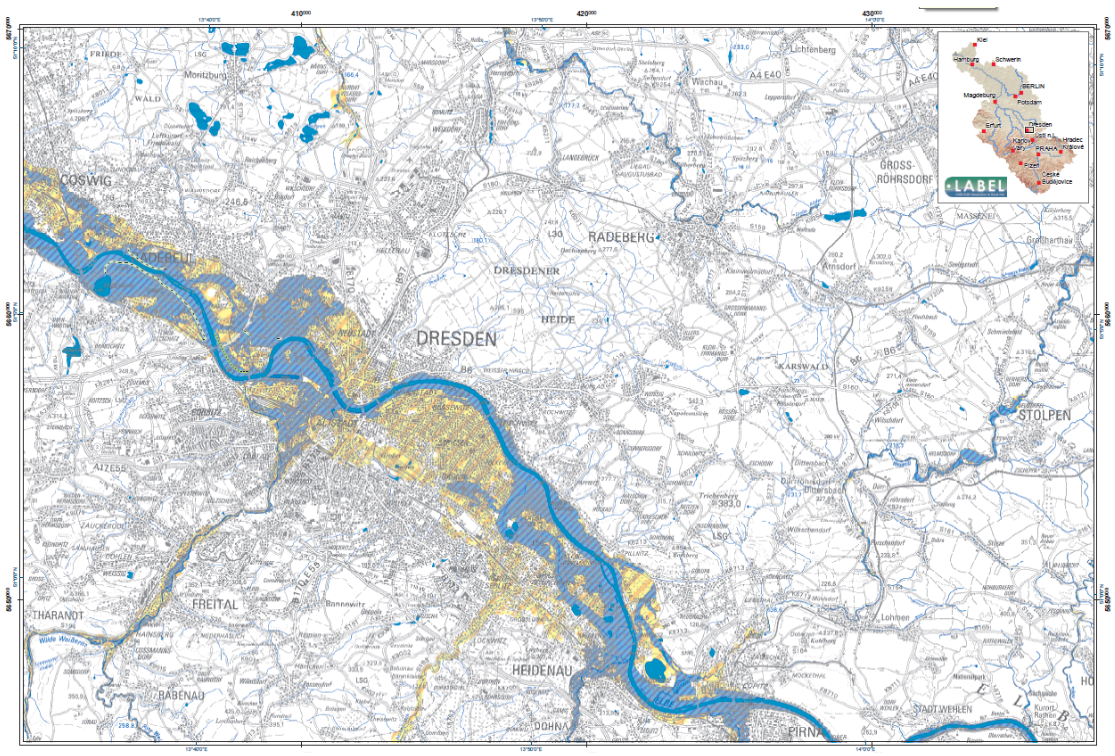


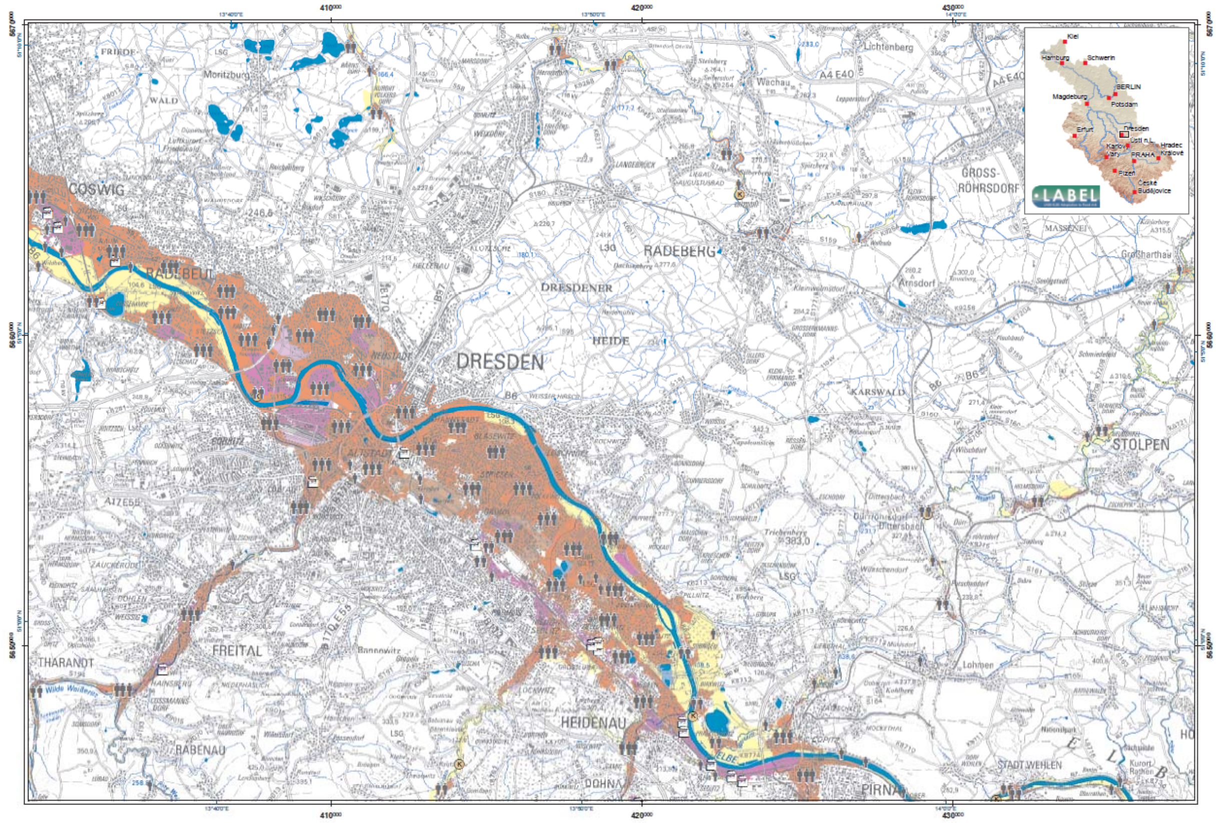
3.4.3 Elbe Flood atlas



With a course of around 1090 kilometres, the Elbe is one of the longest rivers in Europe. Several important cities have become established along the Elbe. And the history of these cities has been greatly influenced by the river and its valley.

With the floods in August 2002 following heavy rain, the public has become increasingly aware of the potential risks posed by the Elbe and its tributaries. Thousands of people suffered greatly during this period, and damage costs for the floods ran into billions. It is therefore crucial to sustainably reduce or even prevent flood damages in the future. Alongside structural flood protection (for example with dikes), particular importance must be placed on land use management here by keeping potential flood areas clear and employing more extensive flood management. The latter predominantly affects the individual, who can help prevent damage with careful construction and risk management. In land use management, local planning authorities must perform special assessments of flood risks for future land developments.





The Elbe Atlas provides an overview and uses small scale basic data (map scale 1:100,000). To highlight the potential risks that exist, even behind protective measures, observations have been made without considering the effect of existing flood control systems. The new edition of the Elbe Atlas also fulfils important points of the EC Directive on the Assessment and Management of Flood Risks.

A total of 121 map sheets cover the catchment area of the Elbe from its source to the end of the area covered. They show, where calculated, the extent of the 100-year flood event (HQ100). In addition to the HQ100 the area of an extreme event (EHQ) with a recurrence interval of 300 years (HQ300) or 1.5xHQ100 is depicted. To take into account the risk of dikes failing even before the designated water level has been reached, all flood areas were determined without considering the effect of existing flood protection measures. Moreover, it should not be assumed that all areas will be affected at the same time by the form of flooding depicted. For each section of the Elbe the estimated maximum extent of the particular event is shown.

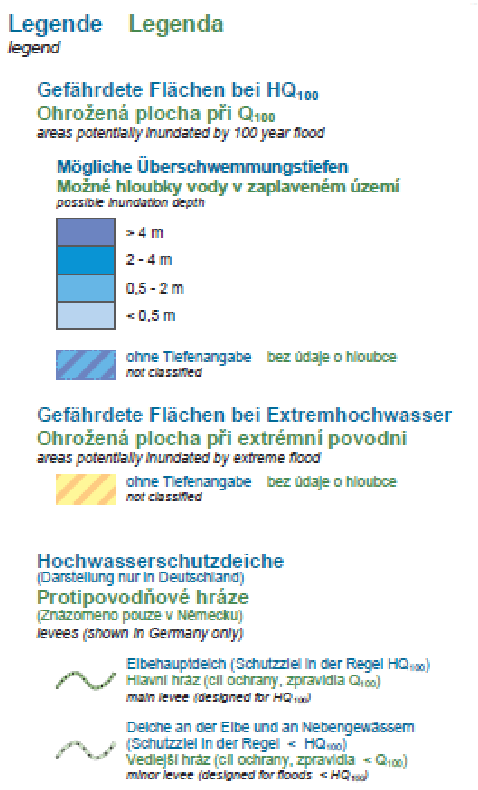
The EC Directive on the Assessment and Management of Flood Risks requires the creation of flood risk maps in areas with a potentially significant flood risk. These maps are developed and provided by the national state offices. The risk maps in the Elbe Atlas complement the flood maps by displaying the assets at risk from flood for the whole of the area covered. Also depicted is the number of inhabitants affected in the flood area. When calculating the assets, it was important that a standardised method was used across all countries and states. The calculated estimate of the assets was performed across the whole area based on the approach of the BEAM data product. BEAM stands for “Basic European Assets Maps” and was developed under the EU GMES Project “SAFER (Services and Applications for Emergency Response)”.

The basic spatial information originates from the CLC (Corine Land Cover) project, which is enriched with NAVTEQ data on the residential and transportation areas in order to achieve a better resolution for these uses. The basic socioeconomic information is based on the figures of the European statistics authority, Eurostat. The assets are visualised according to the following four use classes:

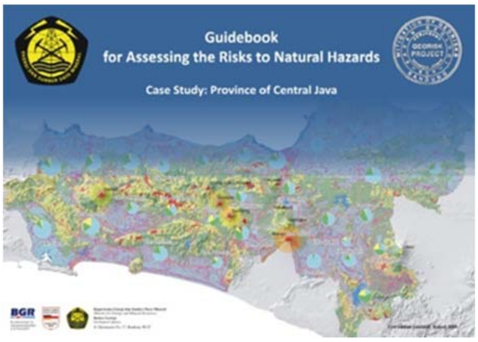
- Residential areas
- Industrial and transportation areas
- Agricultural and forestry areas
- Other areas

For the first two use classes the assets are split into two value areas. For residential areas, the limit stands at 200 €/m² for industrial and transportation areas it is 100 €/m². For agricultural and forestry areas, the value of 5 €/m² is not exceeded. The other areas can be divided into areas of neutral value or non-quantified areas, and areas with a minimum value of 2 €/m² . The maps also show the exposed population in the residential areas. The depiction is based on the proportional assignment to areas of the statistic inhabitant values for contiguous residential areas. Three size classes are used for the depiction. The smallest class begins at 10 inhabitants to allow for statistical imprecision.

The assets and the exposed population are portrayed and evaluated using the spread of the extreme event (EHQ). Where this area was not available, the HQ100 was used. As such, seemingly implausible results may occur in the table in the upper reaches and in the catchment area of the Elbe in Thuringia.

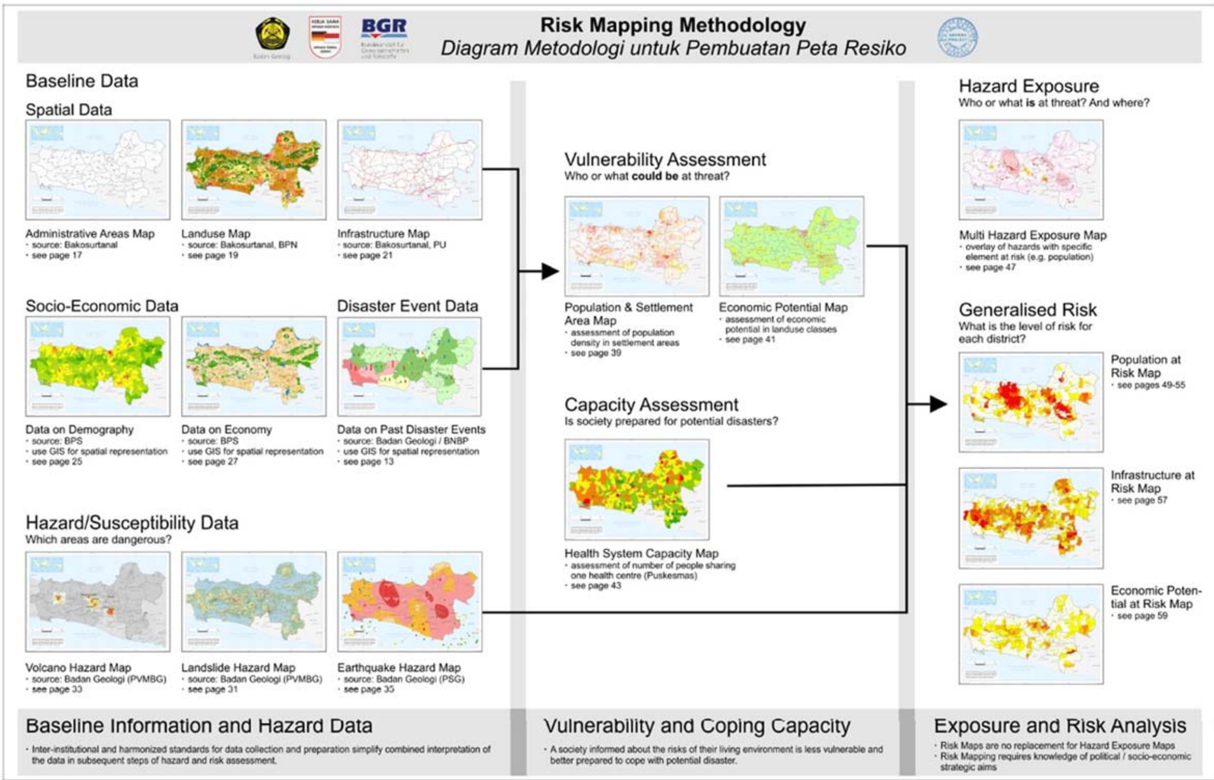


3.4.4 Java, Indonesia



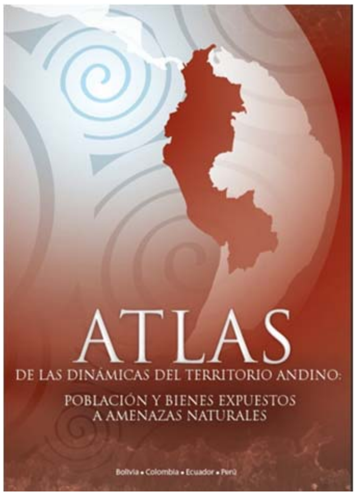
This is an example of a semi-quantuitative risk assessment which was done for the island of Java in Indonesia. Focusing on geological risks, as they are resulting from volcanic eruptions, landslides or earthquakes, the Geological Agency of Indonesia (Badan Geologi) and the German Federal Institute for Geosciences and Natural Resources (BGR) set up a project to elaborate and test practical georisk analysis processes, primarily based on existing hazard and vulnerability data.

A multitude of possibilities exist, to bring together basic data, hazard data (H), vulnerability (V) and capacity (C) information in order to produce a statement regarding the risk (R) that the population, the society or its economy is exposed to. Approaches of various levels of complexity exist. In one way or the other they focus on the often cited equation R = (H*V)/C. All of these approaches have one thing in common: assessing the risk is a subjective venture that will always need someone to decide, what level of risk a society is willing to accept. And to answer this question, one needs to clarify beforehand the (development) goals that this society pursues. In this respect, risk assessment involves socio-economic and political perspectives and input and cannot be tackled by purely technical standard operation procedures.

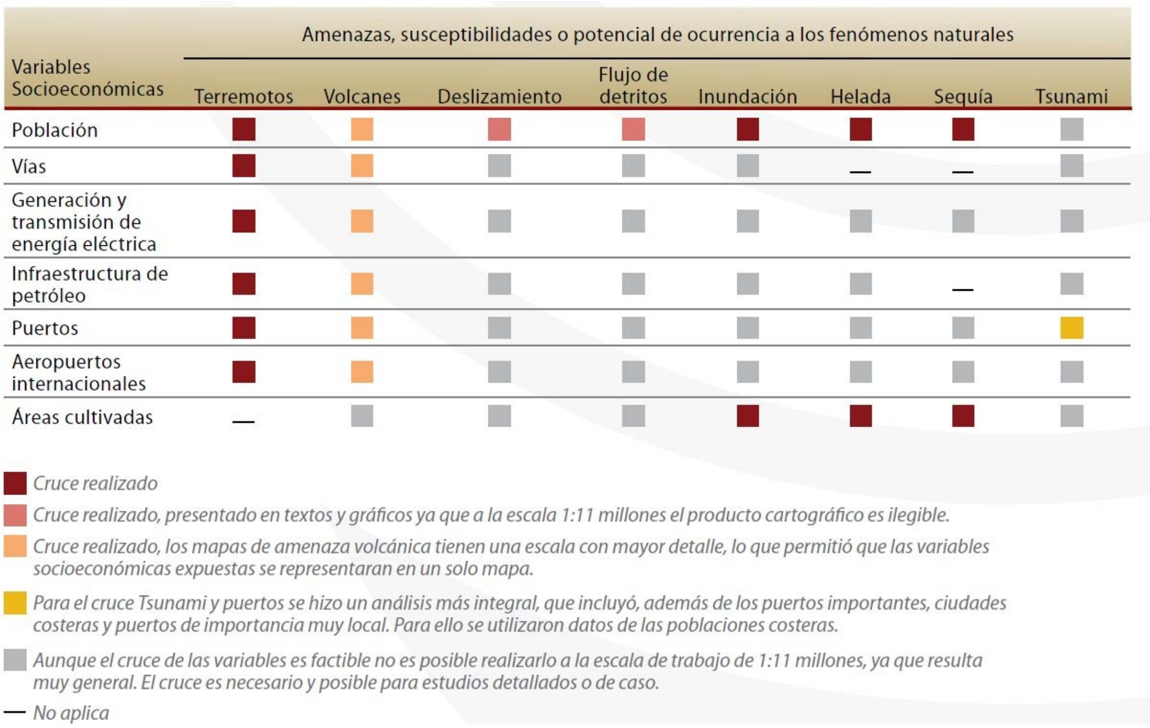


3.4.5 Andean Region

An example of risk analysis at the regional international level is the multi-hazard risk atlas for the Andean region (Communidad Andina, 2009), that is available in paper atlas and Web-based versions. This atlas provides a comprehensive overview of the elements-at-risk in the region (population, production, and infrastructure), the hazard phenomena (earthquakes, tsunami, volcanic eruptions, landslides, flooding, cold waves and drought) and the risks in a very well designed manner. The method which is used is qualitative and each of the hazards is indicated in a standardized manner. The method also calculates exposure for the various elements at risk and the various hazards.



The Method can be consulted at:
http://www.comunidadandina.org/predecan/atlasweb/index.html



3.5 EFFORTS DONE IN THE PPRD-EAST COUNTRIES

This section presents the results of an internet search for available hazard maps for the 6 PPRD-EAST countries that was carried out using the Google search Engine. It is important to note here that we only used search terms in English, and that searching with Russian search terms probably would have resulted in more information.

3.5.1 Ukraine

For Belarus very few hazard maps could be found through internet searches. This might also be due to the fact that the search was only done in English. The maps that were found were of very low detail (e.g. maps generated by WHO).

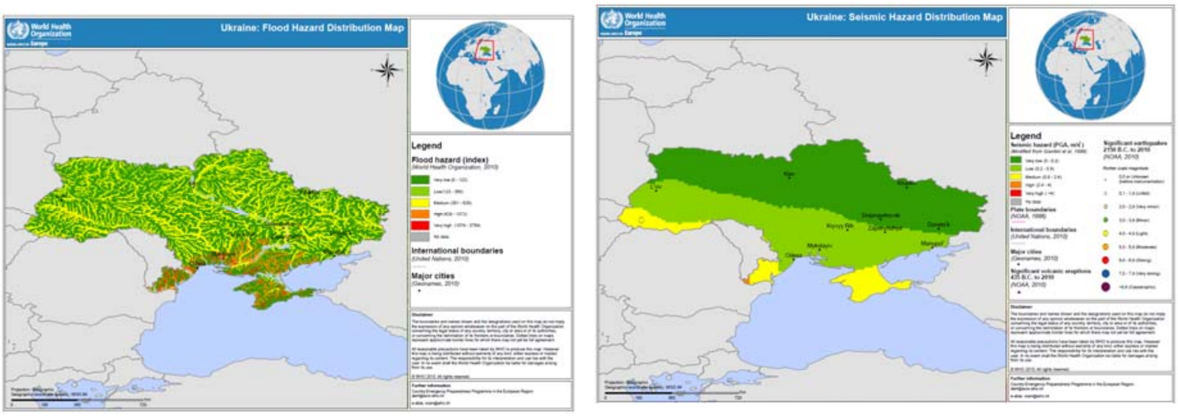


Figure: Examples of very general flood hazard map(left) and seismic hazard map (right) for Ukraine. Source: WHO

3.5.2 Belarus

For Belarus very few hazard maps could be found through internet searches. This might also be due to the fact that the search was only done in English. The maps that were found were of very low detail (e.g. maps generated by WHO).

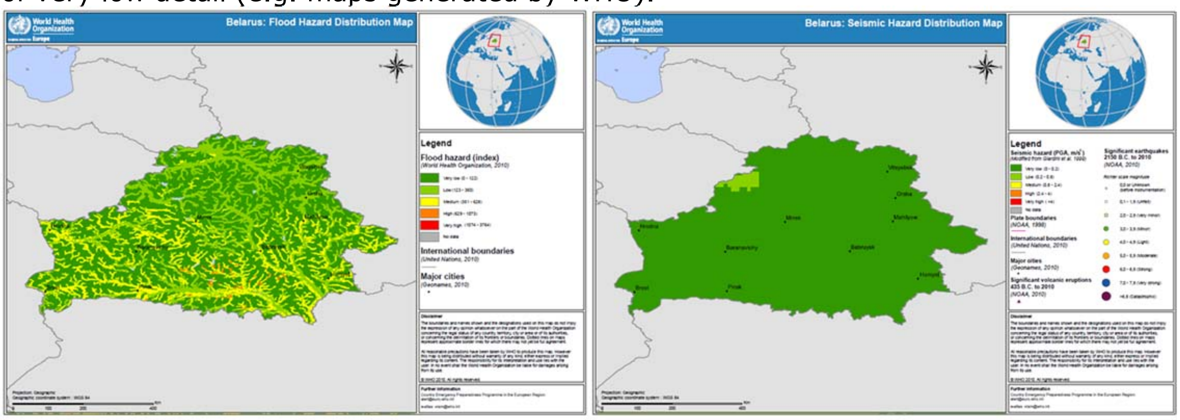


Figure: Examples of very general flood hazard map(left) and seismic hazard map (right) for Belarus. Source: WHO.

For the river Bug in Belarus a calibrated 1D hydrodynamic model was developed in the Central Research Institute for Complex Use of Water Resources (CRICUWR).

In this model the following data were input:

- hydrology data about maximum water levels for Novoselky hydrological stations (downstream Brest city);
- Existing cross sections coordinates: 49 cross section of the Bug river district from Wlodawa (Poland) to Novoselky (Belarus);
- Topographic map with scale 1:50000;
- Topographic data of floodplains, dikes and dike ring areas;
- Land use characteristics

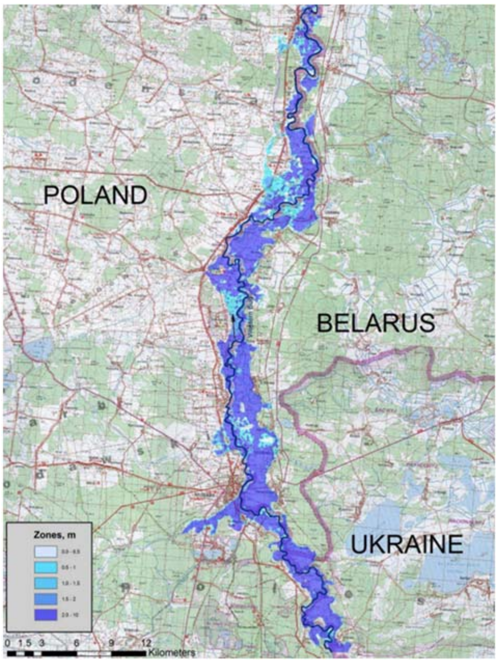


Figure: Flood Hazard Map of the Bug River Pilot District (10% probability). Source: Vladimir Korneev, Aliaksandr Pakhomau (Central Research Institute for Complex Use of Water Resources, Minsk, Belarus)

3.5.3 Moldova

Earthquake hazard assessment has been carried out by the Institute of Geology and Seismology Moldavian Academy of Sciences. Moldova has experience earthquake damage in 1940 (M=7.4), 1977 and 1986 (Vrancea earthquake). Earthquake source areas are in Romania. Also general earthquake risk assessment work has been carried out.

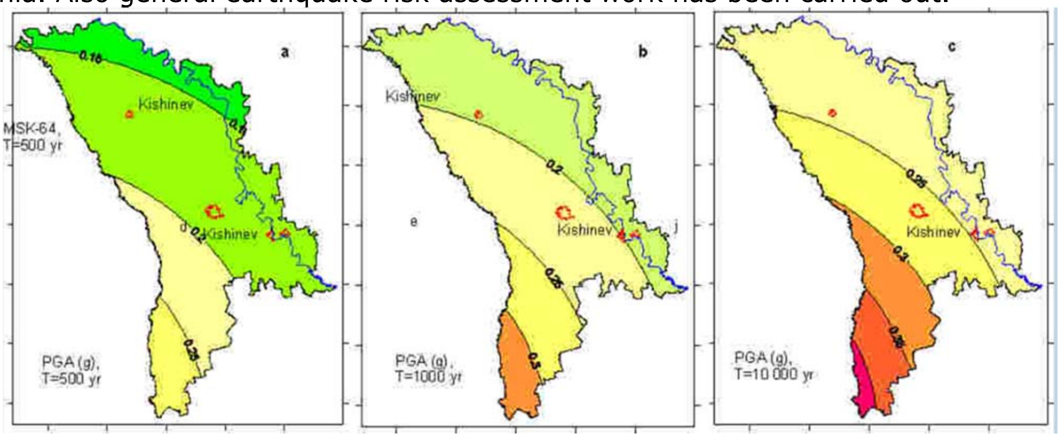


Figure: National scale earthquake hazard maps for Moldova. Earthquake hazard maps from subcrustal Vrancea zone for 500 (left), 1000 (middle) and 10000 (right) years return period. In: Vasile ALCAZ, Institute of Geology and Seismology Moldavian Academy of Sciences

A national program for flood protection was officially approved in 2000. It is a 26-year program (2000-2025) with a total cost of about US$80 million. The cost per hectare would be about US$1100. A alternative, costing 25% less, could provide basic protection from floods of annual exceedance probabilities greater than 1%. The cost per hectare would then be US$ 850. Due to lack of funding, progress with implementation of this program has been minimal. There are at the present more than 16,000 landslides with a total area of 83,000 hectares within he region. The area of active landslides (about 12,400 hectares) is developed within populated areas. Generally, 43,7% of settlements are endangered by landslides an d in the central area this value reaches 98% .

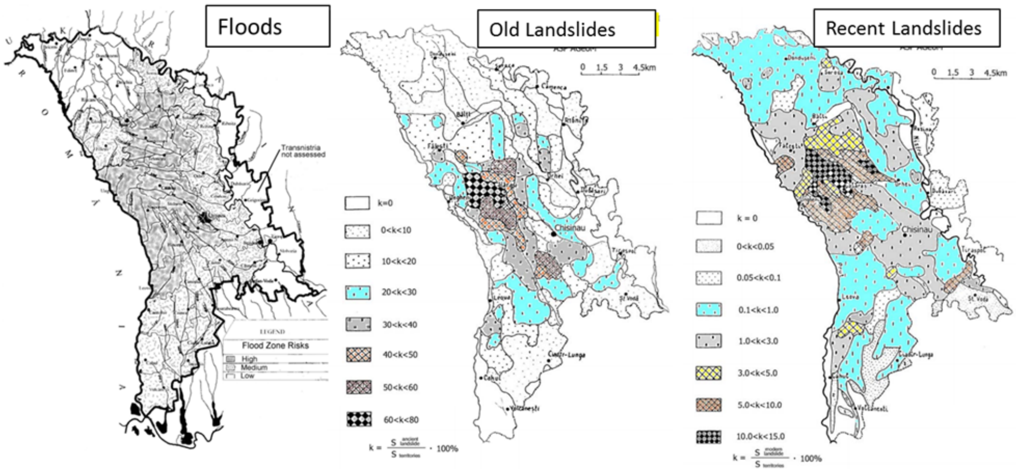


Figure: Current flood hazard map (Left) and landslide hazard maps (middle and right) for Moldova. Source: Vasile ALCAZ, Institute of Geology and Seismology Moldavian Academy of Sciences

3.5.4 Southern Caucasus: examples of regional scale hazard maps

The Atlas of Natural Multi Hazards of South Caucasus is compiled by specialists from Armenia, Azerbaijan and Georgia using existing data. The Atlas contains GIS-based maps of the following hazards, characteristic for the region: earthquakes, landslides, debris flows, flash floods and floods, avalanches. For Georgia the attempt was made to assess also risks from 12 hazards. The contributors are:

Armenia :

- GEORISK - Scientific Research CJS Company, Yerevan, Armenia
- "Garni" - Scientific Foundation "International Center Garni", Armenia
- Institute of Geological Sciences, National Academy of Sciences, Armenia

Azerbaijan :

- Institute of Geology, National Academy of Sciences, Azerbaijan
- Republic Centre of Seismic Survey, Azerbaijan

Georgia :

- M.Nodia Institute of Geophysics. Georgia
- Ministry of Environment Protection and Natural Resources, Georgia
- GGS – Georgian Geophysical Society

The recent probabilistic seismic hazard maps have been constructed in 1992-1999 for the territory of Southern Caucasus in the framework of Global Seismic Hazard Assessment Program, GSHAP (Annali di Geofisica, 42, N 6, 1999). The maps were re-calculated in 2002-2007during operation of the International Science and Technology Centre (ISTC) project: "Caucasian Seismic Information System" ISTC A651 CauSIN.

The assessment of seismic hazard for the Caucasus is based on selected modern, state-of-the-art approaches, which at their core include a range of alternative model formulations.

It is common practice to describe the method of estimating the seismic hazard in terms of the four steps involved in deriving the probability distribution of seismic hazard, as follows:

Step 1: Evaluation of Seismic Sources. Determine the geometries and spatial distribution of potential sources of future seismic activity in the region around the site. Characterize the uncertainty in the spatial description of each source

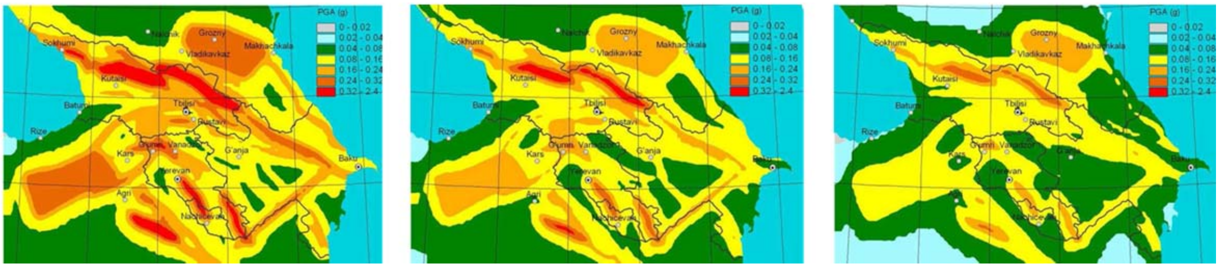


Figure: Regional scale earthquake hazard maps for the southern Caucasus region. Left: Probabilistic hazard map of the studied area in PGA (in g units) having 2% probability of being exceeded in 50 year. Middle: 5% probability of being exceeded in 50 yea. Right: 10% probability of being exceeded in 50 year. In: Atlas of GIs-based maps of Natural Hazards for the southern Caucasus. T. Chelidze, 2009.

Step 2: Assessment of Earthquake Recurrence and Maximum Magnitude. For each seismic source, describe the rates of occurrence of future earthquakes as a function of magnitude. Estimate the maximum magnitude for each source. Characterize the uncertainty in recurrence relations and in maximum magnitude.

Step 3: Ground Motion Attenuation. For the site region, evaluate or determine relations that express how the amplitudes of selected ground motion parameters vary with earthquake magnitude and source-to-site distance. Characterize the uncertainty in these ground motion/attenuation relations.

Step 4: Mathematical Model to Calculate Seismic Hazard. Integrate over each combination of inputs determined in steps 1 through 3 to calculate a seismic hazard and plot a curve expressing the annual probability that a given value of ground motion will be exceeded. Carry out the integration for all combinations of inputs to incorporate the variability of input estimates.

Each of these steps was carried out during the project. The set of probabilistic maps for peak ground acceleration were compiled for the region. Experience in assessing seismic hazard has shown that depending on the frequency of interest, and on the rheological properties of the earth crust, earthquakes can be felt and have substantial damaging effects at distances as far as 300 km, or sometimes even more. For the purpose of this study, the overall geographical area of interest extends from 38 to 53 degrees of longitude and 35 to 45 degrees of latitude, thereby ensuring that the distance from the boundary of the study to any point in Armenia, Azerbaijan or in Georgia is at least approximately 200 km.

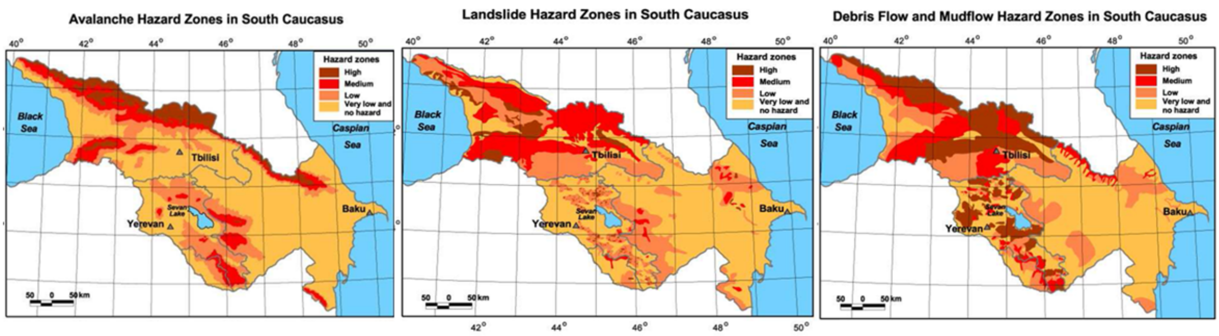
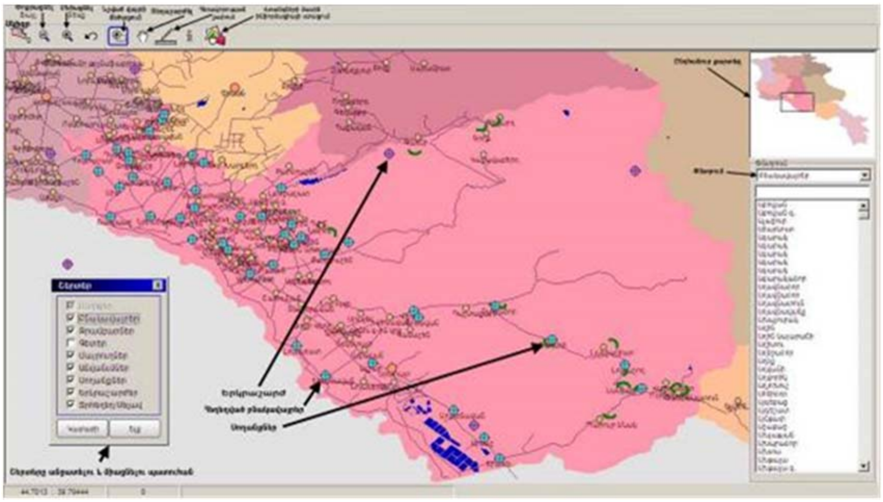
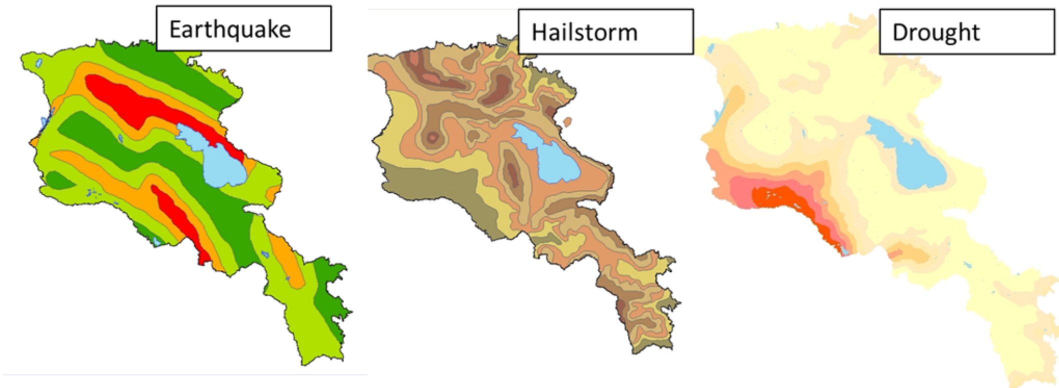


Figure: Regional mass movement hazard maps for the southern Caucasus region. In: Atlas of GIs-based maps of Natural Hazards for the southern Caucasus. T. Chelidze, 2009.

3.5.5 Armenia : examples of existing hazard maps



Earthquakes, floods, hail, landslides, mudflows, drought, erosion, and desertification have caused vast social upheaval and economic damage to Armenia. For example, the 1988 Spitak earthquake killed more than 25,000 people, injured 19,000, damaged over 515,000 homes, and caused some US$15-20 billion in damages—more than two times Armenia's 2007 Gross Domestic Product (GDP). In Armenia a national scale hazard and risk assessment has been carried out, taking into account the main types of hazards, like earthquakes, landslides, debrisflows, floods, drought, hailstorms etc. Also this data has been organized into a GIS system, called Disaster-GIS.



Left: the seismic hazard zones of Armenia in terms of acceleration rate value (values raging from 0.1g to 0.5g, g=9.8 m/sec2). Middle: frequency of hails in Armenia (multi-annual average number of occurrence in a year)

The following criteria were used in the preparation of this map: mudflow capacity, mudflow activity and rate of mudflow saturation with solid matter. Knowing mudflow capacity of a basin and an average frequency of mudflow events, we calculated annual average modulus of mass-movement for each basin; the values of transport vary in rather wide range (100-7100 m3/km2/year), which complicates their generalization. Therefore, relative values of annual average transport modulus were used. As an indicator of decline of erosion and mudflow phenomena, we applied the least value of annual mean transport modulus in the studied basins, which we consider as the grade "No or very low" hazard. The values exceeding 5, 10 and more times that minimum value, is thus estimated as low, medium, and high mudflow capacity of a basin, respectively (Source: Ter-Minasyan, R.. Rescue Service of Armenia).

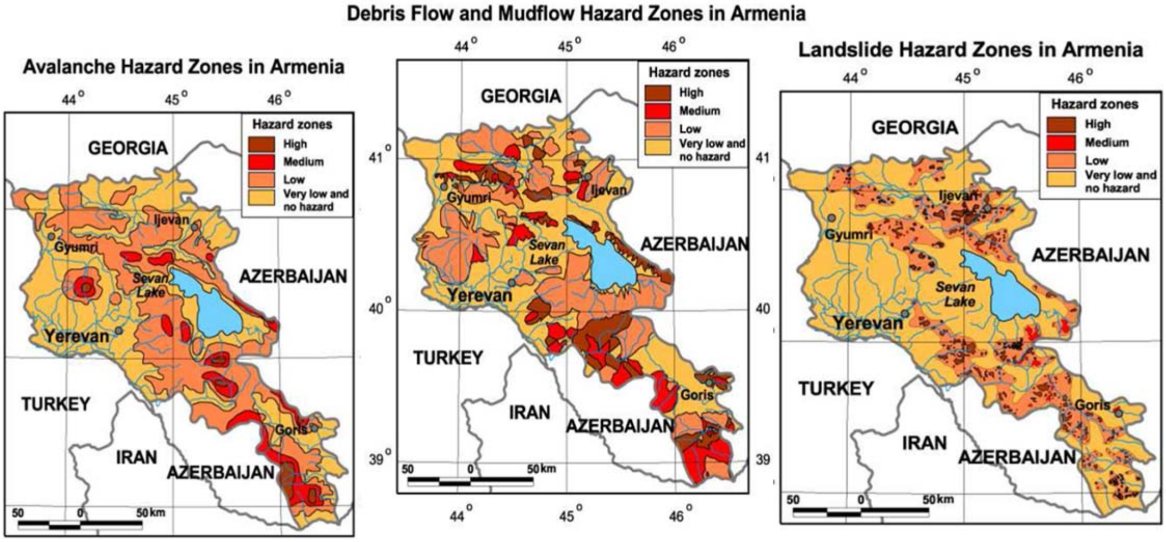


Figure: National scale hazard maps for Snow Avalanche, debris flows and landslide hazards for Armenia. Source: Ter-Minasyan, R.. In: Atlas of GIs-based maps of Natural Hazards for the southern Caucasus. T. Chelidze, 2009.

3.5.6 Azerbeidjan

Source: Shakhsuvarov A.S. State Committee on Geology and Mineral Resources of Azerbaijan Republic. The hazard on the map mapped in the units of affection of the territories by landslides. The affection degree is obtained through ratio of area affected by landslides to the whole area.

Accordingly, four hazard degrees are recognized : No or very low hazard (<0.1); Low (0.1-0.25); Medium (0.25-0.50); High (>0.5). Areas of intensive development of landslides in which 4 and more of landslides occurred per each 15 km of slope are shown on the map especially, as well as the sliding slopes that are considered as dangerous.

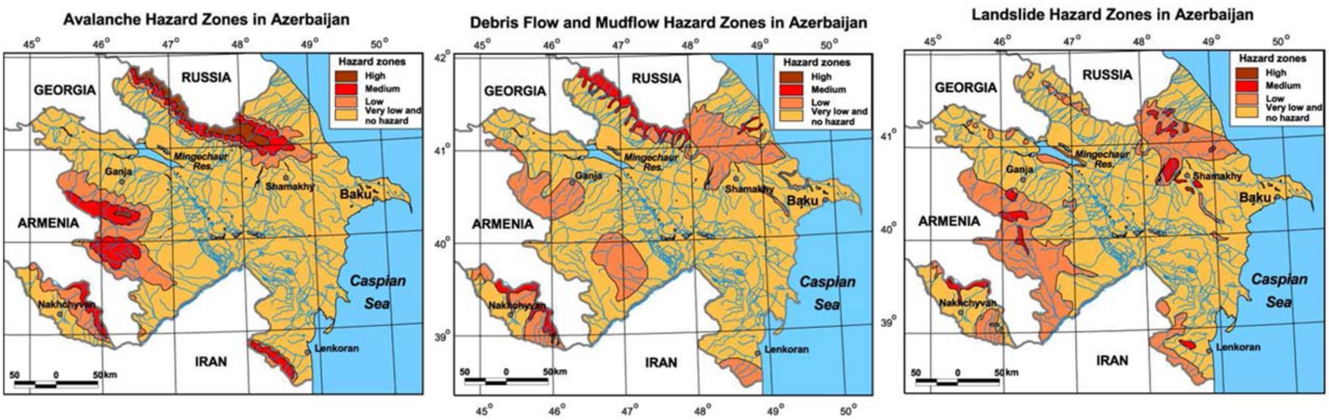


Figure: National scale hazard maps for Snow Avalanche, debris flows and landslide hazards for Azerbeidjan. Source: Shakhsuvarov A.S. In: Atlas of GIs-based maps of Natural Hazards for the southern Caucasus. T. Chelidze, 2009.

3.5.7 Georgia

Since this training package deals with the National Scale hazard and risk assessment methodology adapted for Georgia, we refer to the training manual to get more information on the method and results used for Georgia.

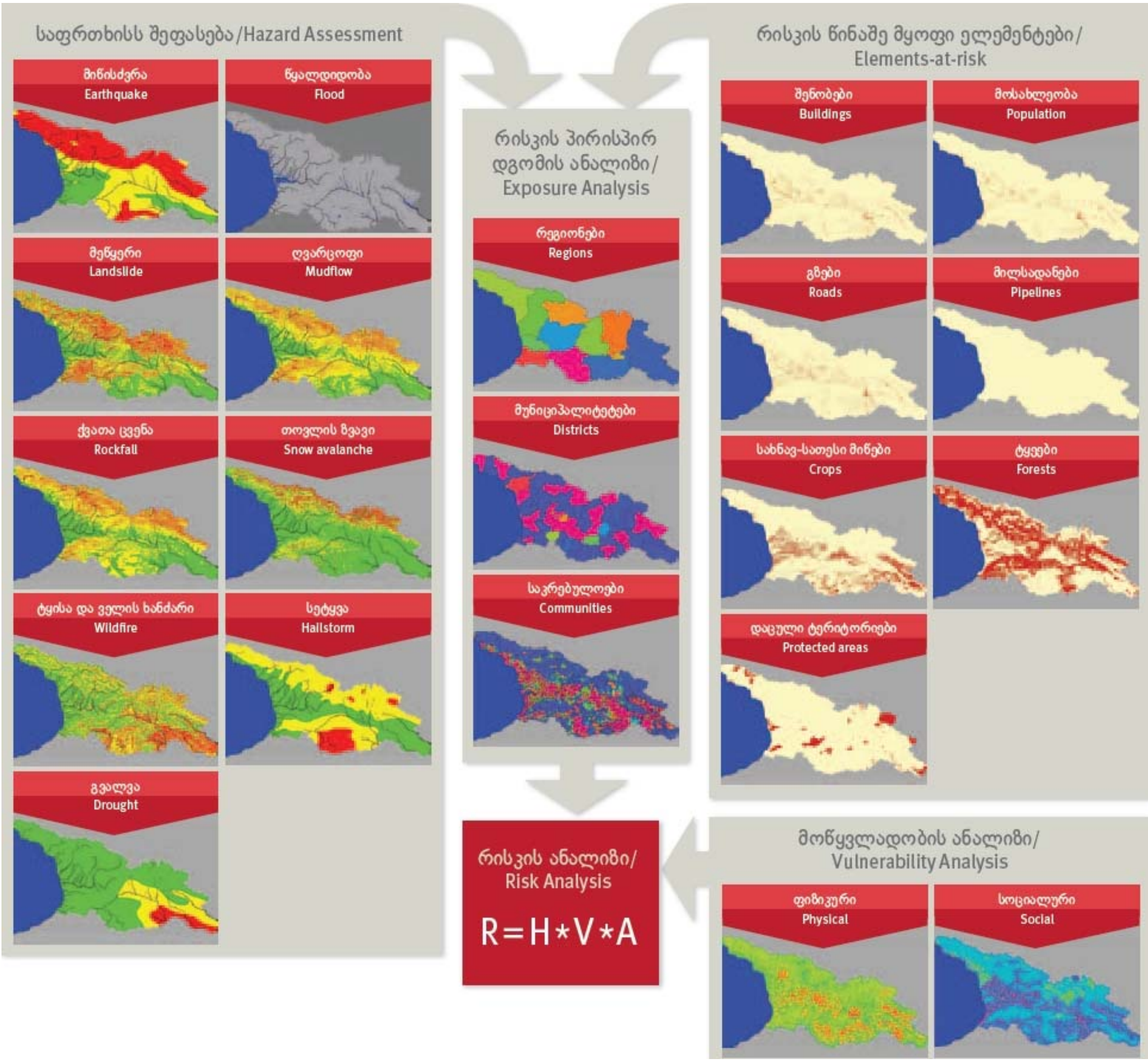


Figure: National scale multi-hazard risk assessment in Georgia

Exercise: make a search on the internet for hazard information available for the various countries of the PPRD-EAST programme.
Possible websites that are of interest:

GripWEB: http://www.gripweb.org/gripweb/?q=data-information
Prevention Web: http://www.preventionweb.net/

Table 3.2: Overview of hazard assessment aspects for flooding and landslide hazard assessment for country-wide and local scales.

<table>
<tr><th colspan="2" rowspan="2">Component</th><th colspan="2">Flooding</th><th colspan="2">Landslides</th></tr>
<tr><th>Country scale</th><th>Local scale</th><th>Country scale</th><th>Local scale</th></tr>
<tr><td colspan="2">Inventory of past events</td><td>Satellite based inventory using
e.g. MODIS data</td><td>Field work; Archives; existing maps;
Interviews</td><td colspan="2">Stereo-image interpretation of multi-temporal high resolution images; Field work; Archives; existing maps; Interviews</td></tr>
<tr><td colspan="2">Analysis of triggering events</td><td colspan="4">Analysis of hurricane tracks, modelling probability of hurricanes with given intensity; empirical relationship with rainfall and storm surge height;
Analysis of available raingauge data; extreme value analysis; magnitude-frequency relations; intensity-frequency duration curves. Application of rainfall generator algorithms to stochastically model rainfall events. Use of Tropical Rainfall Monitoring Mission data (TRMM) from NASA and JAXA.</td></tr>
<tr><td rowspan="3">Initiation modeling</td><td>Input data requirements</td><td>DEM (10-20m)
Land cover
Soil types (special focus on volcanic soils)
Rainfall records</td><td>DEM (<5 m)
Soil types (special focus on volcanic soils)
Soil depth
Land cover
Rainfall records (daily and hourly rainfall)</td><td>DEM (10-20m)
Topographic factors
Soil types
Lithology
Landuse and land use changes</td><td>DEM (<5 m)
Soil types
Soil depth
Land cover
Rainfall records (daily and hourly rainfall)</td></tr>
<tr><td>Assessment method</td><td>Distributed physically based modelling</td><td>Distributed physically based modelling</td><td>Statistical analysis
Spatial Multi-Criteria Evaluation.
Characterisation of spatial and temporal probability using landslide inventories</td><td>Physically based modelling
Soil water modelling
Infinite slope modeling</td></tr>
<tr><td>Possible software tools</td><td>HEC-RAS
OpenLISEM
HBV (not distributed)</td><td>OpenLISEM</td><td>ILWIS
ARC-SDM</td><td>TRIGGRS
STARWARS/PROBSTAB</td></tr>
<tr><td rowspan="3">Run-out modelling</td><td>Input data requirements</td><td>DEM (10-20m)
Land cover</td><td>DEM
Surface roughness</td><td>DEM
Sources resulting from initiation modeling</td><td>Detailed DEM including
Initiation volumes
Rheology</td></tr>
<tr><td>Assessment method</td><td>Empirical runout modelling</td><td>Numerical runout modeling</td><td>Empirical runout modelling</td><td>Numerical runout modeling</td></tr>
<tr><td>Software tools</td><td>PC-RASTER
HEC-RAS
LISFLOOD</td><td>LISFLOOD
OpenLISEM</td><td>FlowR</td><td>PC-RASTER (MASSMOV)
FLO-2D (not Open Source)
RockyFor3D (Rockfall)</td></tr>
<tr><td colspan="2">Validation</td><td colspan="2">Validation is done using discharge data (if available) and past flood events</td><td colspan="2">Validation is done using past landslide events.</td></tr>
<tr><td rowspan="2">Results</td><td>Intensity maps</td><td>Depending on availability of discharge data: either flood extend or</td><td>Water depth, flow velocity</td><td>none</td><td>Not for initiation maps.
For runout maps: depth and impact pressure</td></tr>
<tr><td>Spatial probability</td><td>Spatial probability of 1 for modelled areas</td><td>Spatial probability of 1 for modelled areas. For flashfloods spatial probability is based on past events.</td><td>Susceptibility maps are converted to spatial probability maps for different return periods. Semi quantitative.</td><td>Initiation maps: conversion of safety factor maps.
Run-out maps: based on past events.</td></tr>
</table>

3.6 PROVINCIAL AND MUNICIPAL LEVEL

At local and municipal scales, spatial information is often of sufficient quality to run more sophisticated models, which can be either empirical (e.g. statistical) or deterministic (physically-based). A flood-hazard assessment example follows. The first step is to transform catchment characteristics like topography, relief and land cover, complemented with hydrological boundary conditions into estimates of the discharge at various locations along the river downstream. This can be done with (distributed) 1-dimensional models. These kinds of models are very useful to assess the response of the river to extreme events and to changes in the topography and land cover. Typical models to do this are HEC-HMS and HEC-RAS of the US Army Corps of Engineers, MIKE-SHE (Refsgaard and Storm, 1995), IHDM (Beven et al., 1987), LISFLOOD (De Roo et al., 2000), and HEC-RAS (Brunner, 2002). They require the characterization of the terrain through a series of cross-sections perpendicular to the direction of flow for which the average water depth and flow-velocity are calculated. This type of modelling is often applied for catchment analysis, and the underlying assumption is that all flow is parallel to a predefined river-network. In near-flat terrain with complex topography, it cannot be assumed that all flow will be parallel to the main river. Also in urban environments and in areas with a dominant presence of man-made structures, models are required that calculate flow in both X- and Y-direction. Such models, like SOBEK (Stelling, et al., 1998; Hesselink et al., 2003), Telemac 2D (Hervouet and Van Haren, 1996) and MIKE21 can also be applied in the case of diverging flow at a dike breach. They require high-quality DEMs, which ideally are generated using LiDAR data (Dal Cin et al., 2005; Alkema and Middelkoop, 2005). The flood modelling is usually carried out at a municipal to provincial scale, for a selected stretch of the river. These models provide information on how fast the water will flow and how it propagates through the area. It is very suitable to assess the effects of the surface topography, like embanked roads and different land-cover types on the flood behaviour (Stelling et al., 1998).

Also for landslide-hazard assessment, the provincial and municipal scales offer much more possibilities, as sufficient information can be collected on hazard inventories, and the factors that control the location of landslides (Dai et al.,, 2002). They differentiate between statistical methods and physically-based models. Guzetti et al. (2005) provides an overview of the various statistical methods that can be applied, focusing on the use of multi-variate statistical methods, in which landslide inventories for different periods are used in combination with environmental factors for predicting landslide activity within slope units that are defined from a DEM. Van Asch et al. (2007) provide an overview of the physically-based modelling approaches. Most of the physically-based landslide models make use of the infinite-slope model and are therefore only applicable to modelling shallow landslides. They can be subdivided into static models that do not include a time component, and dynamic models, which use the output of one time step as input for the next time step. Physically-based models for shallow landslides account for the transient groundwater response of the slopes to rainfall and or the effect of earthquake acceleration (van Beek and van Asch, 2004).

The provincial and municipal scales are also the most appropriate for volcanic hazard assessment, as a lot of this work depends on the determination of the eruptive history on the basis of geological investigation and age dating (Tilling, 1989). Given different volcanic eruption scenarios, several modelling techniques can be carried out for the various volcanic hazards (ash fall, lava flow, pyroclastic flow, lahars). Most of these hazard-assessment methods require some sort of spread modelling, where the volcanic products are distributed over the terrain away from the vent. This requires the use of dynamic models (Zuccaro et al., 2008). The evaluation of volcanic hazards from tephra fallout is determined by volcanic ash volumes, eruption height, and wind information (Connor et al., 2001). Remote sensing also plays an important role in volcanic-hazard assessment (e.g., Kerle and Oppenheimer, 2002)

3.7 COMMUNITY LEVEL

Approaches based on local knowledge and experiences may be useful in developing countries, where detailed information required for conventional model-based risk analyses facilitated by GIS is often not available. For instance, historical records on river discharges and rainfall are often missing, whereas knowledge about hazardous events is generally available within the local communities (Ferrier and Haque, 2003). There is a vast quantity of undocumented local knowledge on disaster occurrences in the field, which usually remains untapped because of the lack of funding, a format to systematically collect it, and a low commitment to do so (Hordijk and Baud, 2006). Anderson and Woodrow (1989) state that much of the information needed for risk assessment and mitigation can be obtained from local people who usually already know what the situation is, but do not always have the skills for understanding and organizing what they know. Several organizations, such as the International Federation of Red Cross and Red Crescent Societies (IFRC), have developed community-based assessment instruments for analyzing disaster situations at the grassroots level, and for improving the community's expertise in identifying and articulating its needs and reducing its vulnerabilities. Some examples of these community-based methods are named "Capacity and Vulnerability Assessment (CVA)", "Hazards, Vulnerability and Capacity Assessment (HVCA)", and "Damage, Needs and Capacity Assessment methods (DNCA)" (Provention Consortium, 2010). These methods aim at eliciting tacit local knowledge within communities on historic disaster events, the perception of hazards, characterization of elements-at-risk, identifying the main factors of vulnerability, coping mechanisms, and disaster reduction scenarios. The application of such collaborative approaches is not common in many developing countries, and decision-making about risk is often done in a top-down approach by local authorities where specialists diagnose problems, formulate alternatives and determine options without a meaningful consultation with communities (UN-ESCAP, 2003). Hazard specialists often consider that community participation is difficult to achieve, and the information is perceived unscientific, not always easy to retrieve, difficult to be expressed in quantitative terms or to be converted into spatial formats (Peters and Guarin, 2008).

The integration of geo-information systems and local-community knowledge relevant to hazards, vulnerability and risk modelling is still in an initial stage (Maskrey, 1998; Ferrier and Haque, 2003; Zerger and Smith, 2003). Very often the sketches, paper maps, historical profiles and other results obtained through participatory mapping, are not kept after a risk project has finished, leading to a loss of valuable information. As Cannon et al. (2003) advise, these products need to be converted from raw data into useful spatial information that allows the community and other participants to develop analytical processes for risk analysis and exploration of management alternatives. Several authors have shown that local communities are indeed the primary sources of information for flood depths, time of occurrence, severity measured in terms of damage, and the like (Whitehouse, 2001; Alcantara-Ayala, 2004; Rautela, 2005). Systematic collection of data from significant events using public participation can provide a very useful component for the development of data-sets to be used as input for risk studies at community level, and as a basis for risk management and community planning (Ireland, 2001). Information from local communities can also be useful in calibrating and verifying risk and disaster scenarios (Bassolé et al., 2001; Peters and Guarin, 2008).

4. ELEMENTS-AT-RISK

4.1 INTRODUCTION

The next step in risk assessment, after analyzing the hazard, is to evaluate the elements-at-risk. There are many different types of elements-at-risk and they can be classified in various ways. In this section several types of elements-at-risk and their data sources are evaluated, followed by a discussion on how these are used in vulnerability assessment.

Table 4.1: Classification of elements-at-risk

Physical elements Buildings: Urban land use, construction types, building height, building age, total floor space, replacement costs. Monuments and cultural heritage	**Population** Density of population, distribution in space, distribution in time, age distribution, gender distribution, handicapped, income distribution
Essential facilities Emergency shelters, Schools, Hospitals, Fire Brigades, Police,	**Socio-economic aspects** Organization of population, governance, community organization, government support, socio-economic levels. Cultural heritage and traditions.
Transportation facilities Roads, railway, metro, public transportation systems, harbor facilities, airport facilities.	**Economic activities** Spatial distribution of economic activities, input-output table, dependency, redundancy, unemployment, economic production in various sectors.
Life lines Water supply, electricity supply, gas supply, telecommunications, mobile telephone network, sewage system.	**Environmental elements** Ecosystems, protected areas, natural parks, environmentally sensitive areas, forests, wetlands, acuifers, flora, fauna, biodiversity.

Elements-at-risk inventories can be carried out at various levels, depending on the requirement of the study. Table 6 provides a more detailed description. Elements-at-risk data should be collected for basic spatial units, which may be grid-cells on a global scale (see Tables 3, 6), administrative units (countries, provinces, municipalities, neighbourhoods, census tracts), or so-called homogeneous units with similar characteristics in terms of type and density of elements-at-risk. Risk can also be analyzed for linear features (e.g., transportation lines) and specific sites (e.g., a damsite). The risk assessment will be done for these spatial units of the elements-at-risk, rather than those used in the hazard assessment. In the HAZUS methodology (FEMA, 2004), the loss estimation is done based on census tracts.

Digital information on coastlines, international boundaries, cities, airports, elevations, roads, railroads, water features, cultural landmarks, etc. are available from different sources, for example the Geonetwork established by FAO (2010), with available data comprising base layers (e.g., boundaries, roads, rivers), thematic layers (e.g., protected areas), or a backdrop image (e.g., World Forest 2000).

One of the most important spatial attributes of the mapping units for an elements-at-risk inventory is land use. The land use determines to a large extend the type of buildings that can be expected in the unit, the economic activities that are carried out, and the density of the population in different periods of the day. Land-cover and land-use maps are prepared by image classification at small scales or through visual interpretation at larger scales. Ebert et al. (2009) have developed a method using Object-Oriented Image classification method for the automatic characterization of land-use types in urban areas.

Table 4.2 : Occupancy classes

Name	Code	Description
Com_business	Com_b	Business offices
Com_hotel	com_h	Hotels
Com_market	com_m	Commercial area: market area
Com_shop	com_s	Commercial: shops and shopping malls
Ind_hazardous	ind_h	Hazadous material storage or manufacture
Ind_industries	ind_i	Industries
Ind_warehouse	ind_w	Warehouses and workshops
Ins_fire	ins_f	Fire brigade
Ins_hospital	ins_h	Hospitals
Ins_office	ins_o	Office buildings
Ins_police	ins_p	Police station
Ins_school	ins_s	Institutional : schools
Pub_cemetery	Pub_g	Cemetery
Pub_cultural	pub_c	Institutional: cultural buildings such as musea, theaters
Pub_electricity	pub_e	Electricity installations
Pub_religious	pub_r	Religious buildings such as churches, mosques or temples
Rec_flat_area	rec_f	Recreational: flat area or foorball field
Rec_park	rec_p	Recreational: park area
Rec_stadium	rec_s	Recreational : stadium
Res_large	res_5	Residential: large free stading houses
Res_mod_single	res_4	Residential, moderately sized single family houses
Res_multi	res_3	Residential: multi storey buildings
Res_small_single	res_2	Residential, small single family houses, mostly in rows
Res_squatter	res_1	Residencial, low class houses: squatter areas
River	riv	River
unknown	u	
Vac_car	vac_c	Vacant : car parking and busstation
Vac_construction	vac_u	Vacant area which is prepared for building construction
vac_damaged	vac_d	Area recently damaged by hazard events
Vac_shrubs	vac_s	Vacant land with shrubs, trees and gress

Table 4.3: Main elements-at-risk, and how they can be spatially represented at various mapping scales.

	Scale				
	Global	**Continental**	**National**	**Provincial / Municipal**	**Community**
Basic unit	1 km grid or countries	90 – I km grid & countries	30 – 90 m & municipality	Census tract	Groups of buildings
Population	Gridded population map	Gridded population map	By municipality • Population density	By Census tract • Population density • Daytime/Nighttime	People per building • Daytime/Nighttime • Gender • Age • Education, etc.
Buildings	N.A.	Gridded building density map	By municipality • Nr. Buildings	By Census tract • Generalized use • Height • Building types	Building footprints • Detailed use • Height • Building types • Construction type • Quality / Age • Foundation
Transportation networks	N.A.	Main roads, railroads, harbours, airports	Road & railway networks, with general traffic density information	All transportation networks with detailed classification, including viaducts etc. & traffic data	All transportation networks with detailed engineering works & detailed dynamic traffic data
Lifelines	N.A.	Main powerlines	Only main networks • Water supply • Electricity	Detailed networks: • Water supply • Waste water • Electricity • Communication • Gas	Detailed networks and related facilities: • Water supply • Waste water • Electricity • Communication • Gas
Essential facilities	N.A.	By Municipality • Number of essential facilities	As points • General characterization • Buildings as groups	Individual building footprints Normal characterization Buildings as groups	Individual building footprints • Detailed characterization • Each building separately
Agricultural data	Gridded main land cover types, crops	Gridded maps: • Crop types • Yield information	By homogeneous unit, • Crop types • Yield information	By cadastral parcel • Crop types • Crop rotation • Yield information • Agricultural buildings	By cadastral parcel, for a given period of the year • Crop types • Crop rotation & time • Yield information
Ecological data	Main land cover types, crops	Natural protected areas with international approval	Natural protected area with national relevance	General flora and fauna data per cadastral parcel.	Detailed flora and fauna data per cadastral parcel
Economic data	GDP	By region: Economic production, import / export, type of economic activities	By Municipality • Economic production • Import / export • Type of economic activities	By Mapping unit • Employment rate • Socio-economic level • Main income types Plus larger scale data	By household • Employment • Income • Type of business Plus larger scale data

4.2 COLLABORATIVE MAPPING AND MOBILE GIS

Elements-at-risk information is collected from a wide variety of sources. There are also many areas in the world for which no detailed digital data is available on elements-at-risk. In such situations, data should be digitized from analogue maps, or in case these also don't exist, be mapped in the field, for instance using mobile GIS. With the use of mobile GIS, it is possible to directly collect the spatial information, based on a high-resolution image that can be uploaded into a palmtop computer or smart phone, and link it with attribute information that is collected in the field. Some of the most used tools for mobile GIS in urban elements-at-risk mapping are ArcPad (Montoya, 2003) and Cybertracker (McCall, 2008).

Several initiatives have been established for collaborative mapping of topographic features, also referred to as "crowdsourcing". For example, OpenStreetMap is a free editable map of the whole world, which is made using collaborative mapping by volunteers. It allows users to collect, view, edit and use geographical data in a collaborative way from anywhere on Earth (OpenStreetMap, 2010). Another crowdsourcing example is "Ushahidi" (Ushahidi, 2010), which means "testimony" in Swahili, which was initially developed to map reports of violence in Kenya in 2008, and which has been used later in many disaster events to rapidly collect and visualize spatial information. Other applications that are specifically directed to post-disaster relief coordination are "Sahana" (Sahana, 2010) and "Virtual Disaster Viewer" (Virtual Disaster Viewer, 2009). Sahana is a free web-based Disaster Management system, developed after the Indian Ocean tsunami, as a collaboration tool that addresses the common coordination problems during a disaster. The Virtual Disaster Viewer is a crowd-sourcing tool for collaborative disaster impact and damage assessment, which has proven to be effective after the Haiti earthquake in 2010. Hundreds of earthquake and remote-sensing experts were assigned specific areas (tiles) of the affected areas to review and provide their assessment by comparing before and after high-resolution satellite images, that became available on Google Earth immediately after the disaster, and which served as the basis for the collaborative mapping. Such collaborative-mapping applications might become a very important tool in the future.

4.3 POPULATION DATA

People are the most important elements-at-risk, with a static and dynamic component. The static component relates to the number of inhabitants per mapping unit, and their characteristics, whereas the dynamic component refers to their activity patterns, and their distribution in space and time. Population distribution can be expressed as either the absolute number of people per mapping unit, or as population density. The way population data is collected and represented in a risk assessment depends on the scale of analysis (see Table 3) and the availability of information (Rhind, 1991).

Census data are the obvious source for demographic data. They are used as benchmark data for studying population changes, and are key input for making projections concerning population, households, labour force and employment. Census data is costly to collect, and updating of population information is carried out on average every 10 years. Census data is aggregated to census tracts, and normally data at an individual household level is confidential. This is also the reason why risk assessment is normally carried out at the census tract level (FEMA, 2004). Census tracts are divisions of land that are designed to contain 2500-8000 inhabitants with relatively homogeneous population characteristics, economic status and living conditions. Census data may also contain other relevant characteristics that are used in risk assessment, such as information on age, gender, income, education and migration.

For larger areas, census data may be aggregated into larger administrative units. For large parts of the world, however, census data are not available, outdated, or unreliable. Therefore, other approaches have been used to model population distribution with remote sensing and GIS, based on a number of factors, such as land cover, roads, slopes, and night-time illumination. The use of remote sensing data in combination with other data to redistribute population information over smaller areas based on general population data for large administrative units is also referred to as "dasymetric mapping" (Balk et al., 2006). Global population data is available from the LandScan Global Population Database (Bhaduri et al., 2007; LandScan, 2010) that provides the average population over 24 hours, in a 1 km resolution grid. The Global Rural-Urban Mapping Project (GRUMP) is another example of modelling human populations in a common geo-referenced framework (GRUMP, 2004), as is the African Population Database (APD, 2010). Higher-resolution population databases have also been developed for specific areas, especially in low-income countries where limited information is available and there is a need to generate population information using satellite data. Tatem et al. (2007) made a comparison between semi-automated population distribution mapping for several countries in East Africa, based on 30 m LANDSAT ETM data, and concluded that these produced more accurate results than existing products at a cost of \$0.01 per km^2.

For risk assessment at municipal or community level, population is required at a high spatial resolution, for every census tract or even for each building. In the absence of census data static population information can be derived directly using high resolution satellite imagery (e.g. Harvey, 2002) or through a building footprint map, where the land use type and the floorspace are used to estimate the number of people present in a particular building (Chen et al., 2004; Lwin and Murayama, 2009).

4.4 BUILDING DATA

After population, buildings are the second most important group of elements-at-risk. They house the population, and the behaviour of a building under a hazard event determines whether the people in the building might be injured or killed. In order to assess the potential losses and degree of damage of buildings, it is important to analyze the type of negative effects that the event might have on the building exposed to it, and the characteristics of the building. The negative effects of hazardous events on buildings can be classified into a number of groups, depending on the type of hazard (Blong, 2003; Hollenstein, 2005). Figure 7 depicts a schematic overview of the various hazard processes that may occur and that have a different effect on buildings. For instance, a building may be impacted by a mass, and the damaging effects would be determined by the volume of the mass, speed of impact, and the medium, , such as rocks, soil, debris, snow, water, or air. Buildings are also affected by undercutting (erosion or landslides), shaking (earthquakes), inundation, fires, loss of support (subsidence), gasses, or loading (e.g., volcanic ashes). In each of these situations, particular building characteristics are important for evaluating the damaging effects, such as structural type, construction materials, application of building code, age, maintenance, roof type, height, floor space, volume, shape, proximity to other buildings, proximity to hazard source, proximity to vegetation, and openings (FEMA, 2004; Jones et al., 2005; Grünthal et al, 2006; Douglas, 2007).

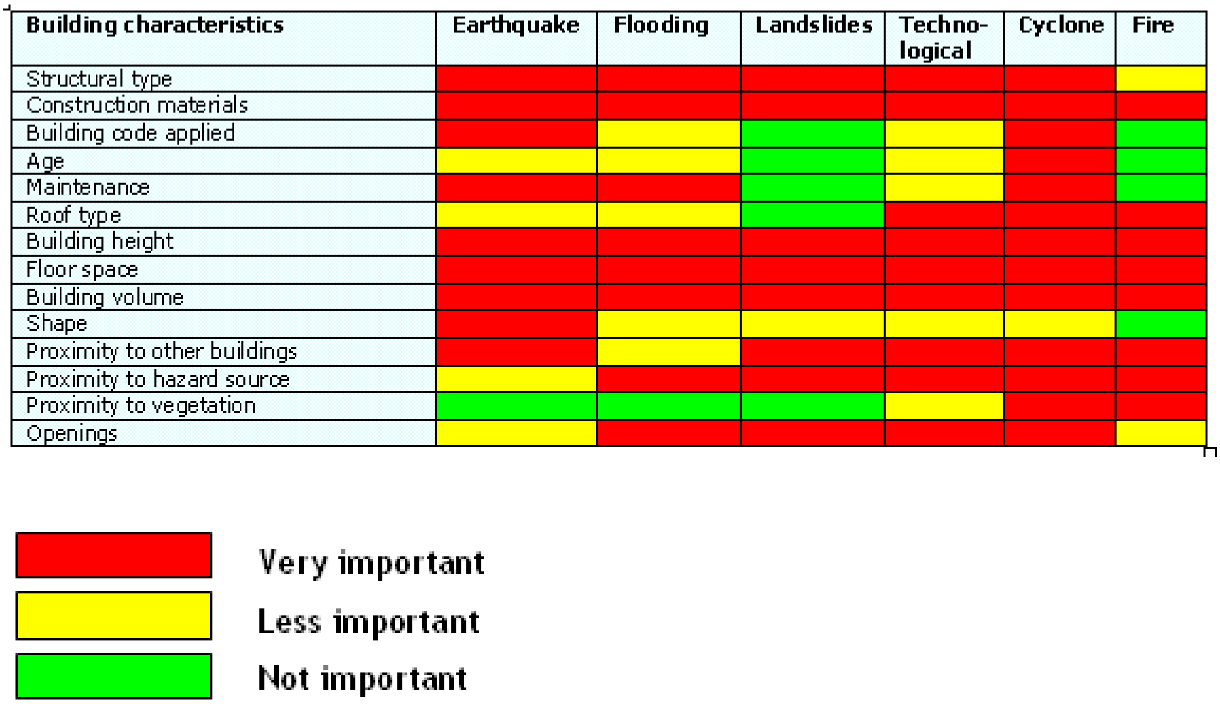
For risk maps that express losses in economic terms, an estimation of building costs is also required. Several sources of information can be used, such as data on house prices from real-estate agencies, information from cadastres that indicate the value used as the basis for taxation, engineering societies that calculate the replacement costs, or insurance companies (Grünthal et al., 2006).

Sources of information:

- Real-estate agencies, which represent the market price (“real”). Of course the market prices of buildings fluctuate depending on the economic situation.
- Cadastres in most developing countries, which indicate the ratable price (“fictitious”) which is used as the basis for taxation.
- Engineering societies, which use the construction price (“replacement”).
- Insurance companies, which use the insured amount for the building, if it is possible to have a building insurance against natural disasters,

It is often difficult to get hold of the building values used by the cadastres, whereas it is easier to use the values from real estate agencies. Samples are taken from each type of building in the various land-use classes. In some countries building societies produce a monthly index that permits an update of property prices. Cost estimation can be carried out by using the replacement value or the market value. Apart from building costs, content costs are also very relevant, especially for those hazards that have less structural damage such as flooding.

Building information can be obtained in several ways. Ideally data is available on the number and types of buildings per mapping unit, or even in the form of building-footprint maps. If such data are not available, building-footprints maps can be generated using screen digitizing from high-resolution images (Van Westen et al., 2002). Automated building mapping has also been carried out using high-resolution satellite images (Fraser et al., 2002), InSAR (Stilla et al., 2003), and specifically using LiDAR (Priestnall et al., 200; Brenner, 2005; Oude Elberink and Vosselman, 2009). LiDAR data also allows the extraction of other relevant features, and the calculation of shapes, building height, and volumes which are needed in risk assessment.



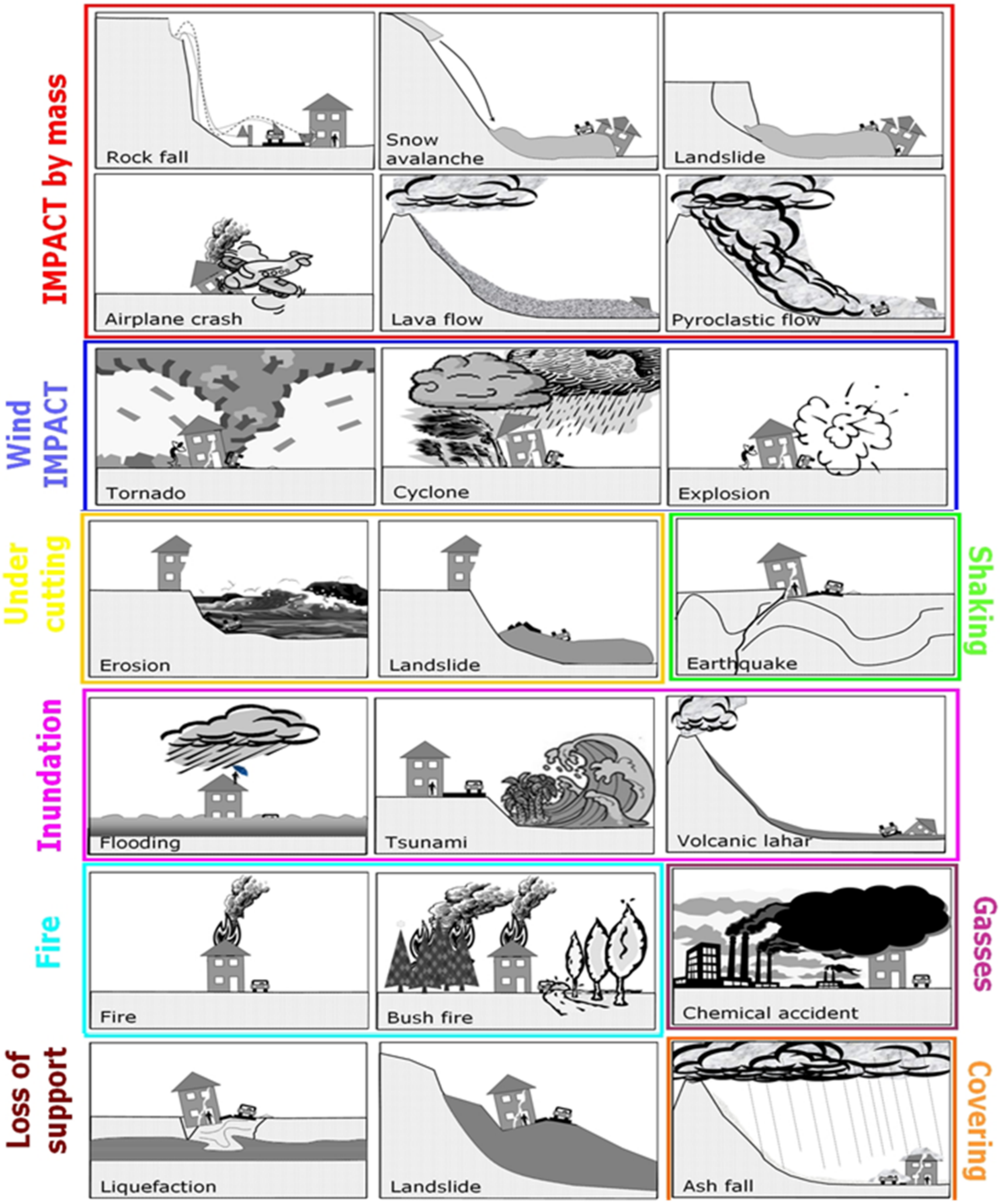


Figure 4.1: Examples of the type of hazardous processes to which buildings can be exposed. Each type of processes will have different effects.

Figure 4.2：Examples of land uses as seen from high resolution imagery

5.VULNERABILITY ASSESSMENT

Vulnerability is the most complicated component of risk assessment, because the concept of vulnerability has a wide range of interpretations.

5.1 COMPLEXITY

$$R \approx H$$

$$R \approx H \times V$$

$$R \approx H \times V / C$$

$$R \approx H(v, c) \times V(h, c) / C(h, v)$$

The concept originated from the social sciences in response to the pure hazard-oriented perception of disaster risk in the 1970s. Since that time, different disciplines have developed their own concepts.
Through the last decades several paradigm shifts of risk and vulnerability have taken place:

- **Technocratic or Behavioral paradigm**: The first approaches to risk were the ones that assimilated it to hazard r focused mainly on it, carried out especially by professionals of the natural sciences (geologists, engineers, meteorologists, etc.). According to Blaikie et al (1994), until the emergence of the idea of vulnerability to explain disasters, there was a range of prevailing views. None of which really dealt with the issue of how society creates the conditions in which people face hazards differently. The first approach was unapologetically naturalist, in which all blame was apportioned to 'the violent forces of nature'. Governments and individuals relied upon physical protection against the hazards.
- **Physical Vulnerability or Structural paradigm**: The concept of vulnerability entered the risk scene. Protection was defined not only according to the physical protection systems built, but also according to the people's behavior. This inclusion of people's behavior led to the design and use of early warning systems and educational programs about hazards and how to protect against them. This paradigm lasted for a couple of decades and was even used during the Yokohama Strategy and Plan of Action for a Safer World (1994), where all the efforts were aimed towards increasing our scientific knowledge about the causes and consequences of natural hazards and facilitate its wider application to reducing vulnerability of disaster-prone communities. This perspective included overall development, attacking root causes, and capacity building.
- **Complexity paradigm**: A new understanding of the complex interaction between nature and society has emerged, and as such, a

new complex approach to understanding risk has to be undertaken. Vulnerability is not only about groups or individuals, but is also embedded in complex and social relations and processes

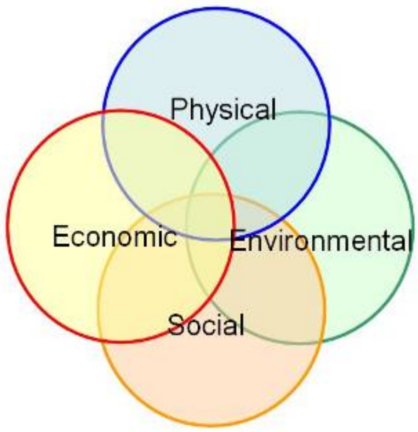
5.2 DEFINITIONS

Multiple definitions and different conceptual frameworks of vulnerability exist (e.g., Blaikie et al., 1994; Pelling, 2003). An overview of the approaches is given by Birkmann (2006). The definition of vulnerability, used in Table 1.2, indicates that vulnerability is multi-dimensional (physical, social, economic, environmental, institutional, and human factors define vulnerability), dynamic (it changes over time), scale-dependent (it can be expressed at different scales from individuals to countries), and site-specific (each location might need its own approach) (Bankoff et al., 2003).
Below some examples are given of definitions of vulnerability:

- "The degree of loss to a given element at risk or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total damage)" (UNDRO, 1991)
- "Exposure to risk and an inability to avoid or absorb potential harm (Pelling, 2003). In this context, he defines physical vulnerability as the vulnerability of the physical environment; social vulnerability as experienced by people and their social, economic, and political systems; and human vulnerability as the combination of physical and social vulnerability" (in Vilagrán de León, 2006)
- "The characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from impacts of a hazard" (Blaikie, Cannon et al. 1994).
- "The degree of susceptibility and resilience of the community and environment to hazards" (EMA, 1995).
- "A human condition or process resulting from physical, social, economic and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard" (UNDP, 2004).
- "The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards "(UN-ISDR)
- "The intrinsic and dynamic feature of an element at risk that determines the expected damage/harm resulting from a given hazardous event and is often even affected by the harmful event itself. Vulnerability changes continuously over time and is driven by physical, social, economic and environmental factors" (UNU-EHS, 2006)
- "The potential to suffer harm or loss, related to the capacity to anticipate a hazard, cope with it, resist it and recover from its impact. Both vulnerability and its antithesis, resilience, are determined by physical, environmental, social, economic, political, cultural and institutional factors" (Provention Consortium, 2007)

- "The degree to which a system is susceptible to, or unable to cope with adverse effects of climate change, including climate variability and extremes". Vulnerability is a function of the character, magnitude, and rate of climate variation to which the system is exposed, its sensitivity, and its adaptive capacity" (IPCC,2001:165).
- Vulnerability = (Exposure) + (Resistance) + Resilience
- With: Exposure: at risk property and population;
  - Resistance: Measures taken to prevent, avoid or reduce loss;
  - Resilience: Ability to recover prior state or achieve desired post-disaster state.

5.3 DIFFERENT DIMENSIONS



It is important to note that quantitative methods focus mostly on physical vulnerability, whereas qualitative methods also incorporate the other definitional aspects.

Physical vulnerability is the potential for physical impact on the built environment and population. It is defined as the degree of loss to a given element-at-risk or set of elements-at-risk resulting from the occurrence of a natural phenomenon of a given magnitude, and expressed on a scale from 0 (no damage) to 1 (total damage). Vulnerability is related to the characteristics of the elements-at-risk, and to the hazard intensity. Physical vulnerability as such is therefore not a spatial component, but is determined by the spatial overlay of exposed elements-at-risk and hazard footprints (Van Westen et al., 2009). Economic vulnerability is defined as the potential impact of hazards on economic assets and processes (i.e., business interruption, secondary effects such as increased poverty and job loss). Social vulnerability is the potential impact of events on groups within the society (such as the poor, single parent households, pregnant or lactating women, the handicapped, children, and elderly), and it considers public awareness of risk, ability of groups to self-cope with catastrophes, and the status of institutional structures designed to help them cope. Environmental vulnerability evaluates the potential impacts of events on the environment (flora, fauna, ecosystems, biodiversity) (Birkmann, 2006). Vulnerability is:

- multi-dimensional (e.g. physical, social, economic, environmental, institutional, and human factors define vulnerability);
- dynamic i.e. vulnerability changes over time;

- scale-dependent (vulnerability can be expressed at different scales from human to household to community to country resolution;
- site-specific.

5.4 VULNERABILITY FRAMEWORK: THE MOVE PROJECT

Figure 5.1 presents a framework for vulnerability assessment that was developed under the EU FP7 MOVE project (See http://www.move-fp7.eu/). The MOVE generic concept of vulnerability includes different components and is set within a holistic framework of risk assessment, governance and management.

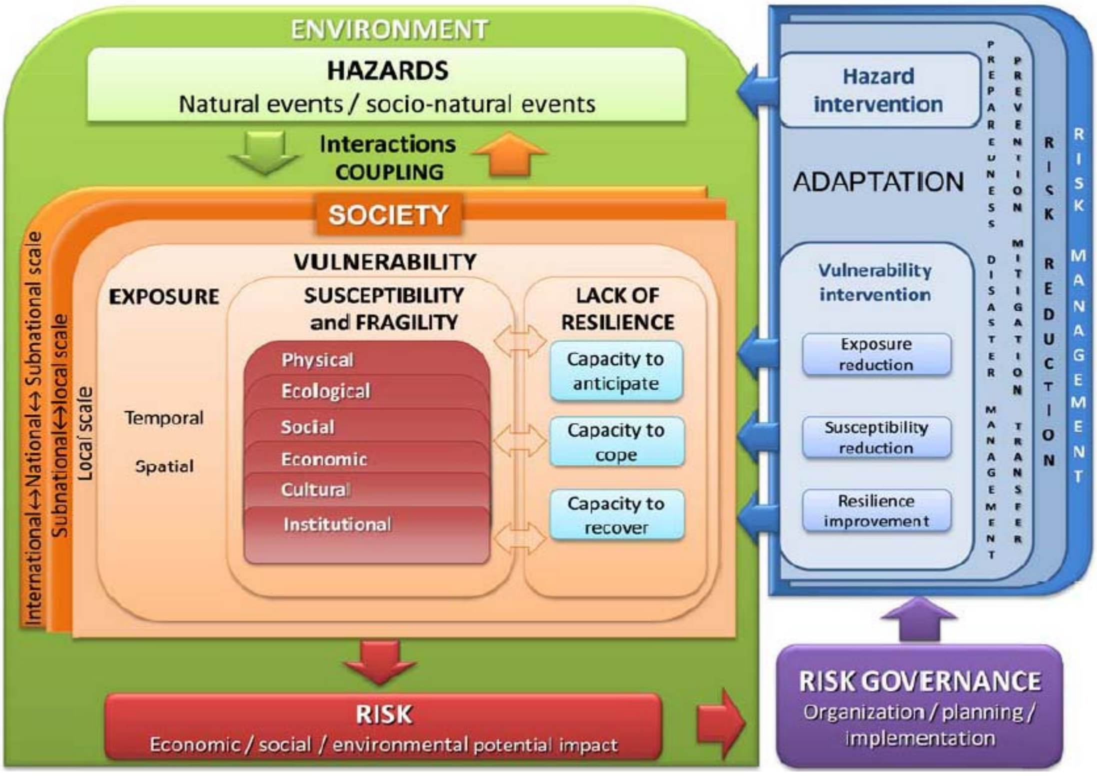


Figure 5.1: Vulnerability framework defined by the MOVE project

The MOVE conceptual framework presented in Figure 5.1 addresses vulnerability and risk to natural hazards from a holistic and multidimensional point of view. The framework illustrates two concepts:

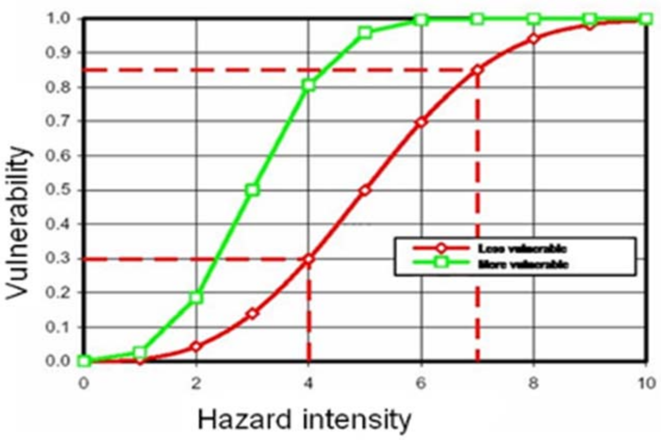
- Risk is the result of the exposure of society to hazards, in time and space , and of the vulnerability of the society.
- Risk management and adaptation aim to modify the initial vulnerability conditions or hazards.

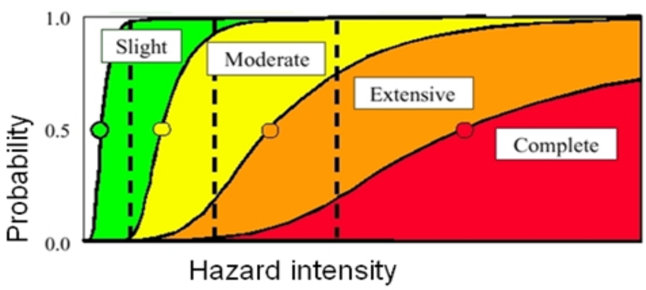
Hazard propagation will expose a particular area and its society. Vulnerability is a combined result of exposure, susceptibility (fragility) and resilience (capacity to anticipate, cope and recover). Identification and awareness of hazards, vulnerability and risk are essential steps to establish effective management of risk caused by geological, hydro-meteorological and anthropogenic or technological hazards.
Susceptibility and fragility (See Figure 5.1) are vulnerability conditions that reflect the predisposition (weaknesses and lack of strength) that can be expressed in physical, social, environmental or economic terms.
The lack of resilience is another important vulnerability factor that reflects the capacity level of a society to anticipate (to intervene proactively the risk conditions), to adapt (to be prepared to face future hazardous events), as well as to cope and recover effectively when such events occur. A lack of these capacities increases the vulnerability of the society.

5.5 MEASURING PHYSICAL VULNERABILITY

Vulnerability can be expressed or presented in various ways (Calvi et al., 2006).

- **Vulnerability indices** are based on indicators of vulnerability and are mostly used for holistic vulnerability, capacity and resilience assessment. Vulnerability tables show the relation between hazard intensity and degree of damage in the form of a table.
- **Vulnerability curves** display the relation between hazard intensity and degree of damage for a group of elements-at-risk (e.g., a certain building type) ranging from 0 to 1. Different types of elements-at-risk will show different levels of damage given the same intensity of hazard (see Figure 3). Vulnerability curves can





be relative curves (showing the percentage of property value damaged) or absolute (show the absolute amount of damage).

- **Fragility curves** provide the probability for a particular group of element at risk to be in or exceeding a certain damage state (e.g., complete destruction, extensive damage, moderate damage, and slight damage) under a given hazard intensity (FEMA, 2004). A damage probability matrix (DPM) indicates the probability that a given structural typology will be in a given damage state for a given intensity.

Flooding	**Landslides**	**Earthquakes**
Water depth Flow velocity Flow duration Wave height Time of onset Water-level ascend rate	Ground movement-displacements Velocity of ground movement Run-out distance Impact forces from rock falls	Mercalli intensity Peak ground acceleration Peak ground velocity Permanent ground displacement Spectral acceleration

Table 5.1: Examples of intensity measures for vulnerability

Measuring physical vulnerability is a complicated process, and can be done using either empirical or analytical methods (Lang, 2002). Empirical methods are either based on damage data from historical hazard events, or on expert opinion. For events that are relatively frequent and widespread, it is possible to collect information on the degree of physical damage to buildings or infrastructure after the event has occurred (e.g., Reese et al., 2007). This method is particularly suited for flooding and for earthquakes, which normally affect many buildings that are of the same type, and allow generating large enough samples in order to make a correlation between the hazard intensity (e.g., modified Mercalli intensity, ground acceleration, water depth, etc.) and the degree of damage. The result is either a DPM or a vulnerability curve. In many situations expert opinion will be the most feasible option for obtaining vulnerability information, either because there is no prior damage information and not enough funding to apply analytical methods, or because building classifications used elsewhere do not reflect the local building stock (Douglas, 2007). This method involves the consultation of a group of experts on vulnerability to give their opinion (e.g., on the percentage damage they expect for the different structural types with different intensities of hazard). Analytical methods are used to study the behaviour of buildings and structures based on engineering design criteria, analyzing the seismic load to derive the likelihood of failure, using physical modelling tests (e.g., shake tables or wind tunnels), as well as computer simulation techniques. Analytical methods are able to model the relation between the intensity of the hazard and the level of damage of objects.

However, they require detailed numerical input data. For instance, in the case of earthquake vulnerability analysis of buildings, it is important to have geotechnical reports to establish the value of the effective peak acceleration coefficient, the value of the effective peak velocity-related acceleration coefficient, and the soil-profile type. Spectral acceleration should also be obtained. One of the common tests is using a shake table. This is a device for shaking structural models or building components with a wide range of simulated ground motions, including reproductions of recorded earthquakes time-histories (Calvi et al., 2006).

Group	Method	Description
Empirical methods	**Analysis of observed damage**	Based on the collection and analysis of statistics of damage that occurred in recent and historic events. Relating vulnerability to different hazard intensities.
	Expert opinion	Based on asking groups of expert on vulnerability to give their opinion e.g. on the percentage damage they expect for the different structural types having different intensities of hazard. In order to come to a good assessment of the vulnerability, many expert have to be asked and this is time consuming, and subjective in general. Re-assessments of vulnerability after building upgrading or repair are difficult to accommodate.
	Score Assignment	Method using a questionnaire with different parameters to assess the potential damages in relation to different hazard levels. The score assignment method is easier to update e.g. if we think about earthquake vulnerability before and after application of retrofitting.
Analytical models	**Simple Analytical models**	Studying the behavior of buildings and structures based on engineering design criteria, analyzing e.g. seismic load and to derive the likelihood of failure, using computer based methods from geotechnical engineering. Using e.g. shake tables and wind tunnels, as well as computer simulation techniques;
	Detailed Analytical methods	Using complex methods. It is time consuming, needs a lot of detailed data and will be used for assessment of individual structures

Table 5.2: Overview of methods for physical vulnerability assessment

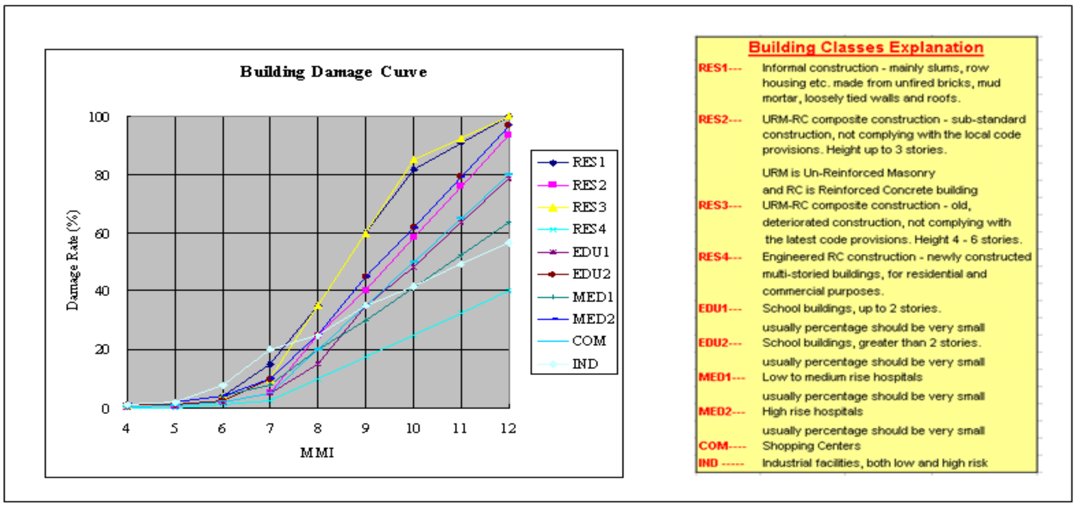


Figure 5.3: Example of a simple set of earthquake vulnerability curves following the Radius method.

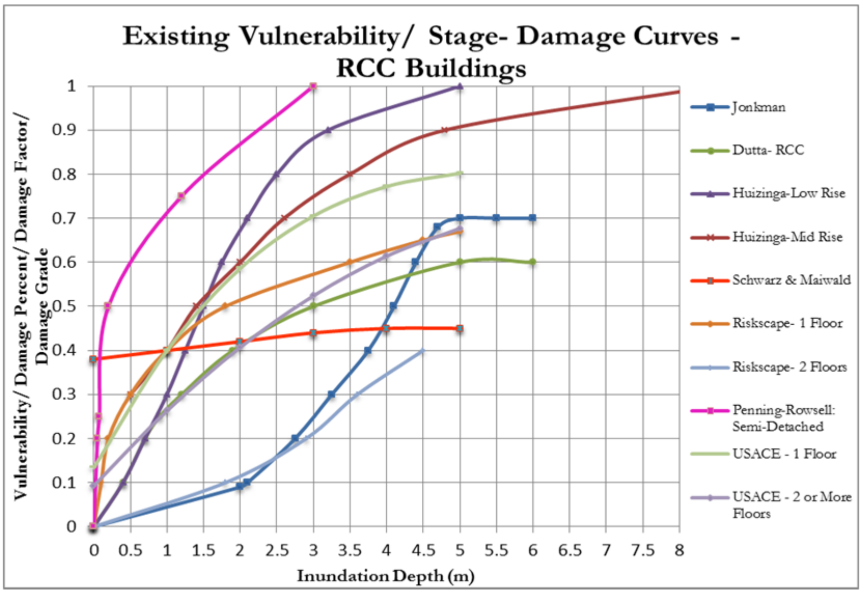


Figure 5.4: Variation in vulnerability curves from different areas, for the same type of buildings.

Most of the work on the measurement of physical vulnerability is done for earthquakes, floods and windstorms (FEMA, 2004). Even though flood vulnerability has been defined in a rather detailed manner (Moel et al., 2009), there are still many uncertainties involved. For volcanic hazards much progress in defining vulnerability has been made in recent years (Spence et al., 2004, 2005). For mass movement, less work has been done on defining vulnerability (Glade, 2003), partly due to the large variation in mass movement processes, the difficulty in expressing landslide intensity versus the degree of damage, and limited amount of landslide-damage data. Some approaches exist for single landslide types such as debris flows (e.g., Fuchs et al., 2007), but an integrated methodology is still lacking. Hollenstein (2005) developed an approach for multi-hazard vulnerability assessment by defining hazards with a common set of parameters (e.g., acceleration, pressure, and temperature change) and fragility functions, that are defined in terms of these common parameters so that they are applicable to all risks.

Population vulnerability can be subdivided into direct physical population vulnerability (injury, casualties, and homelessness) and indirect social vulnerability and capacity. Physical population vulnerability is mostly carried out after a building-vulnerability study by analyzing the effect of the building damage on the population inside, using different injury severity classes. Empirical relations exist for different types of hazards, although most information is available for earthquakes (Coburn and Spence, 2002; FEMA, 2004). For volcanic hazards, such relations were made among others by Spence et al. (2005), for landslides by Glade et al. (2005), for drought by Wilhite (2000) and for flooding and windstorms by FEMA (2004).

Injury Severity Level	Description Of Injury
Severity 1	Requiring basic medical aid without requiring hospitalization
Severity 2	Requiring a greater degree of medical care and hospitalization, but not expected to progress to a life threatening status
Severity 3	Pose an immediate life threatening condition if not treated adequately and expeditiously. The majority of these injuries are the result of structural collapse and subsequent entrapment or impairment of the occupants.
Severity 4	Instantaneously killed or mortally injured

Table 5.3: Injury severity levels as indicated in the HAZUS methodology.

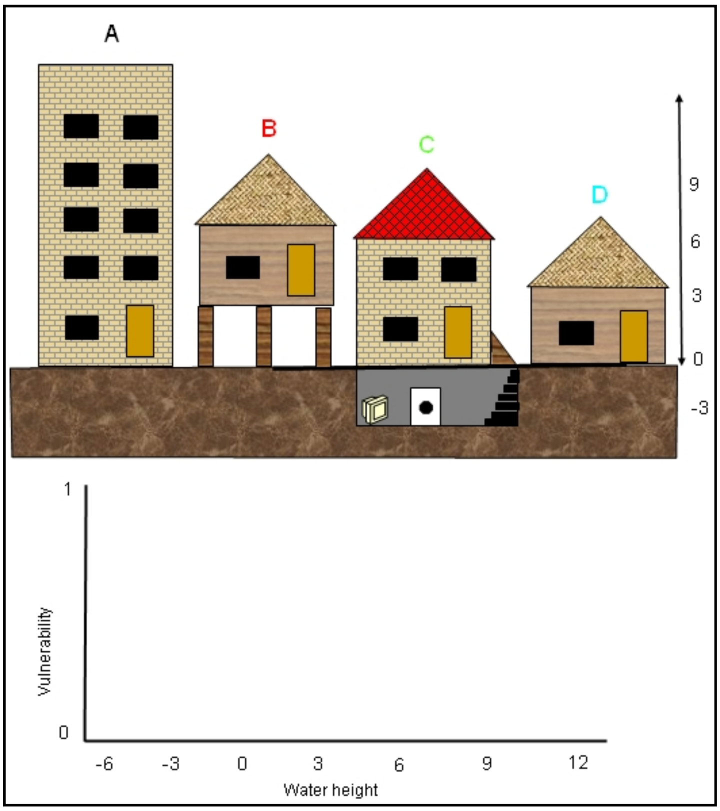
Several methods exist for linking of building damage to these severity levels. Table 5.4 gives the information used in HAZUS for earthquake vulnerability of people. HAZUS doesn't make similar estimates for flooding and hurricanes due to lack of data.

Structural damage	Structural type	Affected people (values are in percentage)			
		Severity 1	Severity 2	Severity 3	Severity 4
Complete (collapse)	Most structural types	40	20	3-5	5-10
	Masonry	40	20	5	10
Complete (no collapse)	Most structural types	5	1	0.01	0.01
	Masonry	10	2	0.02	0.02
Extensive	Most structural types	1	0.1	0.001	0.001
	Masonry	2	0.2	0.002	0.002
Moderate	Most structural types	0.20 – 0.25	0.025 – 0.03	0	0
	Masonry	0.35	0.4	0.001	0.001
Slight	Most structural types	0.05	0	0	0
	Masonry	0.05	0	0	0

Table 5.8: Population vulnerability used in the HAZUS method for earthquake losses.

Exercise: Expert opinion in generating a vulnerability curve

In figure 5.5 there are 4 different buildings, each with different characteristics. Imagine the flood will take place in the area, and the waterlevel is rising slowly but constantly. How would the four buildings be affected? Draw 4 approximate vulnerability curves in the graph.



5.6 HOLISTIC VULNERABILITY ASSESSMENT

The methods described above aim at quantifying physical vulnerability to natural hazards, and mostly follow an engineering approach that is restricted to quantifying the physical effects of disasters on buildings, other infrastructure, and secondary effects of these related to casualties and economic losses. Other approaches also exist that look at vulnerability in a holistic way, and try to incorporate all the components of vulnerability using an indicator approach (qualitative).

One of the methods that has been used extensively in holistic vulnerability assessment is called Spaial Multi-Criteria Evaluation. The input is a set of maps that are the spatial representation of the criteria, which are grouped, standardised and weighted in a 'criteria tree.' The output is one or more 'composite index map(s),' which indicates the realisation of the model implemented.

From a decision-making perspective, multi-criteria evaluation can be expressed in a matrix as shown in Figure 5.5. The matrix A contains the criteria in one axis (C_1 to C_n), and a list of possible alternatives, from which a decision has to be taken on the other axis (A_1 to A_m). Each cell in the matrix (a_{ij}) indicates the performance of a particular alternative in terms of a particular criterion. The value of each cell in the matrix is composed of the multiplication of the standardised value (between 0 and 1) of the criterion for the particular alternative, multiplied by the weight (W_1 to W_n) related to the criterion. Once the matrix has been filled, the final value can be obtained by adding up all cell values of the different criteria for the particular alternative (e.g. a_{11} to a_{1n} for alternative A_1).

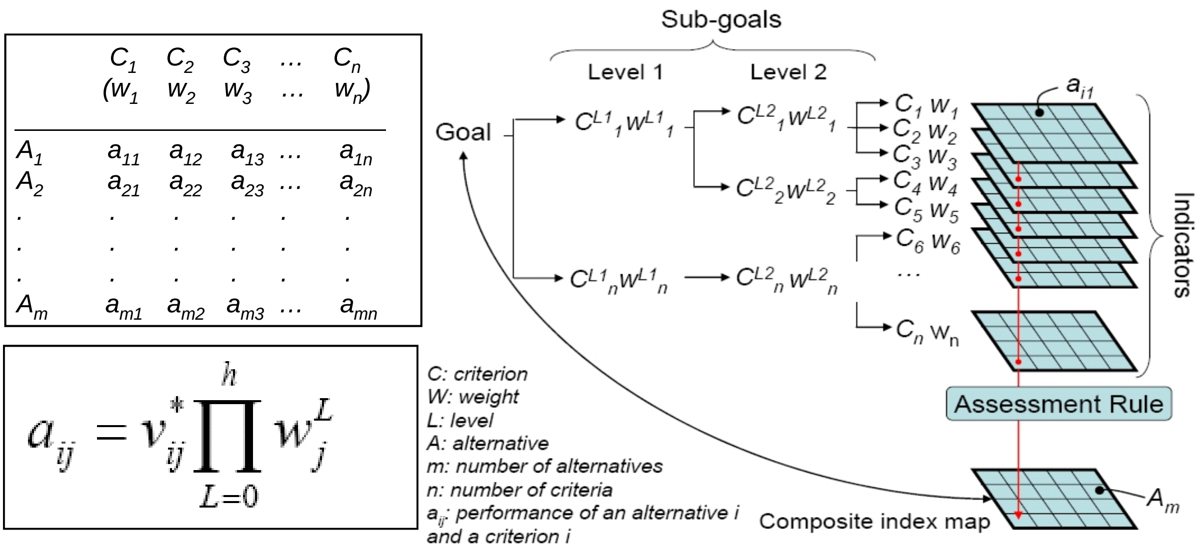


Figure 5.5. Schematic procedure for spatial multi-criteria evaluation based on the analytical hierarchical process

For implementing this matrix three principles steps need to be considered. The first one decomposes the problem (and the weights) into a hierarchical structure. The second one considers the weighting process, employing the pairwise comparisons of the criteria, and the synthesis is related to the multiplications among the hierarchical levels. Additionally, in the spatial implementation of this procedure, every criterion (C_j) becomes a raster layer, and every pixel (or set of pixels) of the final composite index map eventually becomes an alternative *Aj*. The goal (risk index) has been decomposed into criteria levels C_{L1} and C_{L2}. The intermediate levels are often indicated as sub-goals or objectives (e.g. in level 1, the sub-goals are a 'hazard index' and a 'vulnerability index'). Each criterion of each level will also have an assigned weight. Therefore, the values for the layers of the intermediate levels are obtained through the summation of the performance for the alternative at lower levels. As the criteria consist of raster maps, their spatial performance (a_{ij}) and the alternative (A_i) will be identified for particular raster cells.

The composite risk index map is obtained by an assessment rule (sometimes also called decision rule), which is calculated by adding up the performance of all cell values of the different criteria (a_{ij}) for the particular alternative.

Figure 5.6 gives an example of the Decision Tree, including the groups, indicators, and weights for the holistic vulnerability assessment in Georgia.

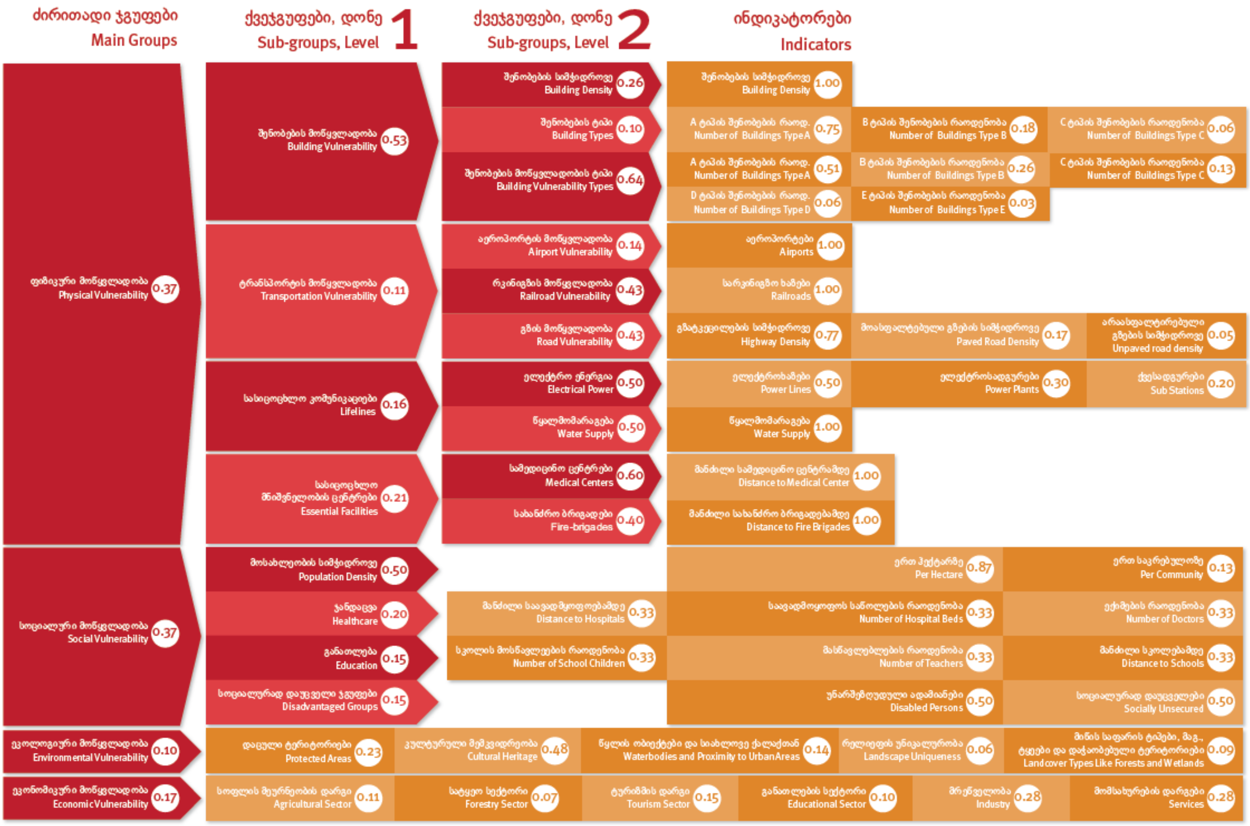


Figure 5.5: Decision tree used for Spatial Multi Criteria Evaluation for vulnerability assessment in Georgia.

6.MULTI-HAZARD RISK ASSESSMENT

A framework of multi-hazard risk assessment is presented in Figure 6.1 that identifies various components. The first component (A) represents the input data, which can be subdivided in datasets required for generating susceptibility maps, triggering factors, multi-temporal inventories and elements-at-risk (treated in chapter 4). The second component (B) focuses on susceptibility assessment, and is divided into two parts. The first one dealing with the modelling of areas where the hazard may initiate (e.g., earthquakes, landslide initiation, hydrological modelling, soil erosion, volcanic eruptions), which can make use of a variety of different methods (inventory based, heuristic, statistical, physically-based models). The resulting maps form the input as source areas in the modelling of potential spreading of the phenomena (e.g. spreading of volcanic deposits, landslide run-out, flood extent modelling, seismic amplification, forest fire spreading).

The third component (C) deals with hazard assessment, which heavily depends on the availability of magnitude-frequency information. The susceptibility maps together with the magnitude-frequency relations of the triggering events are used to determine three components that are needed for the hazard assessment: 1) the spatial probability (indicating the probability that a given area will be affected by the hazard of a given intensity); 2) the temporal probability (indicating the probability of the event to happen in time); and 3) the magnitude probability (indicating the probability that the hazard event will have a given magnitude) (Corominas and Moya, 2008).

The fourth section (D) focuses on vulnerability assessment and indicates the various types of vulnerability assessment approaches that can be used. Section E in Figure 6.1 gives the concept of risk assessment which integrates the hazard, vulnerability and amount of elements-at-risk. The specific risk is calculated for many different situations, related to hazard type, hazard intensity, return period of the triggering event, and type of element at risk. The integration of hazard, vulnerability and risk can be done in two ways: quantitative or qualitative.

Component F present the quantitative risk approach in which the results are shown in risk curves plotting the expected losses against the probability of occurrence for each hazard type individually, and expressing also the uncertainty, by generating two loss curves expressing the minimum and maximum losses for each return period of triggering events, or associated annual probability. The individual risks curves can be integrated into total risk curves for a particular area and the population loss can be expressed as F-N curves.

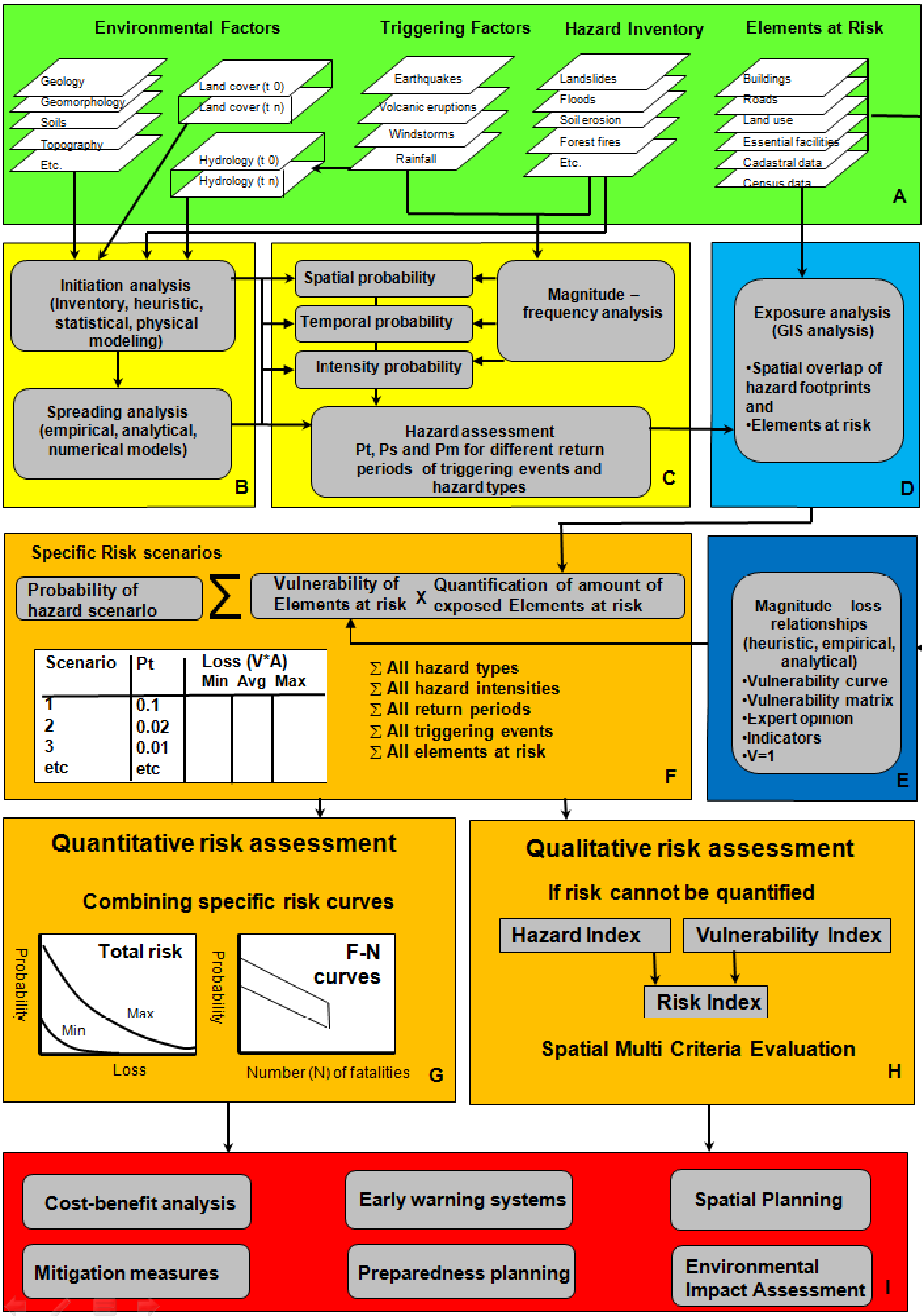


Figure 6.1 : Framework of the use of GIS for multi-hazard risk assessment, based on Van Westen et al (2005, 2008).

The risk curves can be made for different basic units, e.g. administrative units such as individual slopes, road sections, census tracts, settlements, municipalities, regions or provinces.

Component G deals with methods for qualitative risk assessment, which are mostly based on integrating a hazard index, and a vulnerability index, using Spatial Multi Criteria Evaluation. The last component (H) deals with the use of risk information in various stages of Disaster Risk Management.

Hazards will impact different types of elements-at-risk, and it is therefore important to calculate the risk for different sectors/environments (e.g., housing, agriculture, transportation, education, health, tourism, protected areas, forests, wetlands, etc.). Risk assessment should involve the relevant stakeholders (i.e., individuals, businesses, organizations, and authorities). The methodology for conducting risk assessments can be broadly classified into qualitative and quantitative approaches.

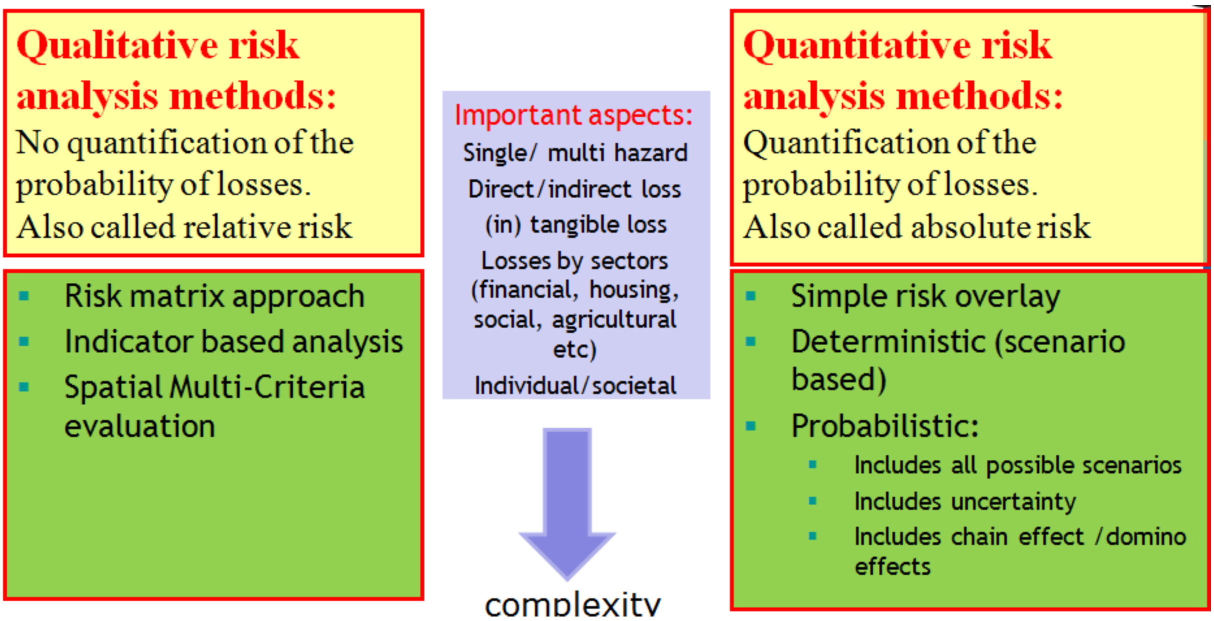


Figure 6.2 : Types of approaches for risk assessment.

6.1 QUALITATIVE APPROACHES

Qualitative methods for risk assessment are useful as an initial screening process to identify hazards and risks. They are also used when the assumed level of risk does not justify the time and effort of collecting the vast amount of data needed for a quantitative risk assessment, and where the possibility of obtaining numerical data is limited.

Table 6.1: Types of input data that will be used for the hazard and risk assessment.

Type	Raster/Vector	Attributes	Remarks
Inventory maps	Polygons	yes	These are polygon maps of landslide and flood events with associated database related to the date of occurrence, damage and characterisation of the event.
Triggering factors	Points	yes	These can be either station data for meteorological stations, or stream gauging stations, with associated attribute databases , or point databases related to earthquake catalogs. Also line database for hurricane tracks.
Digital Elevation Models	Raster	no	Derived from SRTM, ASTER, TanDEM-X, or contour maps. Within the project no new DEMs will be generated.
Land use maps	Vector / raster		Dereived from satellite images, and existing maps for different time periods
Geological data	Vector	yes	These are either polygons maps related to geological units, line maps related to faults and lineaments. Also surface material maps are important with associated hydrological and geotechnical parameters.
Building footprints	Vector	Yes	Attribute data relates to the Structural Type, Occupancy Type, Economic Value (can be both of the structure and contents), and different Population values for population scenarios. Values and population data may be given with Average and Standard Deviation values.
Land parcels	Vector	Yes	
Linear structures	Vector	yes	
Point elements	Vector	yes	
Vulnerability tables	Not spatial	yes	Tables that contain for each type of Element-at-risk a column with intensity classes, and columns with vulnerability values. It is possible to add columns for total vulnerability, structural vulnerability and content vulnerability, and to use average and standard deviation values. The same tables will also store population vulnerability , which can be either casualty probability or injury probability. Also AVG and STD values can be used.
Administrative units	Vector	yes	User defined polygons for which the risk will be calculated. These units are the basis for further decision making
Alternative definition map	Vector	no	These maps are used for visualization purpose only. These are maps showing the risk reduction measures.
Cost information	Not spatial	yes	Costs of construction and maintenance related to the alternatives
Loss maps	Vector	yes	Loss maps have the same spatial units as the associated elements-at-risk, however, they contain information on the economic losses, and/or populations losses for a given hazard and a given return period.
Risk maps	Vector	yes	Different loss maps for events with different return periods and also for different elements-at-risk are combined according to the administrative units supplied by the user, and risk curves are generated from which the Average Annual Loss can be calculated for economic losses, as well as the societal risk and individual risk for population losses.

The simplest form of qualitative-risk analysis is to combine hazard maps with elements-at-risk maps in GIS, using a simple-risk matrix in which the classes are qualitatively defined (AGS, 2000). This method is widely applied, mostly at (inter)national or provincial scales where the quantitative variables are not available or they need to be generalized. Qualitative approaches consider a number of factors that have an influence on the risk. The approaches are mostly based on the development of so-called risk indices, and on the use of spatial multi- criteria evaluation. One of the first attempts to develop global-risk indicators was done through the Hotspots project (Dilley et al., 2005). In a report for the Inter-American Development Bank, Cardona (2005) proposed different sets of complex indicators for benchmarking countries in different periods (e.g., from 1980 to 2000) and to make cross-national comparisons. Four components or composite indicators reflect the principal elements that represent vulnerability and show the advances of different countries in risk management: 1) Disaster Deficit Index (DDI); 2) Local Disaster Index (LDI); 3) Prevalent Vulnerability Index (PVI); and 4) Risk Management Index (RMI). Each composite index is generated on the basis of a number of indicators. For instance, the DDI can be considered as an indicator of a country’s economic vulnerability to disaster. The method has been applied thus far only in Latin America and the Caribbean. Peduzzi et al. (2005, 2009) have developed global indicators, not on the basis of administrative units, but based on gridded maps. The Disaster Risk Index (DRI) (UN-ISDR, 2005b) combines both the total number and the percentage of killed people per country in large- and medium-scale disasters associated with droughts, floods, cyclones and earthquakes based on data from 1980 to 2000. In the DRI, countries are indexed for each hazard type according to their degree of physical exposure, their degree of relative vulnerability, and their degree of risk.

At local scales, risk indices are also used, often in combination with spatial multi-criteria evaluation (SMCE). Castellanos and Van Westen (2007) present an example of the use of SMCE for the generation of a landslide-risk index for the country of Cuba, generated by combining a hazard index and a vulnerability index. The hazard index is computed using indicator maps related to event triggering factors (earthquakes and rainfall) and environmental factors. The vulnerability index was made using five key indicators including housing condition and transportation (physical-vulnerability indicators), population (social-vulnerability indicator), production (economic-vulnerability indicator) and protected areas (environmental-vulnerability indicator). The indicators were based on polygons related to political-administrative areas, which are mostly at municipal level. Each indicator was processed, analysed and standardized according to its contribution to hazard and vulnerability. The indicators were weighted using direct, pair-wise comparison and rank-ordering weighting methods, and weights were combined to obtain the final landslide risk-index map. The results were analysed per physiographic region and administrative units at provincial and municipal levels. Another example at the local level is presented by Villagrán de León (2006), that incorporates 3 dimensions of vulnerability, the scale/level (from human being to national level), the various sectors of society, and 6 components of vulnerability. The method uses matrices to calculate a vulnerability index, which was grouped in qualitative classes (high, medium and low).

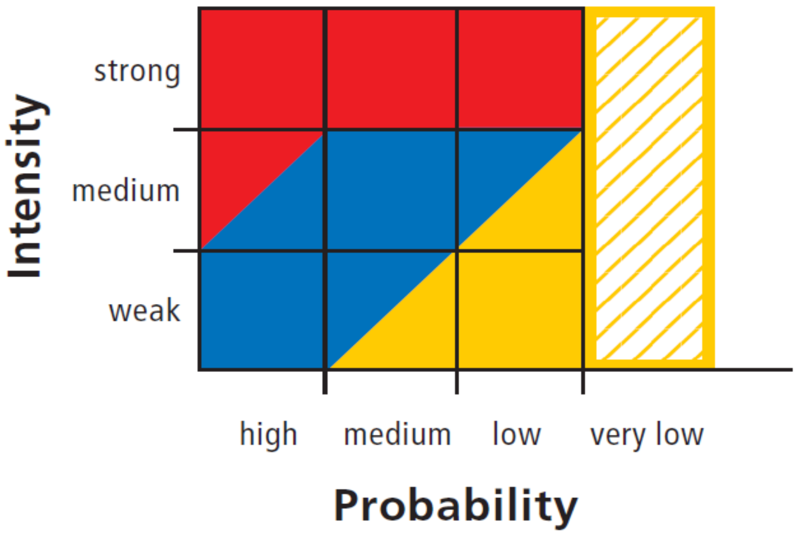


Figure 6.3 : Swiss danger index, as a matrix with X-axis of probability classes and Y-axis of intensity classes.

6.2 QUANTITATIVE APPROACHES

Quantitative approaches aim at expressing the risk in quantitative terms either as probabilities, or expected losses. They can be deterministic (scenario-based) or probabilistic (taking into account the effect of all possible scenarios and uncertainties). Quantitative Risk Assessment (QRA) follows an engineering approach and focus on the evaluation of the direct physical losses resulting directly from the impact of the hazard (e.g. flooded buildings, collapsed buildings). Some also analyze indirect losses due to loss of function (e.g., disruption of transport, business losses, or clean up costs). The focus is on tangible losses that have a monetary (replacement) value. Disasters also cause a large amount of intangible losses for example, lives and injuries, cultural heritage, environmental quality, and biodiversity. For multiple sources of a particular hazard e.g. earthquakes or tsunami, some form of probabilistic modelling is needed. In other situations, “what if?” questions about particular events occurring may be more relevant - these can be addressed by modelling scenarios.

- Probabilistic Modelling: Particularly useful where the risk of damage to a region can arise from multiple sources of a hazard, e.g. earthquakes, volcanoes and tsunami. A probability distribution of hazard magnitudes and average recurrence intervals needs to be assigned to each source. Then, using a Monte Carlo approach, the impacts of many possible events can be simulated to derive the risk profile for a particular target locality.

- Scenario Modelling: The generation of specific hazard scenarios, with the same average recurrence interval, is essential to compare impacts across several hazards. Scenarios are also useful to discover the potential impacts of "what if?" scenarios, e.g. if a breach occurs in a stop bank at a critical location or if, after a volcanic eruption, the wind blows persistently in a particularly direction. Such "what if" scenarios are difficult to assign probabilities of occurrence.

Quantitative risk assessment aims at quantifying the risk according to the equation given in Figure 8. There are several approaches, which differ in the way to calculate the hazard or to calculate vulnerability and consequences. For a number of different hazard scenarios, the consequences are plotted against the temporal probability of occurrence of the hazard events in a graph. Through these points a curve is fitted, the so-called risk curve, and the area below the curve presents the total risk. This procedure is carried out for all individual hazard types, and care should be taken to evaluate interrelations between hazards. 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. The (epistemic and aleatory) uncertainties are incorporated in the modelling and used to calculate Exceedance Probability Curves, Average Annual Losses (AAL) and Probable Maximum Losses (PML).

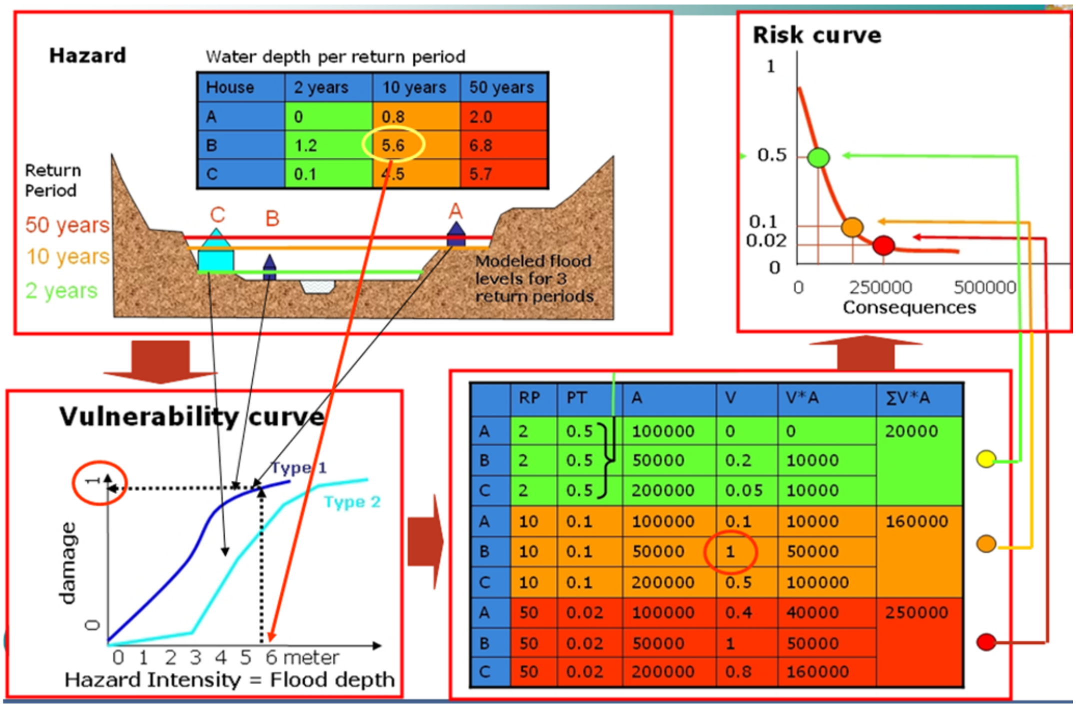


Figure 6.4: Calculation of a risk curve for flooding.

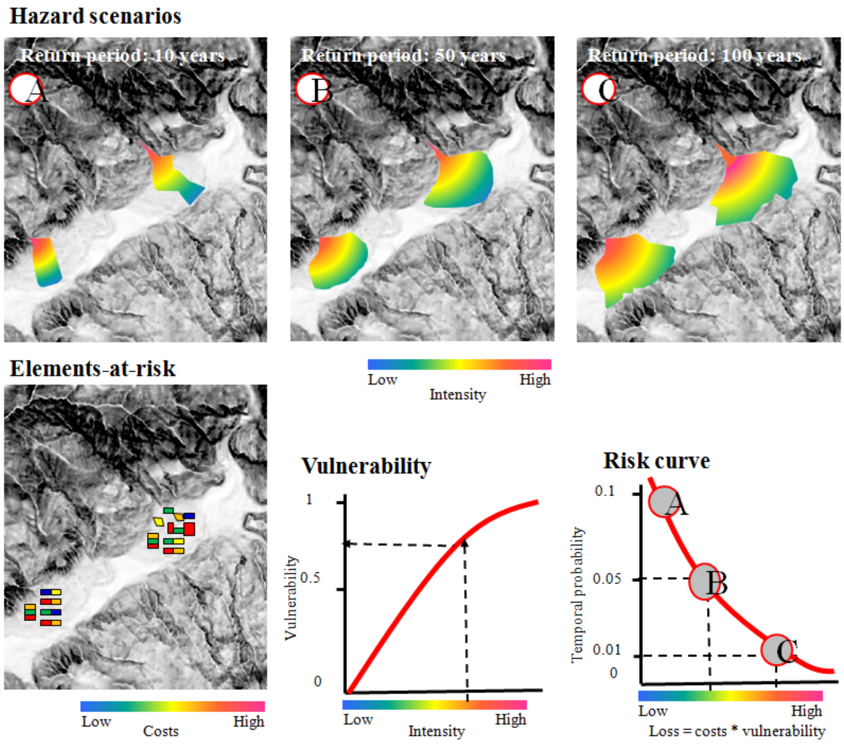


Figure 6.5: Generating risk information using different temporal scenarios.

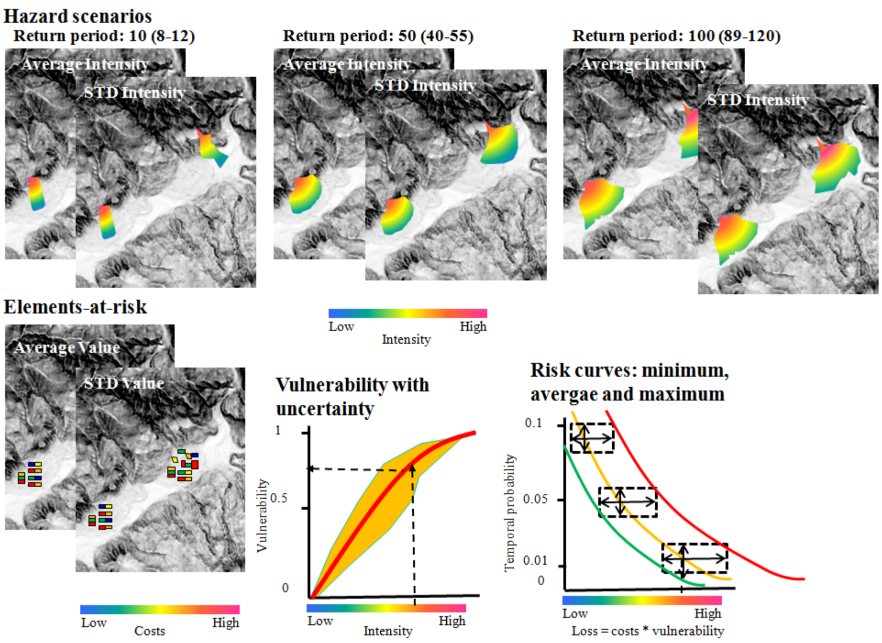


Figure 6.6 : Risk Assessment Approach incorporating uncertainties.

6.3 MULTI-HAZARDS CONCEPT

A generally accepted definition of multi-hazard still does not exist. In practice, this term is often used to indicate all relevant hazards that are present in a specific area, while in the scientific context it frequently refers to "more than one hazard".

Likewise, the terminology that is used to indicate the relations between hazards is unclear. Many authors speak of interactions (Tarvainen et al. 2006, de Pippo et al. 2008, Marzocchi et al. 2009, Zuccaro and Leone 2011, European Comission 2011), while others call them chains (Shi 2002), cascades (Delmonaco et al. 2006a, Carpignano et al. 2009, Zuccaro and Leone 2011, European Comission 2011), domino effects (Luino 2005, Delmonaco et al. 2006a, Perles Roselló and Cantarero Prados 2010, van Westen 2010, European Comission 2011), compound hazards (Alexander 2001) or coupled events (Marzocchi et al. 2009).

There are many factors that contribute to the occurrence of hazardous phenomena, which are either related to the environmental setting (topography, geomorphology, geology, soils etc.) or to anthropogenic activities (e.g. deforestation, road construction, tourism). Although these factors contribute to the occurrence of the hazardous phenomena and therefore should be taken into account in the hazard and risk assessment, they are not directly triggering the events. For these we need triggering phenomena, which can be of meteorological or geophysical origin (earthquakes, or volcanic eruptions). Figure 2 illustrates the complex interrelationships between multi-hazards potentially affecting the same mountainous environment. This graphic indicates that a multitude of different types of interrelations exists.

The first multi-hazard relationship is therefore between different hazard types that are triggered by the same triggering event. These are what we would call coupled events (Marzocchi et al., 2009). The temporal probability of occurrence of such coupled events is the same as it is linked to the probability of occurrence of the triggering mechanism.

For analyzing the spatial extent of the hazard, one should take into account that when such coupled events occur in the same area and the hazard footprints overlap, the processes will interact, and therefore the hazard modeling for these events should be done simultaneously, which is still very complicated. In order to assess the risk for these multi-hazards, the consequence modeling should therefore be done using the combined hazard footprint areas, but differentiating between the intensities of the various types of hazards and using different vulnerability-intensity relationships. When the hazard analyses are carried out separately, the consequences of the modeled scenarios cannot be simply added up, as the intensity of combined hazards may be higher than the sum of both or the same areas might be affected by both hazard types, leading to overrepresentation of the losses, and double

counting. Examples of such types of coupled events is the effect of an earthquake on a snow-covered building (Lee & Rosowsky, 2006) and the triggering of landslides by earthquakes occurring simultaneously with ground shaking and liquefaction (Delmonaco et al. 2006b, Marzocchi et al. 2009).
Another, frequently occurring combination are landslides, debris flows and flashfloods caused by the same extreme rainfall event. The consideration of these effects is fundamental since chains "expand the scope of affected area and exaggerate the severity of disaster" (Shi et al. 2010).
A second type of interrelations is the influence one hazard exerts on the disposition of a second peril, though without triggering it (Kappes et al. 2010). An example is the "fire-flood cycle" (Cannon & De Graff, 2009): forest fires alter the susceptibility to debris flows and flash floods due to their effect on the vegetation and soil properties.
The third type of hazard relationships consists of those that occur in chains: one hazard causes the next. These are also called domino effects, or concatenated hazards. These are the most problematic types to analyze in a multi-hazard risk assessment.
The temporal probability of each hazard in a chain is dependent on the temporal probability of the other hazard causing it. For example a landslide might block a river, leading to the formation of a lake, which might subsequently result in a dam break flood or debris flow. The probability of the occurrence of the flood is depending on the probability of the landslide occurring in that location with a sufficiently large volume to block the valley. The occurrence of the landslide in turn is related to the temporal probability of the triggering event. The only viable solution to approach the temporal probability of these concatenated hazards is to analyze them using Event Trees (e.g. Egli 1996 or Marzocchi et al., 2009) a tool which is applied extensively in technological hazard assessment, but is still relatively new in natural hazard risk assessment. Apart from analyzing the temporal probability of concatenated events, the spatial probability is often also a challenge, as the secondary effect of one hazard (e.g. the location of damming of a river) is very site specific and difficult to predict. Therefore a number of simplified scenarios are taking into account, often using expert judgment.

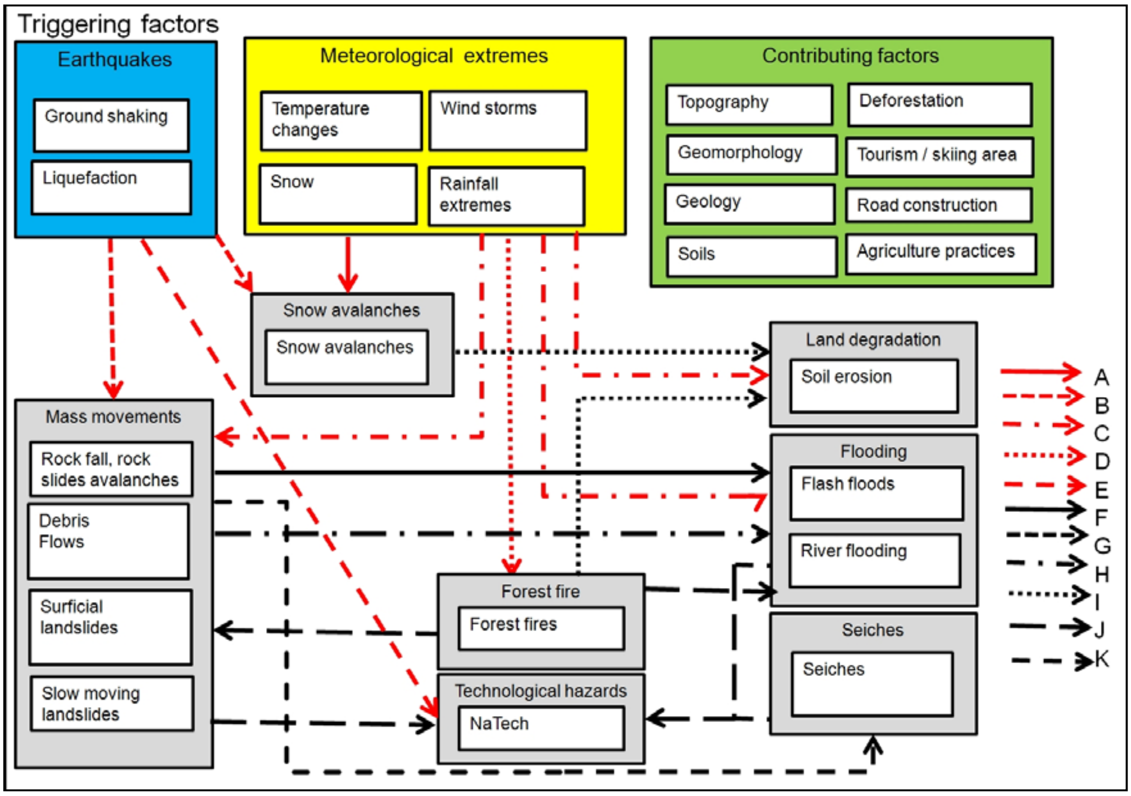


Figure 6.7 : Multi-hazard in a mountainous environment, and their interrelationships. Above the triggering factors are indicated (earthquakes, meteorological extremes), and the contributing factors. The red arrows indicate the hazards triggered simultaneously (coupled hazards). The black arrows indicate the concatenated hazards: one hazard causing another hazard over time. (A) Snow accumulation causing snow avalanches; (B) earthquakes triggering landslides and snow avalanches simultaneously; (C) Extreme precipitation causing landslides, debris flows, flooding and soil erosion; (D) drought and/or lightning causing forest fires; (E) earthquakes causing technological hazards; (F) mass movements damming rivers causing dam break floods; (G) large rapid landslides or rockfalls in reservoirs causing seiches; (H): debris flows turning into floods in the downstream section; (I) snow avalanches or forest fires leading to soil erosion; (J) forest fires leading to surficial landslides, debris flows and flashfloods; (K) landslides, debris flows or floods leading to technological hazards.

6.4LOSS ESTIMATION MODELS

Loss estimation modelling science has originated from the fields of property insurance and the science of natural hazards. Loss estimation has been carried out in the insurance sector since the late 1980’s using geographic information systems (Grossi, Kunreuther and Patel, 2005). Computer-based models for loss estimation were developed by combination of natural hazard studies with historical information and spatial analysis using GIS. This Chapter presents the main types of loss estimation modelling tools, which will be further described in detail later in the report.

6.4.1 Commercial catasthrope models

Since the end of the 1980's risk modelling has been developed by private companies, resulting in a range of proprietary software models for catastrophe modelling for different types of hazards. Nowadays a limited number of specialized risk modelling companies are dominating the market for the (re)insurance sector, such as:

- Risk Management Solutions (RMS) was formed in 1988 at Stanford University. RMS models risk in over 100 countries, allowing stakeholders to analyze the probability of losses in regions with the highest exposure. The models are built using detailed data reflecting highly localized variations in hazards, and databases capturing property and human exposures.
- EQECAT began in San Francisco in 1994 as a subsidiary of EQE International. In 2001, EQE International became a part of ABS consulting. Through its modelling platform, WORLDCATenterprise, EQECAT supports clients to model financial impact of natural hazards. The tool includes 181 natural hazard software models for 95 countries in 6 continents.
- AIR Worldwide was founded in 1987 in Boston. AIR Worldwide is active in more than 90 countries. More than 400 insurance, reinsurance, financial, corporate and government organizations work with the output of the models from AIR Worldwide. AIR is a member of the Verisk Insurance Solutions group.
- RMSI was founded in 1993 in New Delhi, India as a joint venture with RMS, USA, and become independent in 2011. RMSI develops innovative solutions that integrate geographic information with niche business applications. RMSI has over 150 active clients in 30 countries.

Apart from these there are also a number of organizations that have specialized systems for loss estimation, such as the main reinsurance companies (e.g. SwissRE, MunichRe, Willis, AON).

Complicated catastrophe modelling tools have been developed, for windstorms, earthquakes, flooding and other types of hazards. However, these models are proprietary and are not publicly available, which is a major obstacle to the development of risk assessment for many parts of the world by government organizations. The four basic components of a catastrophe model are: hazard, inventory of elements-at-risk, vulnerability, and loss. The hazard modelling is generally using a stochastic set of possible events, based on historical occurrence and modelling. The models generally provide information in the form of Loss Exceedance Curve (LEC). For a given portfolio of structures at

risk, an LEC curve is a graphical representation of the probability that a certain level of loss will be surpassed in a given time period. The exceedance probability curve enables to determine the PML or Probable Maximum Loss for a given number of elements-at-risk.
The insurance industry is currently working with the Association for Cooperative Operations Research and Development (ACORD) to develop an industry standard for collecting and sharing exposure data. To date, the industry has been operating on closed, proprietary data formats.

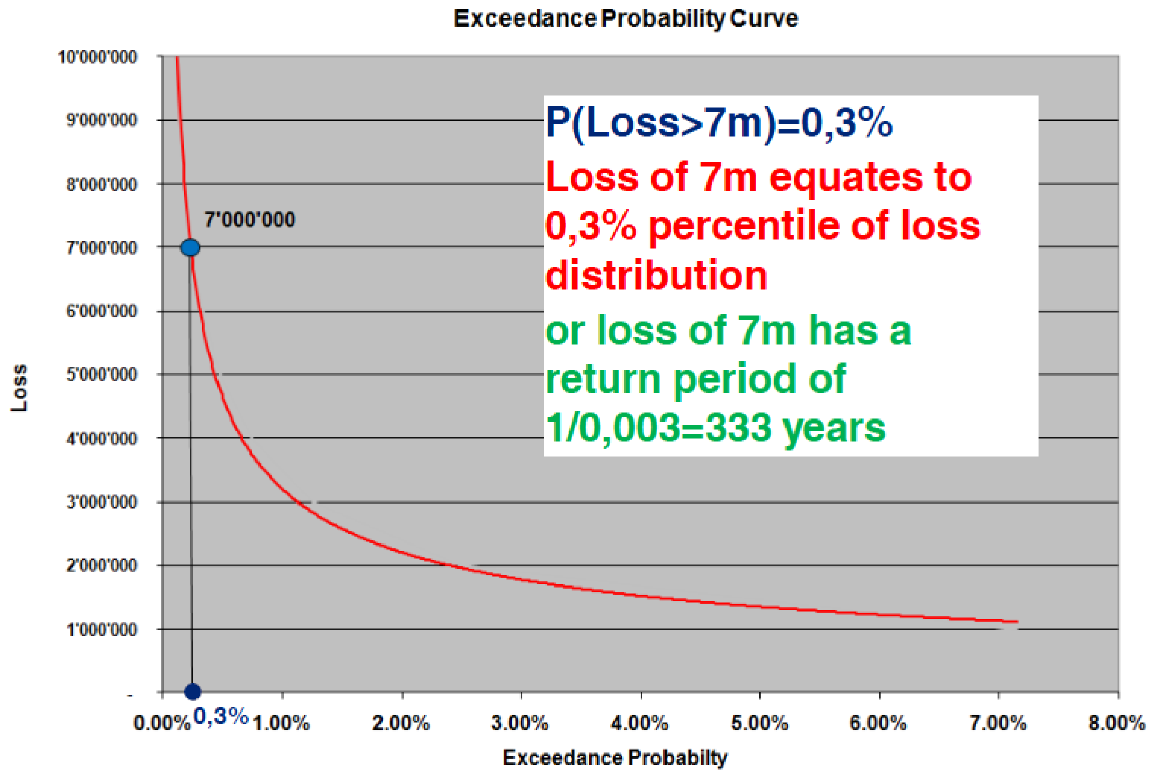


Figure 6.8 : Example of an Loss Exceedance curve

6.4.2 Publicly available simple tools

One of the first loss estimation methods that was publicly available was the RADIUS method (Risk Assessment Tools for Diagnosis of Urban Areas against Seismic Disasters), a simple tool to perform an aggregated seismic loss estimation using a simple GIS (RADIUS, 1999). The IDNDR secretariat launched the RADIUS initiative in 1996 to promote worldwide activities for the reduction of the urban seismic risk, which is growing rapidly particularly in developing countries, by helping the people understand their seismic risk and raise public awareness. The direct objectives were to develop earthquake damage scenarios and practical tools for seismic risk management, to conduct

a study to understand urban seismic risk around the world and to promote information exchange for seismic risk.
As part of the Radius initiative a simply tool was developed for earthquake loss estimation which was publicly available. The goal of this tool was to aid users in understanding the seismic hazard and vulnerability of their cities and to guide them in starting preparedness programs against future earthquakes. Designed in MS Excel to provide a simple and very familiar interface, the tool is user friendly, and provides risk-mapping functionality. The area of a city and probable loss to infrastructure and life is displayed as a mesh of rectangular cells that allows the user to get a graphical view of the data. Outputs are seismic intensity, building damage, lifeline damage, and causalities, which are presented in tabular as well as map forms.
Although the damage estimations provided by this tool are rough, the results of the program can be used in various ways. Through using this tool, users can gain a better understanding of earthquakes and the disasters associated with them. The potential extent of damage and the vulnerable points of the city are highlighted by the use of this tool. The information presented through this tool is very important and useful to manage effective seismic disaster reduction measures, including preparedness, emergency response activities, and seismic retrofit and recovery actions and policies. It can be concluded that the calculations of the damage amount should not be considered as a final goal of earthquake damage estimation, but instead as a starting point for seismic disaster reduction.

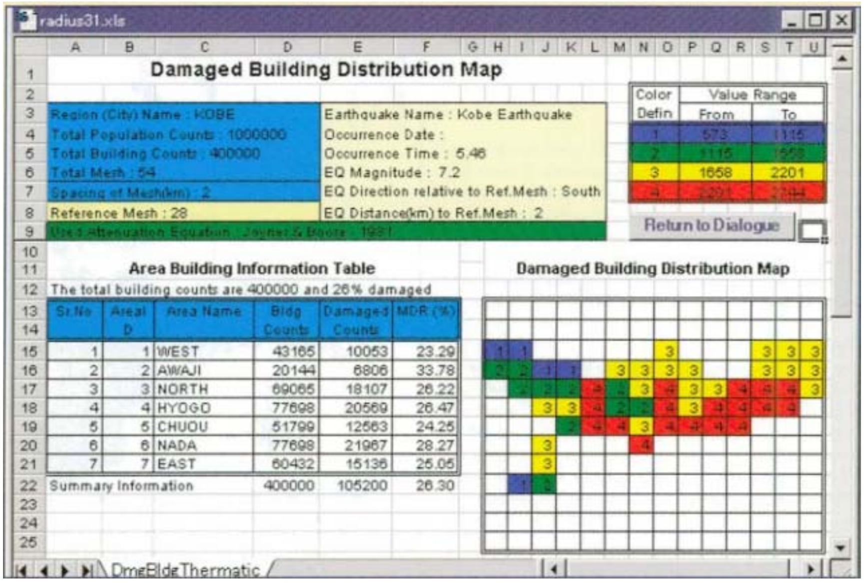


Figure 6.9 : Example of the Radius Excel tool for earthquake loss estimation.

6.4.3 GIS-based tools

Another major stream within the development of loss estimation tools has been on the development of software tools that run as add-ons or plugins of existing Geographic Information Systems. The best example of such systems that provide publicly available loss estimation tools thus far has been HAZUS (which stands for "Hazards U.S.") developed by the Federal Emergency Management Agency (FEMA) together with the National Institute of Building Sciences (NIBS, Buriks et al. 2004). The first version of HAZUS was released in 1997 with a seismic loss estimation focus, and was extended to multi-hazard losses in 2004, incorporating also losses from floods and windstorms (FEMA, 2004). HAZUS was developed as a software tool under ArcGIS. HAZUS is considered a tool for multi-hazard risk assessment, but the losses for individual hazards are analyzed separately for earthquakes, windstorms and floods. Secondary hazards (e.g. earthquakes triggered landslides) are considered to some degree using a basic approach. Although the HAZUS methodology has been very well documented, the tool was primarily developed for the US, and the data formats, building types, fragility curves and empirical relationships cannot be exported easily to other countries. Several other countries have adapted the HAZUS methodology to their own situation, e.g. in Taiwan (Yeh et al., 2006) and Bangladesh (Sarkar et al., 2010). Another successful and published international studies was performed by Bausch (2010), who developed an earthquake assessment framework on the Haiti earthquake with the major focus of aggregated inventory building data (General Building Stock) for potential damage assessment. There were no known publications about the internationally applied Hazus-MH Flood Model, until Kulmesch (Kulmesch et al. 2010) manually integrated local Austrian inventory and flood hazard datasets into the Flood Model data structure and performed a building loss estimation in a case study in Carinthia. Another study by Kaveckis (2011) successfully showed how Hazus-MH can significantly contribute to support the European Flood Directive at a national level and deliver requested assignments and outputs like flood hazard and flood risk maps.

The HAZUS methodology has also been the basis for the development of several other software tools for loss estimation. One of these is called SELENA (SEimic Loss EstimatioN using a logic tree Approach), developed by the International Centre for Geohazards (ICG), NORSAR (Norway) and the University of Alicante, Spain (Molina et al., 2010).

In the areas of industrial risk assessment also a number of methods have been developed using GIS-based decision support systems. One of these is the ARIPAR system (Analysis and Control of the Industrial and Harbour Risk in the Ravenna Area, Analisi e controllo dei Rischi Industriali e Portuali dell'Area di Ravenna, Egedi et al., 1995; Spadoni et al., 2000). The ARIPAR methodology is composed of three main parts: the databases, the risk calculation modules and the geographical user interface based on the Arc-View GIS environment.

Currently the system is converted to ArcGIS, and also natural hazards are included in the analysis.

Another noteworthy example of such a plug-in has been the INASAFE initiative (Indonesian Scenario Assessment for Emergencies) which is a relatively simple tool for estimating exposure and losses from different hazards, using a Python plugin within the Open Source GIS Quantum-GIS. INSAFE is not a hazard modelling tool, as hazard scenarios have to be provided as input into the software.

6.4.4 Standalone tools

Another development in loss estimation tools has been the generation of tools that are standalone, and which are not dependent on a GIS system. One of the best examples of this is the CAPRA tool for Probabilistic Risk Assessment, developed by the ERN consortium for the World Bank.

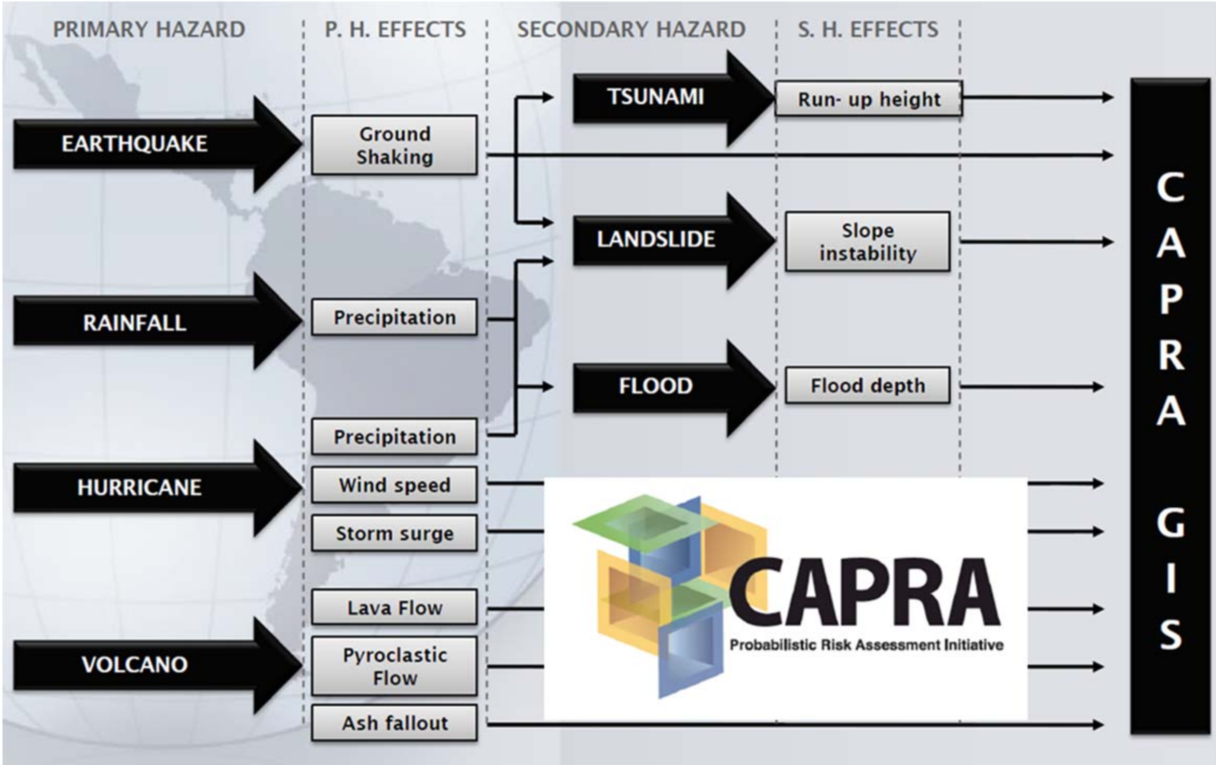


Figure 6.10: Structure of the CAPRA tool.

Whereas most of the above mentioned GIS-based loss estimation tools focus on the analysis of risk using a deterministic approach, the CAPRA has a true probabilistic multi-hazard risk focus. The aim of CAPRA was to develop a system which catastrophe models in an open platform for disaster risk assessment, which allows users from developing countries to analyze the risk in their areas, and be able to take informed decisions on disaster risk reduction. The methodology focuses on the development of probabilistic hazard assessment modules, for earthquakes, hurricanes, extreme rainfall, and volcanic hazards, and the hazards triggered by them, such as flooding, windstorms, landslides and tsunamis. These are based on event databases with historical and simulated events. This information is combined with elements-at-risk data focusing on buildings and population. For the classes of elements-at-risk, vulnerability data can be generated using a vulnerability module. The main product of CAPRA is a software tool, called CAPRA-GIS, which combines the hazard scenarios, elements-at-risk and vulnerability data to calculate Loss Exceedance Curves.

In New Zealand a comparable effort is made by developing the RiskScape methodology for multi-hazard risk assessment (Reese et al., 2007; Schmidt et al., 2011). This approach aims at the provision of a generic software framework which is based on a set of standards for the relevant components of risk assessment. Another good example of multi-hazard risk assessment is the Cities project in Australia, which is coordinated by Geoscience Australia. Studies have been made for six cities of which the Perth study is the latest (Durham, 2003; Jones et al., 2005). Also in Europe several project have developed multi-hazard loss estimations systems and approaches, such as the ARMAGEDOM system in France (Sedan and Mirgon, 2003) and in Germany (Grünthal et al, 2006).

6.4.5 Open Source Web-based tools

Another recent development is towards Open Source web-based modules for multi-hazard risk assessment. A tool which is currently under development as part of the Global Earthquake Model (GEM), called OpenQuake, is most probably going to be the standard for earthquake loss estimation, and there are also plans to expand it into a multi-hazard risk assessment tool.

To manage risk from natural and technological disasters (earthquakes, hurricanes, industrial accidents, etc.) and to understand the potential impacts of new disaster science or policy, requires access to analytical and computer risk models. The models are constantly in flux as science, engineering, and disaster social science develop, but most researchers and practitioners lack risk-integration tools and methods needed for an overall understanding of risk, and must either re-develop existing integrative software or abandon potentially fruitful study. In order to exchange information on Open Source loss estimation tools the AGORA was founded. The Alliance for Global Open Risk Assessment (AGORA) is conceived as a nonprofit, international virtual organization created to promote and coordinate development of open-source risk software and methodologies to perform end-to-end risk modelling. (End-to-end refers to modelling the occurrence of hazardous events, site effects,

physical damage to the built environment, and economic and human impacts.). Open-source risk software (OSR) represents an emerging solution. It is software whose source code is publicly available for review and enhancement. An example of such tools is the OpenRisk, a set of methodologies and object-oriented, open-source software for conducting multi-hazard risk analysis. It is under development and will assess risk to single sites and portfolios of facilities in terms of repair costs, casualties, and loss of use ("dollars, deaths, and downtime"). Initial applications have been collaboratively developed by Caltech , USGS , SCEC , and Kyoto University. The AGORA doesn't seem to have gained a lot of momentum as evidence by their website.
Other examples of Open Source loss estimation tools include RISIKO, RiskInABox, INASAFE, and Kalypso.

6.5 LOSS ESTIMATION IN EUROPE

The loss estimation methods described above should also provide more detailed loss estimations for European countries. Maccaferri et al (2012) from the European Commission (EC) Joint Research Centre (JRC), on a request by DG Internal Market and Services (DG MARKT) investigated the publicly available information on insurance practices for Natural Catastrophes (NatCat) in place across European Member States (EU MS). The analysis should help future EC initiatives in the area of insurance for NatCat, e.g. to promote the development of an appropriate market for NatCat insurance products and/or improve the efficiency of existing markets. This research is a first step in the development of a EU database on NatCat and of a methodology to analyze and compare NatCat risk and insurance practices across EU Member states.
The analysis focused on flood, storm, earthquake, and drought. For each of these NatCat, publicly available qualitative and quantitative information was collected and processed from a
number of different sources in order to describe the size of the risks and detail existing practices of insurance systems. Interested stakeholders have been also consulted and involved in the collection of data. The research shows that that there is a need for more and better data on risk and insurance for NatCat and that common definitions should be agreed in order to make data comparable. Figure presents the results of their analysis in terms of maximum expected losses as percentage of the GDP for European countries for Floods, Storms, Earthquakes and Drought. These data are only based on historical loss data for the period between 1990 and 2010, and are not based on the use of catastrophe models incorporating large events with a small frequency. They are therefore underestimation the expected losses to a large extend, as is the case for instance for flood losses in the Netherlands, which would be very high in the case of occurrence of a very rare extreme flood event. Therefore there

is a great need to use this historical data in combination with catastrophe modelling to come up with better estimations and Loss Exceedance Curves.

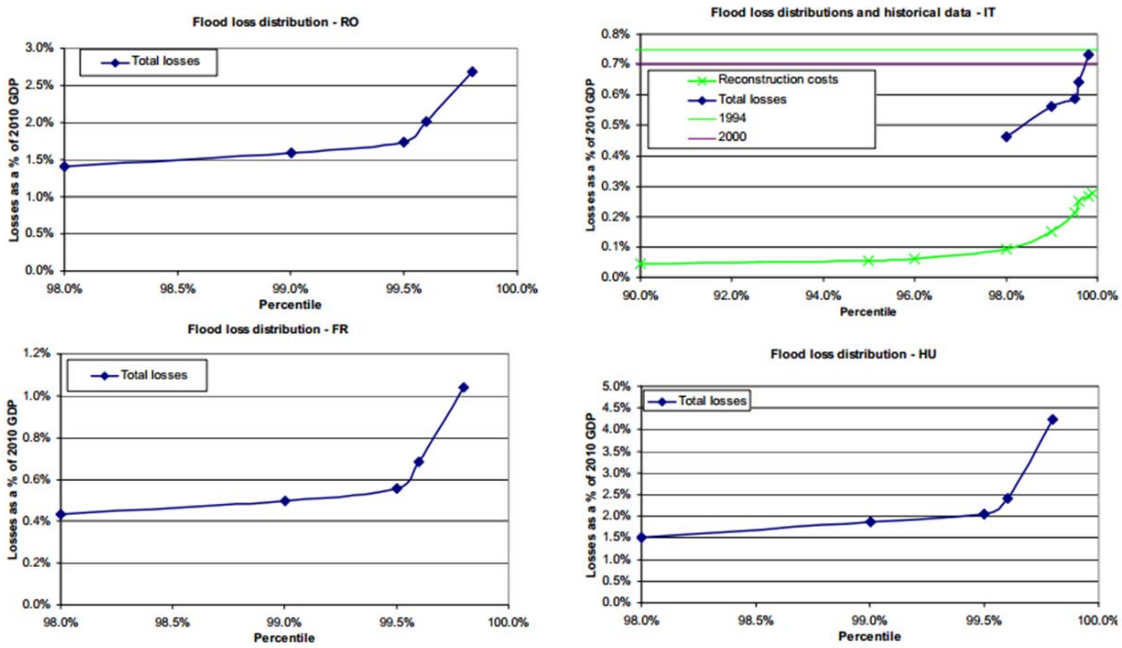


Figure 6.11: Simulated distribution of total losses for flooding for Romania, Italy, France and Hungary. Source: Maccaferri et al (2012).

7.DISASTER RISK MANAGEMENT

7.1 INTRODUCTION

Risk management cannot take place without proper risk governance. Risk governance has been promoted in the ISDR, Hyogo framework for action to: "Promote and improve dialogue and cooperation among scientific communities and practitioners working on disaster-risk reduction, and encourage partnerships among stakeholders, including those working on the socio-economic dimensions of disaster-risk reduction" (UN-ISDR, 2005a). Governance depends on the level of political commitment and strong institutions. Good governance is identified in the ISDR Framework for disaster reduction as a key area for the success of effective and sustained disaster-risk reduction (IRGC, 2005). One of the important processes in risk governance is risk communication, which is the interactive exchange of information about risks among risk assessors, managers, news media, interested groups and the general public. An important component of that is the visualization of risk. Since risk is a spatially varying phenomenon, GIS technology is now the standard approach for the production and presentation of risk information. Risk can be presented in the form of statistical information per administrative unit, such as a Risk Index value resulting from qualitative risk assessment, the Probable Maximum Loss (PML) or Average Annual Loss (AAL), Loss-Exceedance curve for economic risk, or F-N curves for societal population risk. Risk can also be visualized in map form, that shows the spatial variation of risk.

Figure 7.1 shows the overall approach is to subdivide the aspects related to Disaster Risk Management into three components:

- The technical hazard and risk assessment component;
- The decision making component;
- The data management component;

The Technical hazard and risk assessment component
This component has been discussed already in the previous chapters. It deals with the generation of the input data, and the hazard and risk assessment components.

Decision making component
The decision making component is often using Spatial Decision Support Systems (SDSS) which are an "Interactive computer system designed to

support a user or a group of users in achieving a higher effectiveness of decision making while solving a semi-structured spatial decision problem". The SDSS should be able to analyze the effect of risk reduction planning alternatives on reducing the risk now and in the future, and support decision makers in selecting the best alternatives. Figures 4 and 5 show the concept of the SDSS.

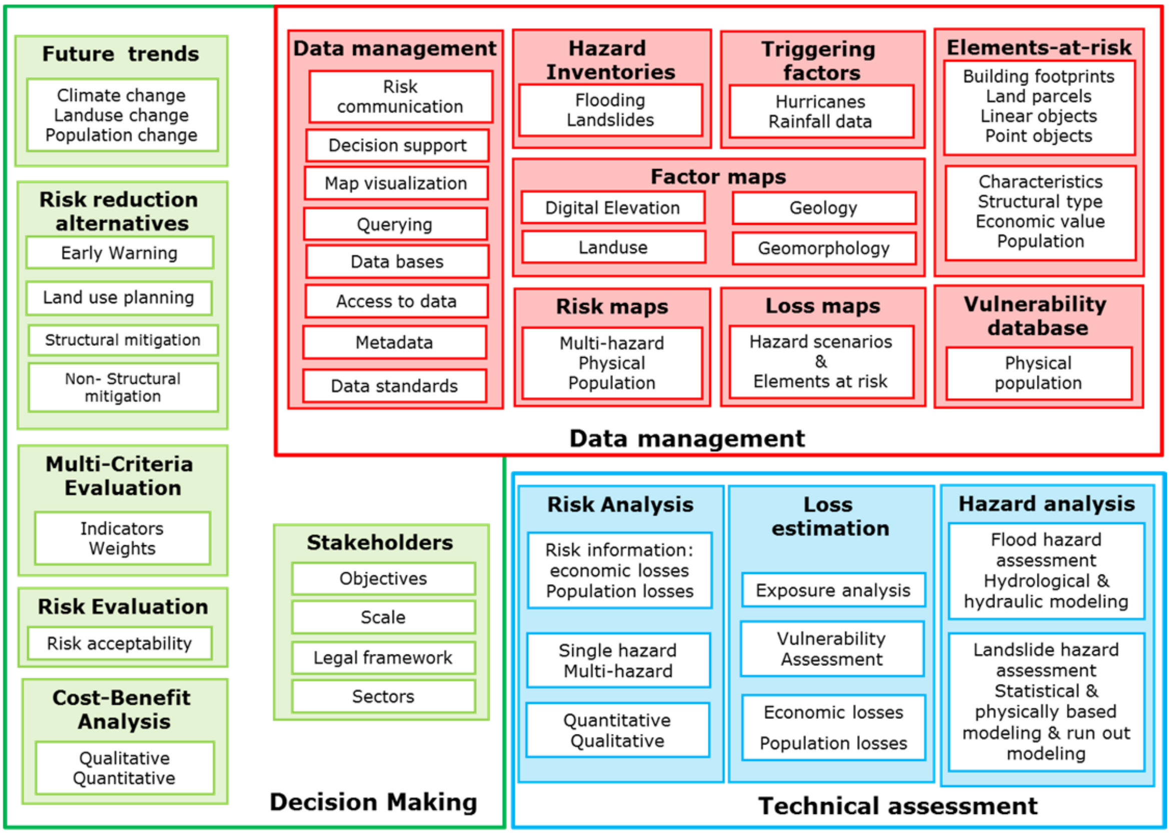


Figure 7.1: Approach for the use of risk information is Disaster risk Management. The methodology is divided into three sections: Technical assessment of hazard and risk, Decision making on optimal risk reduction measures, and data management.

7.2 STAKEHOLDERS.

It is important to define some of the terms that are used in DRM for the involvement of parties in the process. Different terms are used: stakeholders, beneficiaries, users, players, actors. We are using the following descriptions for these terms:

- **Stakeholders**: A stakeholder is any individual or group with an interest in the success or failure of an organization/project/endeavor in delivering intended results. A stakeholder is an individual or group that is affected by the outcome of the project. A stakeholder might be called on to provide input, feedback, or authorization for the use case. Sometimes stakeholders are also called players (as in Figure 7.2) although that is a more confusing term, because a player is not necessarily directly actively involved in the project. If the stakeholder has an interest in the positive outcome of the project without actively participating, he is also called a **Beneficiary**. There are many stakeholders in the development of an optimal spatial planning, reducing the impact of disasters. However, many of the stakeholders will not be actual users of an SDSS.

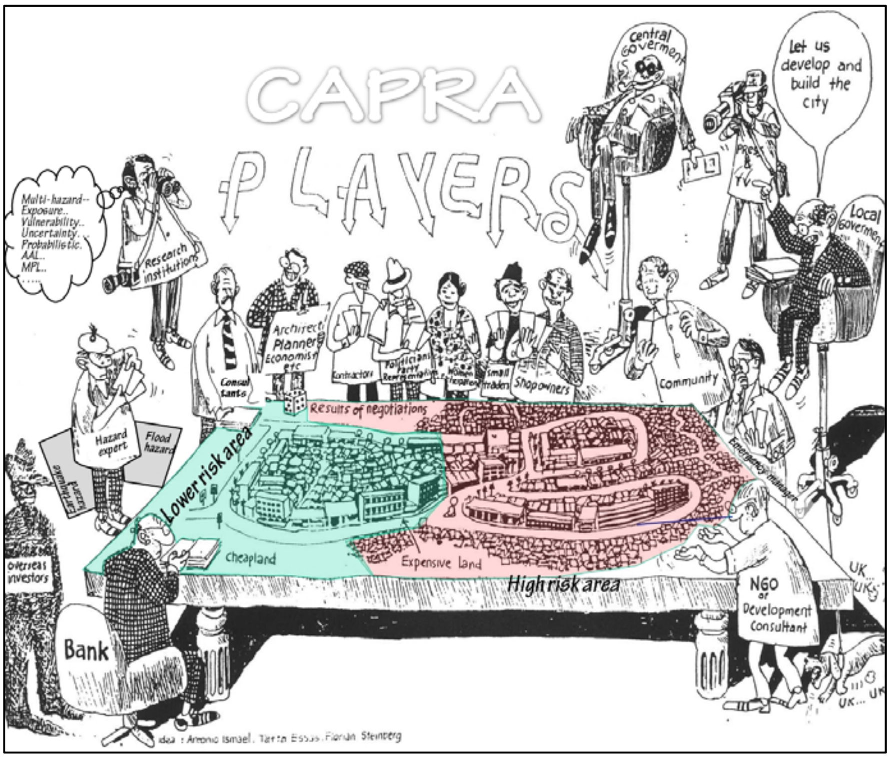


Figure 7.2: Cartoon illustration the complexity of stakeholders/players involved in spatial planning and risk management. Adapted from source: ITC students Tatta Essas and Florian Steinberg.

- **Users**: a user is any individual or group that is actively involved in the organization/project/endeavor. This is in fact a smaller component of the stakeholders. Many of the stakeholders, although having an interest in the overall objective and outcome of the project, will not actively use it because it is beyond their mandate, level of knowledge, expertise, interest, awareness. In the case of an SDSS a user is an individual or group that actively works with the platform. This can be in different components of the system. For instance by using the system for hazard modeling, actual risk modeling, or using the system for the implementation of risk reduction measures. An example of the definition of users of Geoinformation for disaster management is given by the EU ORCHESTRA project (See box below)

The ORCHESTRA project was an EU FP6 project (http://www.eu-orchestra.org/) with the aim to design and implementing the specifications for a service oriented spatial data infrastructure for improved interoperability among risk management authorities in Europe, which will enable the handling of more effective disaster risk reduction strategies and emergency management operations. The ORCHESTRA Architecture is open and based on standards. They defined three types of users:

- **System users** such as IT architects, system developers and integrators that conceive and develop risk management applications would be enabled to share and integrate data that can be transformed into relevant information. By facilitating the integration of their current technological solutions this group would be able to provide improved services to their end users.
- **Providers of data and application services** that are used for risk management will benefit from thematic information services that can be applied in many different risk scenarios. Information services represent a new channel to be exploited by this group. These information services should be more profitable, since they can be directed to more customer segments than mere data services.
- **End-users** such as members of public, agencies or private companies that use the thematic applications (built according to the ORCHESTRA specifications and using the ORCHESTRA services) benefit from more efficient interoperable services that easily integrate with the current technological reality. To coherently handle both spatial and non-spatial data and to assure the exchange of information among different actors at different levels from local to national is a major efficiency and effectiveness benefit.

Users tend to think of functionality in terms of needs. "I need the system to do this." "Wouldn't it be great if the system could do that?" The ever persistent "the system won't do what I need it to do because of something." Users drive change because they need 'things' to perform their duties and make decisions.

- **Actors**: an actor specifies a **role** played by a person or organization when interacting with a system (e.g. CAPRA). The same person/organization using the system may be represented as different actors because they are playing different roles. Actors represent the different roles that something outside has in its relationship with the system whose functional requirements are being specified. An individual or group in the real world can be represented by several actors if they have several different roles and goals in regards to a system. These interact with system and do some action on that.

When referring to the risk management process, we propose to use the term "**actor(s)**" instead of the terms "**stakeholders**", "**users**" or "**user groups**". An "actor" represents the type of role played by an entity (person or organization) in a specific process. An actor thought of as a "role" does not necessarily represent a specific physical entity but merely a particular facet (i.e., "role") of some entity that is relevant to the specific process under consideration. A "role" can be played by several entities; conversely several different roles can be played by the same entity. E.g., in the case of risk assessment an institution could be defined as an actor that can either play the role of information "consumer" or "provider" in the corresponding workflow.

Table 7.1 presents a list of "actors" that are somehow related to the disaster risk management activities; these actors could be broadly classified into two types:

- **Risk information consumers (RC):** refers to governmental and non-governmental institutions (national, regional, local) as well as to communities and individuals, who may require "information on risk" as an input to carry out their specific tasks.
- **Risk information providers (RP):** governmental and non-governmental institutions (national, regional, local), who are requested to provide the required data inputs to carry through the decision making process concerning risk assessment (the technical aspects); this includes providers of basic data as well as providers of information on risk.

From the table it can be concluded that there is not always a clear division between Risk Information Consumers and Risk Information Providers. The most likely situation is to find institutions/organizations that, as a whole, may belong to both groups (it is at the same time provider and consumer of information). In these cases, however, it should be possible to find within the organization a department/office whose main role is either provide information or use the information created by others to carry out related risk management activities.

There are different stakeholders with different objectives. The envisaged users are organizations involved in planning of risk reduction measures, and that have staff capable of visualizing and analyzing spatial data. These could be subdivided into:

- Civil protection organization with the mandate to design disaster response plans.
- Expert organizations with the mandate to design structural risk reduction measures (e.g. dams, dikes, check-dams etc).
- Planning organizations with the mandate to make land development plans.

Another set of users are those working in organizations that are responsible for providing hazard maps related to flooding and landslides. These are different from the end –users, and they should provide relevant information on request of the end-users.
A third set of users are those that provide data on elements-at-risk (called assets in the rest of this document). They are related to organizations related to cadastral data, transportation organizations, etc.

Table 7.1 : Different “stakeholders” and “actors” in Disaster Risk Management and their possible roles as Risk Information Consumer (RC) or Risk Information Producer (RP).

Stakeholder	Actors Main Role	Explanation
Local Communities	RC	Local communities are supposed to be direct beneficiaries of risk management policies. They could be regarded as “information consumers” when they make use of participatory mechanisms to take part in the decision making process, and therefore would require to be informed about the topics under discussion (defining insurance policies, land use management plans, etc.) Communities can also take part in the risk assessment process as “information providers”, especially when considering issues related to vulnerability assessment (risk perception, etc.)
Local authorities	RC	Local authorities are mostly using risk information for local decision making. They normally do not have the capacity to generate risk information on their own.
Governmental organizations - sectors	RC RP	Ministries use risk information in their planning processes, they main role is as “information consumers”. However, in many cases, the different sectors make use of their own technical resources to produce risk assessment studies; in this case they are also “providers” of information.
National basic data producers	RP	For instance national bureau of statistics, topographic surveys. Though they produce “general purpose” information, they are relevant for the risk assessment process.
National thematic organizations	RP	For instance: meteorological, seismological, geological that, generally, should be considered and “information producers”
Disaster management organization	RP RC	A disaster management organization is both generating risk information, and is also using this information for early warning, preparedness planning and disaster prevention.
Private sector	RP RC	Consultants can be important source for specific data for hazard, vulnerability and risk assessment. A special case is also the insurance industry, which can be a RP as RC at the same time. Sometimes the entire process of hazard, vulnerability and risk assessment is done entirely by a consulting company. The private sector as a whole is also RC as beneficiary of disaster risk reduction
NGO	RC RP	NGO’s often are actively involved in collecting relevant hazard and vulnerability data at community level. They can also be RC
Universities	RP	Universities can be active in generating hazard and risk information. They can sometimes have the main role in this process
International organizations	RP RC	International organization can bring in additional support for generating hazard and risk information (e.g. World Bank) They also require risk information for making sound investments.

Figure 7.3 presents a general description of the "actors" needs ("actors" defined in general terms as consumer or provider on information). What the figure shows is a "flow of information". Each "actor" is defined in terms of the "information needed" and "the information offered". Looking at the workflow presented in Figure 7.3 it is clear that the "actors" could not be described as either "net provider" or "net consumer" of information.

Additionally, to understand this general description of "needs" and "offerings", it is necessary to consider the specific risk management/assessment institutional context. In this regard: what are the specific institutions that could be assigned to each of the different "actors"? What is the specific type of risk information these "actors" require and how should this information be presented to them?

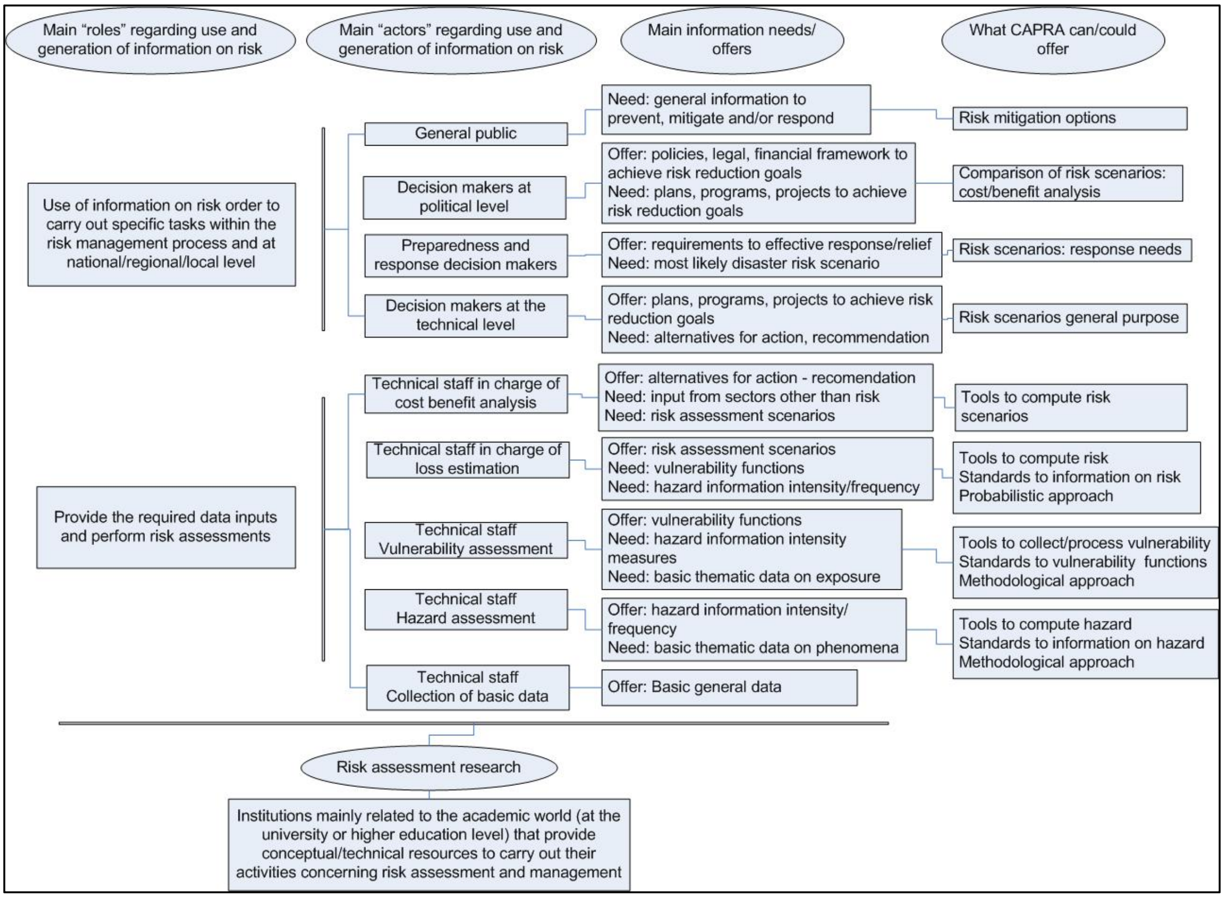


Figure 7.3: general description of "actors" and their roles in terms of information needs and offerings

To answer these questions, we use the following criteria:

- Definition of general "actors: using the CAPRA workflow we present a description of the type of "actors" (roles and responsibilities) to be involved in the different moments of the risk assessment process.
- Definition of specific "actors": "specific actors" can only be identified by looking at "use cases"; a "use case" is the definition of a particular

"risk assessment information need". Only in this way it is possible to identify the individual actors, and define their responsibilities. In doing so, attention should also be paid to the different administrative levels: local (municipality or lower level), sub-regional (group of municipalities or other administrative units below national level), national (country level) and regional (involving two or more countries).

In Table 7.2 we have made an attempt to present a general characterization of "actors" based on the workflow previously described.

Table 7.2: General characterization of main actors

SDSS workflow	"Actors"	Role/responsibility
Preprocessing: Hazard modeling	Thematic experts – phenomena: meteorologist, hydrologist, geologist, etc.(data provider)	Modeling of the specific events which provide input data to develop hazard analysis. E.g.: -seismologist provide characterization of seismic sources (seismic hazard) -meteorologist model weather events and provide data required to estimate stream flows (flood hazard)
	Hazard analyst	Execution of the hazard analysis and publication of the results. Using information provided by the thematic experts determines the temporal and spatial distribution of the hazard intensity values. E.g.: -seismic hazard: annual probability of exceeding certain ground shaking intensity -flood hazard: annual probability of exceeding certain flood extent and severity
Preprocessing: definition of vulnerability functions	Thematic experts – mapping of elements at risk: mapping agencies, national bureau of statistics	Provide the information of the elements at risk: vectors and attributes
	Vulnerability analyst	Creation of the elements at risk inventories, development and publication of the loss functions. Using the characterization of the different hazards (type of effects) defines the sort of information that should be collected to analyze the possible impact of the hazard and develops the "loss functions". E.g: -elements at risk: where the interest to analyze risk lies (infrastructure, housing, key facilities, etc) -attributes of the elements at risk: what type of information allows for the assessment of the impact a certain hazard might have on the elements at risk under consideration
Processing: Risk assessment	Government, public, and private institutions (user of risk assessment information products)	Definition of the specific risk information needs Definition of the way the risk information products should be delivered
	Risk analyst	Selection of the risk assessment methods and procedures, execution of the risk assessment; comparison of the resulting risk assessment scenarios according to specific demands, and publication of the risk assessment results. Using the information on hazard and vulnerability to perform the risk assessment; based on the particular interest (risk management process) selects the risk assessment methodology (single – probabilistic scenario) and the risk assessment output format (loss curves, etc.). The risk assessment could be designed to give answers to "what if" scenarios (decisions over implementation of prevention/mitigation measures) or to "response" scenarios (decisions over preparedness)
Post processing: -publishing	Government institutions (user of risk assessment information products)	Definition of the way the risk information products should be delivered use the information on risk to support decision making process, which might to redefine risk information needs
	General public (user of risk assessment information products)	The general public checks for available information according to specific interest. e.g.: insurance; hazardous areas, etc.

7.3 CONCEPTUALIZATION OF A DRR SDSS

The SDSS can be used in different ways (see Figure 7.4):

A. **Analyzing the current level of risk.** In this workflow the stakeholders are interested to know the current level of risk in their municipality. They request expert organizations to provide them with hazard maps, asset maps, and vulnerability data, and use this information in risk modeling. They use the results in order to carry out a risk evaluation.

B. **Analyzing the best alternatives for risk reduction.** In this workflow the stakeholders want to analyze the best risk reduction alternative, or combination of alternatives.. These could be:
   - Disaster response planning: focusing on analyzing the effect of certain hazard scenarios in terms of number of people, buildings and infrastructure affected. It can also be used as a basis for the design of early warning systems.
   - Planning of risk reduction measures, which can be engineering measures (such as dikes, check-dams, sediment catchment basins), but also non structural measures such as relocation planning, strengthening/protection of existing buildings etc.
   - Spatial planning, focusing on where and what types of activities are planned and preventing that future development areas are exposed to natural hazards. Here, some attention has to be paid to the specific characteristics of the planning systems and cultures in the case study areas.

   For areas where the risk is considered too high, risk reduction alternatives are proposed by the governmental organisations involved within a specific sector (e.g. transportation, physical planning, health etc.). Initially a number of possible alternatives are evaluated. For each of these experts should define whether the alternative requires reanalysis of the hazard, an updated elements-at-risk layer, or new vulnerability data. This is illustrated in table 7.1.

   The users **define the alternatives**, and request the expert organizations to provide them with updated hazard maps, assets information and vulnerability information reflecting the consequences of these scenarios. Once these hazard and asset maps are available for the alternatives, the new risk level is analyzed, and compared with the existing risk level to estimate the level of risk reduction. This is then evaluated against the costs (both in terms of finances as well as in terms of other constraints) and the best risk reduction scenario is selected.

Table 7.3: Examples of use cases for disaster risk reduction and their effect on hazards, elements at risk and vulnerability. Specific additional expertise is indicated apart from landslide, flood and geo-spatial data experts

Main type	Example	Possible effects on:				Specific expertise
		Hazard intensity	**Hazard probability**	**Elements-at-risk**	**Vulnerability**	
Structural mitigation measures	Relocation of assets, e.g. relocation of buildings (schools, hospitals, shelters)	Not changed	Not changed	Should be updated, with new locations	If structural type changes it should be updated	Strucutral engineer
	Mitigation works: slope protection works, flood defence strucutres	Hazard intensity should be reanalyzed	For landslide the spatial probability will change	If elements-at-risk are same, no need for updating	No need for updating	Structural engineer / transportation engineer
Non-strucutral mitigation measures	Implementation of an Early warning system	No changed		Characteristics of population might change	Population vulnerability will change	Social scientist / technical expert of EWS
	Emergency response planning	Run specific hazard scenarios		Specific population scenarios	Different levels of population vulnerability	Emergency manager
	Land use planning: restrictive zoning taking into account hazard zones	Use baseline hazard maps for floods and landslides, expressing intensity and spatial probability		Updated elements-at-risk	Updated vulnerability data	Spatial planner
	Safe location of new transportation infrastructure	Use baseline hazard maps for floods and landslides, expressing intensity and spatial probability		Updated transportation data	Updated vulnerability data	Tranportation engineer
Specific future scenarios	Reconstruction planning	Post event hazard assessment, taking into account new situation		Updated elements-at-risk	Updated vulnerability data	Spatial planner/ Transportation & structural engineer
	Population change scenarios related to tourism sector	Not changed		Updated elements-at-risk	Updated vulnerability data	Social scientist
	Climate change scenariosand their effect on risk.	Based on climate change and land use change scenarios new hazard modeling should be carried out resulting in new intensity and probability maps		Updated elements-at-risk	Updated vulnerability data	Climate change expert / landuse expert

Cost Benefit analysis is then used for the risk reduction measure(s), in quantitative terms. The analysis requires the definition of the risk reduction alternatives. The input consist of an administrative unit map, with annualized risk information (from the risk analysis module). The user also has to provide the costs associated with the implementation of the measure, the period of investment, the lifetime of the project, the interest rate etc. The outcome is an administrative unit map with attribute data on the internal rate of return, and metadata on the cost of the alternative.

A multi-criteria evaluation component aims at providing support for decision makers in choosing the optimal risk reduction alternative. This modules requires as main input the metadata file resulting from the alternative definition module, and the results of the Risk Analysis and the Cost-Benefit analysis components. The MCE allows the users to create criteria trees (decision tree containing an ordered list of indicators used in the evaluation, organized in groups, which are scored and weighted) for each of the alternatives, and to subdivide these in quantitative components and non-quantitative components.

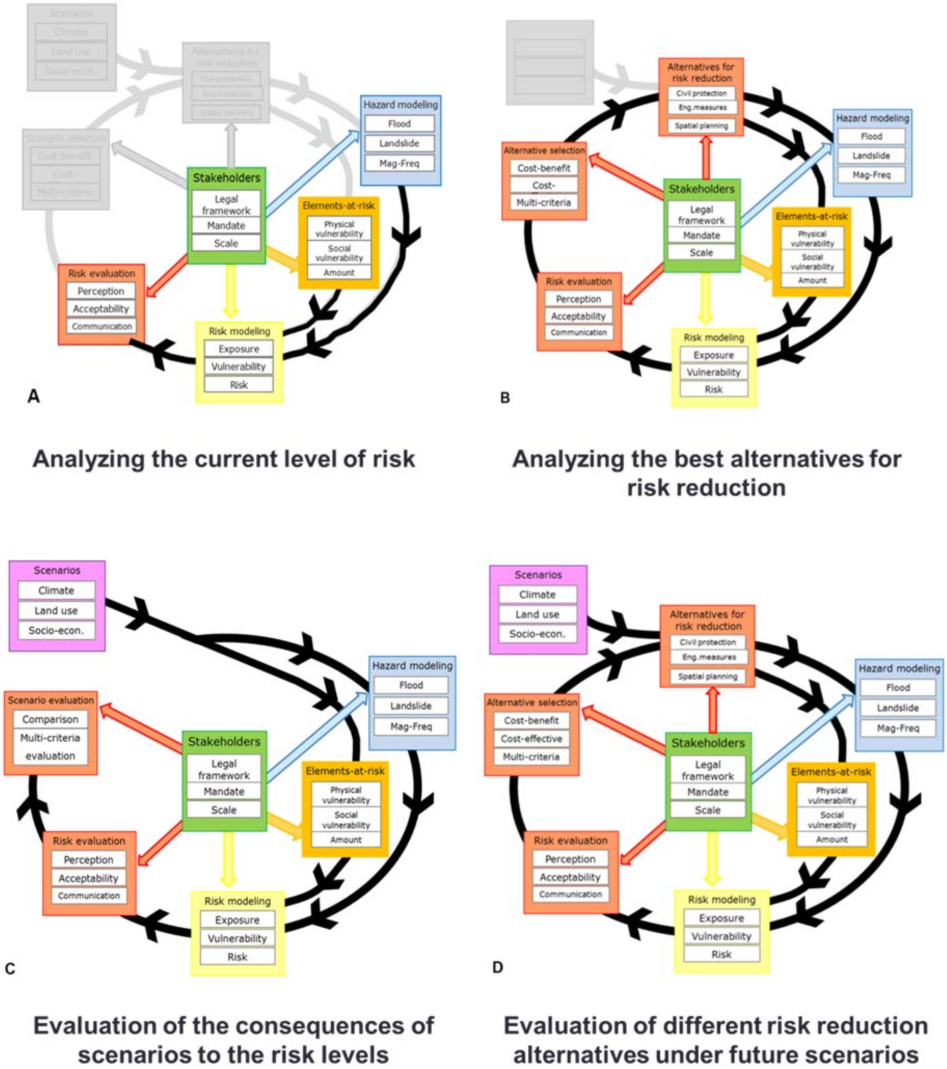


Figure 7.4: Conceptual design of a SDSS for disaster risk reduction. Different colors refer to different components: green = stakeholders, Blue = organizations responsible for providing hazard maps. Orange = organizations responsible for providing elements at risk maps, Yellow = organizations responsible for providing risk modeling, Violet = Organizations that are working on the analysis of trends related to climate changes, land use change and population change, Red = end-users of the platform that use the information from the others Four different ways in which the SDSS could be used. See text for explanation

C. **The evaluation of the consequences of future scenarios to the risk levels**. The scenarios are related to possible changes related to :
- Climate change: involving changes in the magnitude-frequency of precipitation extremes and other relevant climatic stimuli (such as evaporation, days with snow cover) and in the occurrence in the time of the year of these extremes (e.g. related to changes in springtime temperature changes).
- Land use change: long term land use changes relate to socio-economic developments that might occur in an area.
- Population change: also related to political and socio-economic developments within a country.

The user will evaluated how these trends have an effect on the hazard and assets (again here the updated maps should be provided by expert organizations) and how these would translate into different risk levels. The users can describe each scenario with a narrative. Users should also be able to make sketches of the scenarios. The users should then define so-called reference year. A reference year is a year in future for which the effects of the scenarios will be worked out. For each scenario and reference year it is decided during a workshop with (hazard, elements at risk, and vulnerability) experts, whether the scenario requires new hazard maps (also for which hazards), updated elements-at-risk maps, and/or updated vulnerability tables. Comparison of different risk scenarios is done by visualization of these maps, and through the comparison of risk results.

D. **The evaluation how different risk reduction alternatives will lead to risk reduction under different future scenarios** (trends of climate change, land use change and population change). This is the most complicated, as it requires to calculate the present risk level, the effect of different risk reduction alternatives, and the overprinting of these on the scenarios. For each of these combinations of alternatives & scenarios new hazard, assets and risk maps need to be made.

Data management component

Data in an SDSS for Disaster risk reduction can be stored in web-based data repository which is based on OGC standards. The OpenGeo suite will be the basis for the development of the data repository, and the maps can be stored in a PostGIS database. Detailed metadata should be provided for each data set, following data standards (e.g.ISO 19115:2003). An overview of the input data is given in a spatial data catalog that lists the data requirements for hazard risk assessments at different scales. Table 7.2 gives an example of the metadata that should be stored in order to be able to query the database and use the various data.

Table 7.4 Example of metadata that should be stored for elements-at-risk data, vulnerability tables, hazard maps and loss maps.

Data type				Metadata Item	Description
Elements at risk	**Vulnerability**	**Hazard**	**Loss map**		
X	x	x	X	**ProjectName**	name of the project or study area
X	x	X	X	**Made by**	Person and organization that made the hazard map
x		X		**Method used**	Explanation of the hazard assessment method used.
		X	X	**Data format**	Information is stored on cell size, nr of rows and columns, coordinates and projection.
	X	X	X	**Hazard Type**	type of hazard (river flood, flashflood, debrisflow, snow avalanche, landslide, rockfall etc.). This is user defined, can be in different language, and can also make combinations of hazards, in the case of a cascading hazard type
		X	X	**Return Period**	the user should indicate the return period of the hazard scenarios. For each return period a separate hazard map is entered in the system. The user can also indicate the range of return periods that indicate the certainty
	x	X		**Intensity**	**Scale** = scale of intensity (water depth, flow velocity, impact pressure etc.) this is user defined. It should link with the vulnerability tables. **Metric** = the indication of the scale of measurement (e.g. meters, centimers) etc. This is also user defined. **AVG** = the name of the map with intensity values **STD** = the user can also upload a map showing the standard deviation of the intensity values. In most cases this would not be available.
		X		**Spatial probability**	this indicates the chance that a given pixel might be actually affected by the hazard phenomena. This is particularly so for the modelling of mass movement phenomena, where the modelled area is always larger than the actual area that will be affected. The use can indicate either a value that applies for the entire map, or upload a map that contains different spatial probabilities for different pixels (or map units, but this is the same as we deal only with raster maps).
X	x	X	X	**Alternative**	the number or name of the alternative for which this hazard map was made. For the current situation this is the 00 alternative. Other alternatives get a code, after the alternative definition module
X	x	X	x	**Scenario**	the number or code of the scenario, and the reference year in future for which this map is made.
X	x		x	**Elements-at-risk type**	either building footprints, land parcels, linear elements or point elements.
x	x		x	**Element-at-risk attributes**	Use = occupancy type, land use type of the elemtn at risk Structural Type = structural type linked to vulnerability tables Value = value of the element at risk and its contents Population = population in/on the element at risk for different temporal scenarios.

GeoNode is an Open Source, Content Management System (CMS) for geospatial data. It is a web-based application and platform for developing geospatial information systems (GIS) and for deploying spatial data infrastructures (SDI).

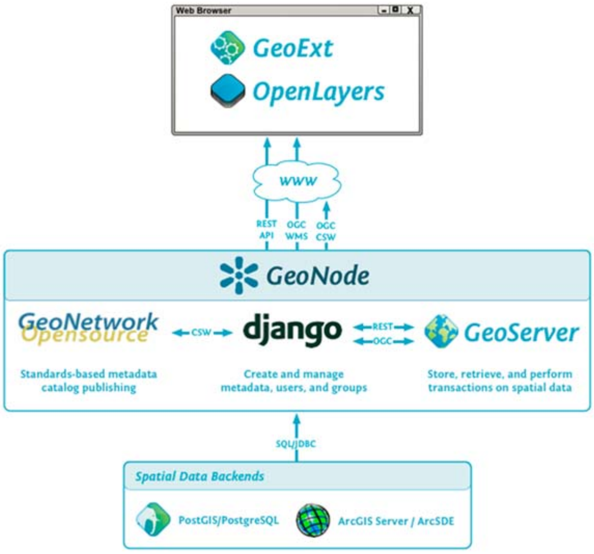


Figure 7.5: GeoNode architecture overview.

7.4 SDSS STRUCTURE

The SDSS will allow users to upload data to a web-database, carry out loss estimations for different combinations of hazards and elements-at-risk. The user can then generate risk maps for specified hazards and elements-at-risk combinations, and calculate these using risk curves for user-defined administrative units. User can define risk reduction alternatives and indicate the requirements for updating hazards, elements-at-risk and vulnerability data which have to be uploaded and reanalysed using the system. A cost-benefit module calculates the Internal Rate of Return of (a) risk reduction measure(s), in quantitative terms, and the final selection of the optimal alternative is done using Multi-Criteria Evaluation. The SDSS aims to carry out the following activities (See Figure 7.4)

1. Analyze the risk of the current situation. This is the most conventional part of the platform. It is the starting point also for the other types of analysis. The user can select the hazard types, the assets, and depending on the input type can carry out either a simple exposure analysis (how many assets are located in the hazard zones), qualitative risk assessment or quantitative risk assessment.
2. Analyze the risk of the current situation for different alternatives of risk reduction. After analyzing the current risk, the user can define one or more alternatives for risk reduction (either disaster preparedness planning, planning of engineering measures, or spatial planning). The user will then define whether the implementation of the alternative would require another hazard map and another asset map as input.

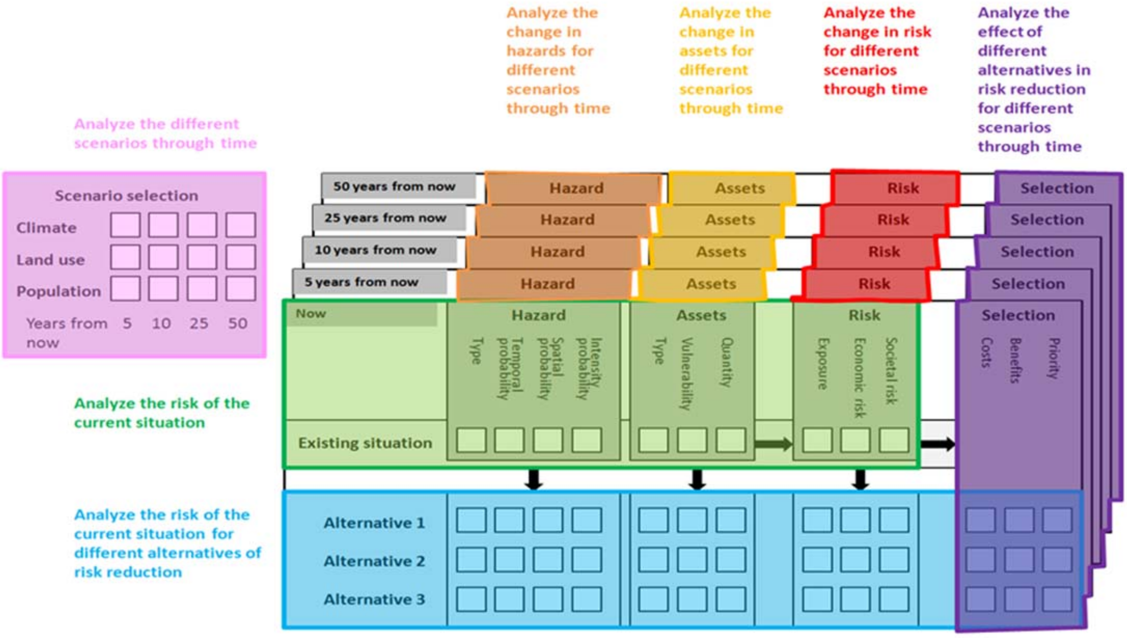


Figure 7.7: Conceptual design of the web-based Spatial Decision Support system allowing different types of analysis. See text for explanation.

3. Analyze the different scenarios through time. In order to evaluate the effect of changes. The user should define here which future scenarios will be taken into account. The user can select scenarios for climate change, land use change and population change. The user can also select which time periods are selected, and also whether for the same time period different scenarios will be evaluated.
4. Analyze the change in hazards for different scenarios through time. The effect of the scenarios selected in step 3 on the hazards considered will be evaluated. The actual hazard assessment is not carried out within the system, only the hazard maps are loaded into the system. The user can select the hazard scenarios for the situation without implementation of risk reduction alternatives (the current situation projected into time) for the different scenarios. This component has mainly a visualization and change analysis component. Not an actual hazard modeling component.
5. Analyze the change in assets for different scenarios through time. The effect of the scenarios selected in step 3 on the assets considered will be evaluated in this step. What is the effect of the land use and population scenarios on the location, type, vulnerability and quantity of the assets in the different future years considered. Note that these are not including the effect of alternatives of risk reduction planning, but are the projected changes from the current situation. This will also be mainly a visualization and change analysis tool.

6. Analyze the change in risk for different scenarios through time. This is major component of the platform: to analyze how for the scenarios defined in step 3 and the changes in hazard and assets that are analyzed in step 4 and step 5. What will be the change in risk if no risk reduction measures are taken, and the development of the area is governed by trends in landuse and population change. So this is the "what will be the risk if we don't do anything" analysis.
7. Analyze the effect of different alternatives in risk reduction for different scenarios through time. The last part will allow to analyze what would be the effect of implementing risk reduction alternatives (defined in step 2) combined with the scenarios (defined in step 3) on the risk over a period of time, and will allow to select which of the risk reduction measures would have the largest effect on the long term.

8. DATA VISUALIZATION

8.1 RISK VISUALISATION

The type of risk (qualitative/quantitative, direct/indirect, societal risk/individual risk etc.) and the visualization technique used depends on the stakeholder to which the risk information is communicated. Table 8.1 gives an overview of the relation between stakeholders and the type of risk visualization.

Table 8.1: Relationship between stakeholders in risk management and risk visualization options.

Stakeholder	Purpose	Type of risk visualization
General public	General information on risks over large areas	Basic WebGIS applications in which they can overlay the location of major hazard types with high-resolution imagery or topographic maps.
	Awareness raising	Animations (what if scenarios)
	Community-based DRR projects	Simple maps of the neighborhood with risk class, buildings, evacuation routes, and other features.
Businesses	Investment policies, and location planning	General information about hazards and risks in both graphical and map format.
Technical staff of (local) authorities	Land use regulation / zoning	Map with simple legend including construction restricted, construction allowed, further investigation required.
	Building codes	Maps indicating the types of building allowed (building type, number of floors).
	Spatial planning	Hazard maps, with simple legends related to probabilities and possible consequences.
	Environmental Impact Assessment	Maps and possible loss figures for future scenarios.
	Disaster preparedness	Real time simple and concise Web-based information in both map and graphical forms.
Decision makers / local authorities	Decision making on risk reduction measures	Statistical information, loss-exceedance curves, F-N curves, maps.
	Investments	Economic losses, projected economic losses for future scenarios.
	Strategic Environmental Assessment	General statistical information for administrative units.
NGO's	Influence political decisions in favor of environment and sustainable development	This can vary from simple maps to Web-based applications, depending on the objectives of the NGO.
Scientists / technical staff of hazard data producers	Hazard information exchange to public and other agencies	WebGIS applications where they can access the basic information.
	Exchange of basic information for hazard and risk assessment	Spatial Data Infrastructure / Clearinghouse for exchanging information.
Insurance industry	Development of insurance policy	Loss-Exceedance Curves of economic losses, F-N curves.
Media	Risk communication to public	Animations of hazard phenomena that clearly illustrate the problems.

Examples of different approaches for visualizing flood hazard and risk maps from 19 European countries, USA and Japan are presented in EXCIMAP (2007). Many countries are also developing their own Web-based risk maps. For example the CEDIM Risk Explorer Germany is a web-based map viewer that interactively presents the results of the CEDIM project "Riskmap Germany" (Müller et al., 2006). A more complicated Web-GIS system has been developed in the Netherlands, which can be accessed by the general public as part of the national risk communication strategy. A secured section of the same system can be accessed by professionals involved in risk management, allowing them to get more detailed information required for emergency response planning. National-scale risk mapping in the Netherlands was carried out after the occurrence of major technical and flood disasters in the last decades. The Web-GIS application (see Figure 8.1) shows information on natural hazards (flooding, natural fires and earthquakes), technological hazards (transportation accidents, hazardous substances, nuclear) and vulnerable objects (Risicokaart, 2008). The flood-prone areas are defined by more than 1 meter flooding depth with a frequency larger than 1/4000 per year.

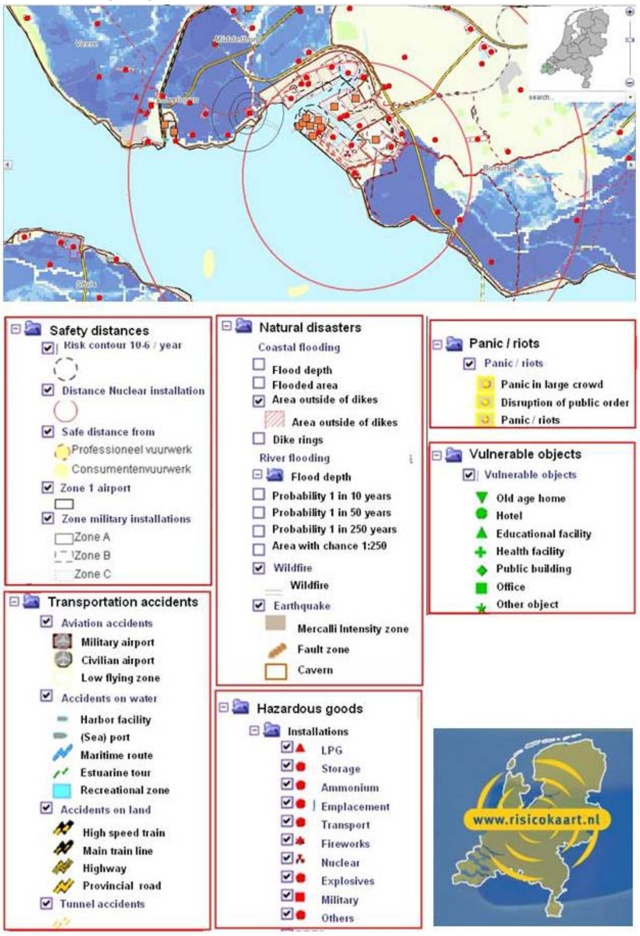


Figure 8.1: The national risk atlas of the Netherlands is publicly available on the internet (www.risicokaart.nl).

8.2 LAYOUT AND DESIGN

The term map layout (or map composition) refers to the spatial arrangement of the various map components making together what is called the map.
Such map components are: the mapped area, title, scale, legend, etc.
A map is a symbolized graphic representation of geographic reality. Map design is a matter of making choices based upon selection and interpretation of features or themes by the map “creator” and used whenever spatial relationships are essential!
The cartographic visualization process is based upon knowledge and experience in the translation or conversion of spatial data and their characteristics into graphics. Such translation or conversion requires knowledge of the “cartographic grammar”; this is a set of rules or guidelines which may assist the map author to translate spatial data characteristics into graphics which are able to communicate these characteristics to the map user.

Layout basics

The (conceptual and graphical) process of making a layout for a specific map involves the cartographers’ knowledge of the anticipated utilization of the map by the user as well as creativity from the side of the cartographer. Map layout is not a standard straightforward process, e.g.: often initial layout decisions are changed when the first draft copy of the map is produced.
Map layout strongly relates to what often is referred to as: “The art of cartography”.
The decisions of the arrangements of the map elements often involve aesthetic choices. This is especially the case for maps that have to appeal to a wide public like tourist maps, atlases, Internet maps, etc.
Not all cartographers can deal with these aesthetic choices. This element of the map layout requires a good eye for the visual impact of the map to the map user. No fixed receipts are available.
Map series like topographic maps often have a standardized map layout.
Although one might get the impression that map layout is only referring to the optical balance and arrangement of the map components, it must be obvious that the aggregated visual impression of the cartographic symbols used in the map face has a direct impact on the map layout. On the other hand the selection of background tints, illustrations, typography, etc. can strongly influencing the map face.
Preconditions for map layout:
The process of map layout can only start after it is clear:

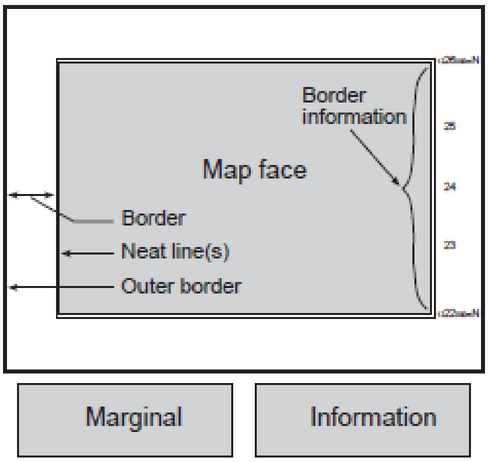
- What is the purpose of the map
- who is the map user
- what is the topic of the map
- what is the scale and the format (size)
- how the map will be reproduced

8.2.1 Map elements

The majority of maps will show one or more of the following map components:
• Map face
• Neatline / border
• Border information
• Marginal information

Map face (or: Mapped Area):
The surface of the printed-paper or computer screen that is actually covered with the mapped information. The map face is bordered by the neatline. Ideally the map face should cover approximately 2/3rd of the map.

Neatline:
This is a line that limits the mapped information. The word neat is well chosen because all point, line and area symbols of the map face run up to this line and any slight misfit caused e.g. by (mis-)printing will be obscured or masked by this line. The outer border is a frame, rectangular or squared, and positioned around the neatline. The space between the neatline and outer borderline can vary from 0.5 up to 2 cm. The outer border is optional on maps, but is conventionally applied on topographic map series.



Border information:
This is information, like ticks and figures, concerning geographical and rectangular coordinates. It is positioned between the neatline and the outer border(-line).

Marginal information:
This is all information required to evaluate, interpret and use the map. It is

in most cases positioned next to or around the neatline or outer border (Note that for topographic maps a comprehensive list of marginal items has been defined by international agreements).
The content of the marginal information is not fixed, yet there are a number of items that are more or less obligatory to be included in the map.

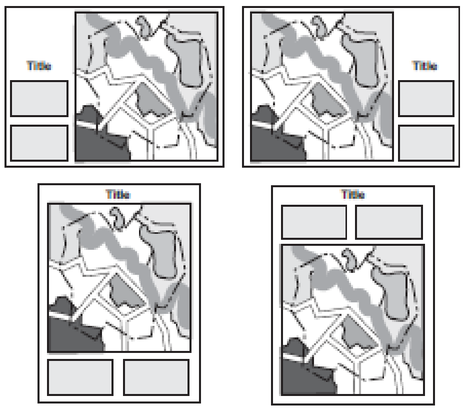
- Title
- Legend
- Scale

Title:

Every map should have a title; it is an important part of the design. In fact the title is the most generalized information describing of the entire content of the map and should therefore be at an eye-catching position.
We can make a distinction between main title and subtitle. The main title covers the area being mapped; the subtitle explains the theme of the map (or vice versa). The text used for the title is in size the largest that appears on the map.

Legend:

All maps need a legend or legends. It is in the legend that the symbols used in the map are presented and described and therefore the key to understand the content of the map. Legends can, depending on the type and complexity of the map, vary enormously in size. It is quite a tradition to place the legend(s) to the left, right and/or lower margin in the case of frame maps.



In the case of island maps (these are maps which extent is created by an irregular neat line such as a district, province or country boundary), the irregular mapped area influences the position of the legend(s).
The amount of items in the legend must be added up and its required space calculated in order to arrange the legend(s) properly in the layout. This space includes legend items representing point, line and area symbols used in the map face.
Depending on the dimensions of the map face, the legend(s) can be arranged as a long vertical column placed along the left or right margin, or if the vertical space is limited, the legend(s) can be split in two or more columns. In other cases it may be best to arrange the legend(s) horizontally along the bottom margin. In any case, legend(s) should be avoided to be positioned horizontally along the top of the map face!!

Scale:

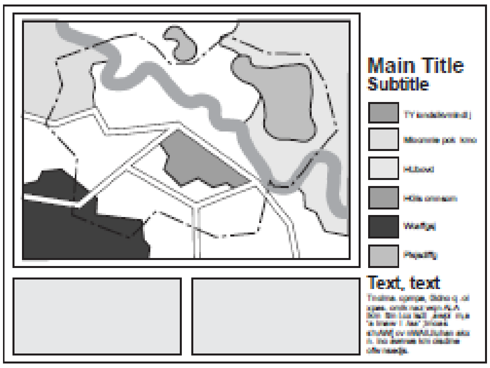
Since the mapped area is a representation at a reduced scale of (a part of) the earth surface, a graphical and or numerical scale indication has to be given to assist the map user in getting a better understanding about the real world dimensions of the mapped area. Whether a map needs a graphical or numerical scale is depending on the theme and use of map.
In general, maps showing quantitative information e.g. population, rainfall, temperature, etc. need only a statement of scale to let the map user have some idea of the size of the area being mapped.

8.2.2 Types of map layout

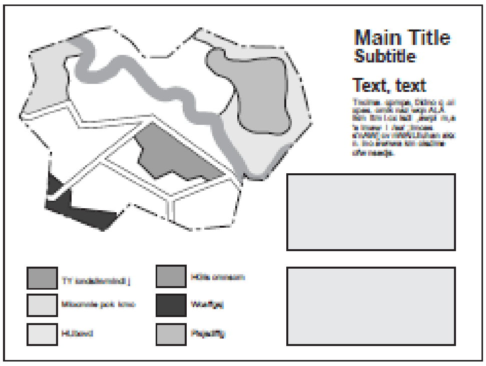
In map layout, three distinctive types of compositions can be distinguished:

- Frame map
- Island map
- Bleeding edge map

Frame map:



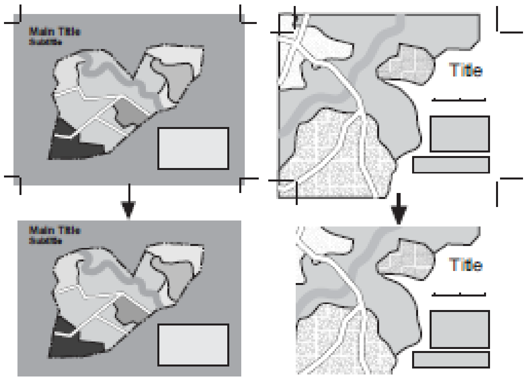
This is the most conventional type of map layout. A rectangular- or square shaped map frame encloses the map face. This frame functions as a separation between the marginal information and the map face. Topographic
maps are good examples of frame maps. This type of map is specifically suitable for map series. Statement of scale to let the map user have some idea of the size of the area being mapped.



Island map:

Less traditional than the frame map is the Island map. The neatline or boundary of the surveyed area functions as the frame. Therefore, an island map has an irregular shaped appearance. This type of layout allows the cartographer more freedom compared to the frame map in designing a layout.

Bleeding edge map:
This type of map lacks frames and has the mapped information running up to the trim edges of the map. In the example below (left) a background colour has been used up to the edge of the trimmed paper, in the example to the right, a major part of the topography runs up to the edge of the paper.



Any of these three types of maps can be orientated landscape or portrait.

Landscape orientated map:

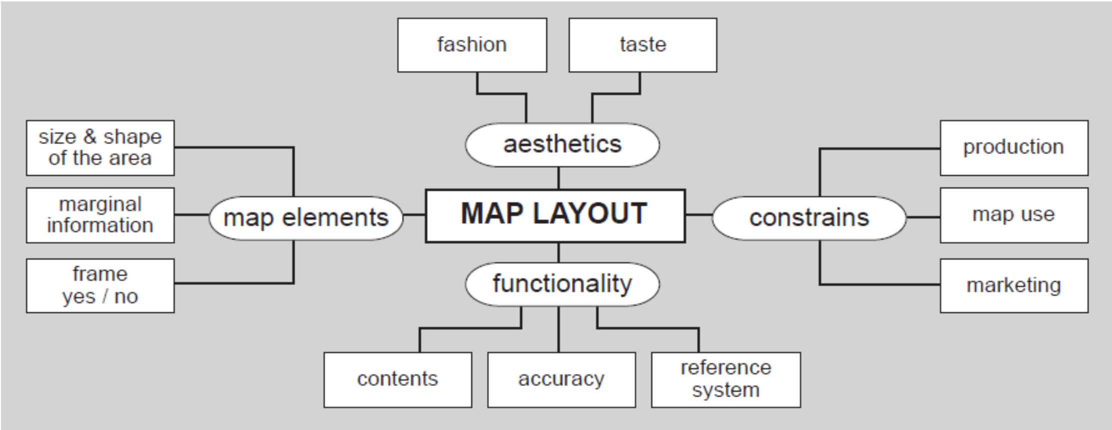
In this type of map, the width of the entire map (including marginal information) is more than the height of the map.

Portrait orientated map:

In this type of map, the height of the entire map (including marginal information) is more than the width of the map.

8.2.3 Aspects influencing a map layout

Besides the presence of the map components mentioned in the preceding chapters, the appearance of the entire map is influenced by the content and scale of the map. Furthermore conditions like available equipment and marketing considerations can influence the map layout. Aesthetic choices a cartographer makes will give the map its final (unique) appearance.



Functionality of the map.

Map purpose / contents

For which group of map users the map has to be designed for and how much information has to be given per unit of area (density of the mapped information).

This will indirectly determine the amount of marginal information.

Example: A road map is obviously designed to be used by motorists:

- colours should be readable in dimmed light conditions
- paper size may not be too large
- mapped information should mainly be related to road
- the density of information should not be too high
- the map requires a folding system to store in the glove compartment
- etc.

Map scale / accuracy:

The map purpose and the density of map contents are inherent to the scale. The degree of accuracy is proportional to the scale of the map.

Reference system:

This information is essential to accurately locate the data on the map. This information is usually placed in the border information.

Map production constrains

Production:

Technical capability and facilities available for cartography, reproduction and printing.

Example: In an organization no offset colour-printing machine is available but only a monochrome copy machine. This implies that colour cannot be used in the map to be produced and that the amount of prints has to be limited.

Map user:

The map users requirements, e.g. size of the printed map, density and amount of information, number of languages used, folding system, etc.

Marketing:

A good marketing survey will indicate the number of copies required and a proper price per copy. Result of this marketing survey also determines the map production method, the use of colour etc.

Aesthetics.

Fashion:

Although not a general rule, trends are noticeable in different periods of time, e.g. ornaments around the mapped area in the 18th and 19th century or colour shaded backgrounds around the mapped area nowadays.

Taste:

Although this is highly personal and depending upon taste, well designed and balanced maps appeal more to the map user than bad designs and poor layout. Market demand plays an important role in this.

In principle map layout can be divided into two groups.

layout for individual maps;

a unique layout is made especially for one particular map.

layout for series of maps;

for this type of layout a master design is made, suitable for the whole series and is known as the ‘pilot sheet layout’. This is done to give the entire map series a uniform appearance. Examples are: topographic maps, geological maps, etc.

8.2.4 Visual balance

The information so far has not given you a guide for a "proper map layout". As stated before, map layout is based upon the appropriate balance between the map face, applied colours, typography and map components like legend, illustrations, scale line, etc.

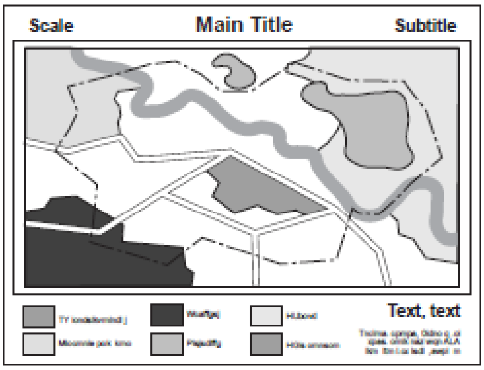
Main types of balances

In (carto-)graphic design three types of balance can be distinguished;

- symmetric balance
- informal balance
- formal grid based balance

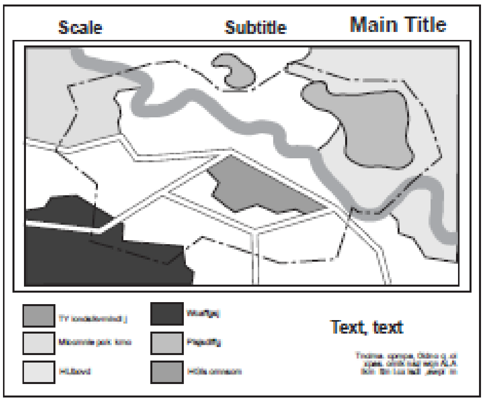
Symmetric balance.

In this kind of balance, the marginal information has been positioned in such a way that it is in perfect symmetry with the map face. The title of the map has been positioned above the map face along the central axis; the other marginal information has evenly been distributed above and below the map face, aligned to the sides.



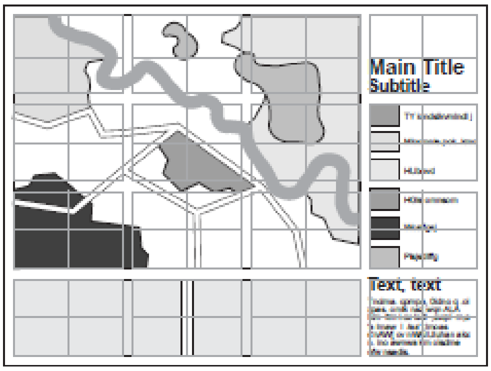
Informal balance.

In this type of balance, the shape of the map face determines the position of the marginal information. The creativity of the cartographer plays an important role where the marginal information will be positioned. However it is important that 'optical balance' is achieved. Optical balance means wherever positioned, none of the map elements is emphasized.



Formal grid based.

Although not visible on the final printed version, a grid has been used during the process of layout to position all information in a systematic way to obtain a pleasant and well-balanced map.



8.2.5 Inset maps

Location diagram:

One of the most common inset maps is the location diagram. See the description given earlier.

Detail insets:

The detail inset map is a small additional map face within the neat line of a larger map face (main map). The detail inset map focuses on a small area that contains dense information and cannot be represented in a legible way in the main map. Therefore the inset map most often has a larger scale.

Extension insets:

In cases when the area to be mapped has a fragmented nature and smaller areas (like remote islands) are far apart from the main mapped area, a too small scale has to be chosen to represent the entire information.
Alternatively, in extension inset maps, a suitable scale is chosen for the main mapped area and the 'remote' areas are shifted closer to the main mapped area. Important for extension insets is to maintain as much as possible the same scale for all mapped areas, to give coordinates around the insets and include a location map displaying the actual position of all mapped information.

Thematic insets

To be able to explain the features of the main map, an inset representing a special theme is known as thematic inset.
E.g. in a map of Portugal, additional thematic insets (e.g. climatic map, industry map, etc.)

8.2.6 Design tools

To be able to make a good graphic design, it is essential to know what the output device (monitor or printer) delivers as a result. The designer needs some help when selecting colour, in choosing the correct type family and font size and also to define correct line thickness and line-interspace.
Using the correct set of tools makes the difference.

8.2.7 Colourcharts

A colour chart is a set of different colours, usually ordered and displayes in some logical way. Colour charts display subsets of the complete colour spectrum. A colour chart used for map design shows only a very limited number of colours, since colour use in maps is very limited (see chapter 2.3.1 «Data analisys»).

Displayed is the ITC colourchart, available as a pdf. The pdf can be displayed on the monitor and used for selecting colours for monitor display, or it can be printed on the target printer (the printer used for the final map output), the printed chart will be used to select colour from.

8.2.8 Line-stylesheet

A pixel is the smallest element a monitor can display, so it makes no sense to define a line that is thinner than a pixel. On paper the thinnest line to be shown is depeding on the printer. There is a variation of printer technology (offset, laser, inkjet) and each of them performs differently. A document with different line-thicknesses and different line-interspaces can serve as a testsheet for as well the monitor as the printer.

Output shows how the details will be shown and how differences in linethickness appear.

8.2.9 Text-stylesheet

A font is a graphic object, designed for a specific use. Not every font is suitable for use on the monitor, not every font is good for large text-blocks. Similar to the line-stylesheet also a font-stylesheet can be created.

Choose one specific font, define it in different sizes and styles (normal, bold, italic, bold-italic. See the example below). Display it on the monitor or print it on the target printer. Base your type selection, font-size and font-style on the output result.

Arial

5. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()
7. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()
8. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()
9. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()
10. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()
11. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()
12. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()
14. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()
18. The quick brown fox jumps over the lazy dog 1234567890
22. The quick brown fox jumps over the lazy dog 1234567890
30. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()

5. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&()*
7. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&()*
8. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&()*
9. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&()*
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12. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&()*
14. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&()*
18. The quick brown fox jumps over the lazy dog 1234567890
22. The quick brown fox jumps over the lazy dog 1234567890
30. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&()*

5. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()
7. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()
8. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()
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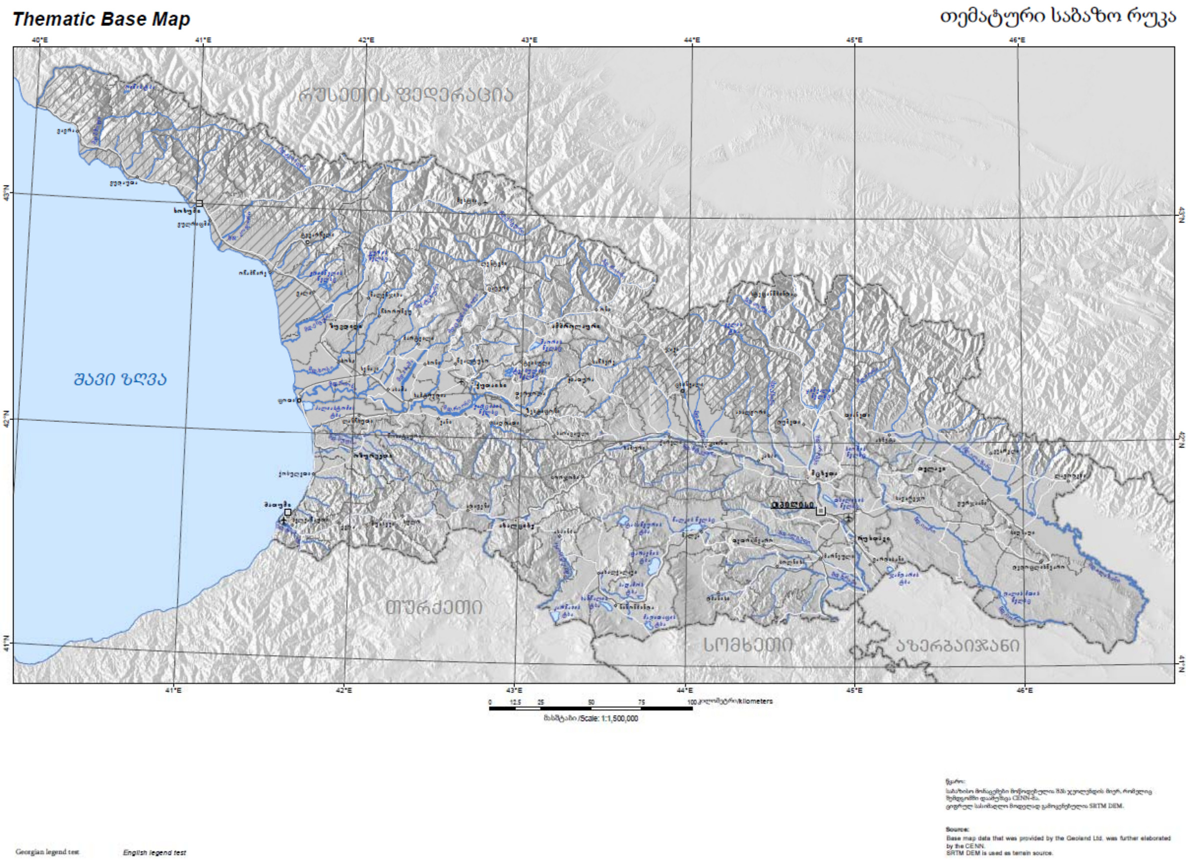
12. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()
14. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()
18. The quick brown fox jumps over the lazy dog 1234567890
22. The quick brown fox jumps over the lazy dog 1234567890
30. The quick brown fox jumps over the lazy dog 1234567890 !@#$%^&*()

8.3 BASEMAP

A base map is used as a geographic “framework” to assist the map user to locate the portrayed thematic information. The base map reveals distribution patterns. A base map therefore is secondary information, and has to be visually on a lower level than the thematic information.



8.3.1 Minimal required topographic information

The minimal required information to be included in the base map depends on the main theme and the scale of the map. The smaller the scale, the lower the density of the information of the base map.

Elements to be included:

- Grid and/or Graticule
- Relief (incl. height information, contours etc.)
- Natural features (forest, lakes, rivers etc.)
- Man-made features (settlements, buildings, roads)
- Boundaries (national, districts etc.)
- Geographical names (toponomy)

8.3.2 Use of hill shading as backdrop image

Especially for regions where the terrain is hilly or mountainous and the theme relates to the terrain (landslides, avalanches…) a hill shading visually and content wise enhances the quality of the map. Also if the map is rather "empty" the hill shading adds visual value to the map.

The hill shading can be produced using SRTM elevation data and the software ILWIS. The procedure will be explained in 2.2.3 "Exercise".

8.3.3 Exercise "Hill shading"

The exercise will be a "hand-on" workshop, the documentation and data will be distributed.

With the use of ILWIS and SRTM data hill shading as backdrop image for the base map will be created.

8.4 MAP VISUALIZATION

A map is a symbolized image of our geographic reality representing selected features and their characteristics as a result of its author's execution of choices, and that is designed for any use when spatial relationships are of relevance. (International Cartographic Association 2001).

The core of good map design lies in the combination of know-ledge, experience and creative talent to translate the nature and characteristics of the selected features into Graphic symbols (whose locations are geographically defined) which are capable to communicate the nature and characteristics of the selected features to the map user.

8.4.1 Data analysis

To find the proper symbology for a map one has to analyse the cartographic data. The core of this process of analysis is to access the characteristics of the data to find out how they can be visualized, so that the map user properly interprets them. The first step in the analysis process is to find a common denominator for all the data. This common denominator will then be used as the title of the map. For instance, if all data are related to land use collected in 2005, the title could be 'Land use of . . . 2005'. Second, the individual component(s), such as land use, and probably relief, should be analysed and their nature described. Later, these components should be visible in the map.

Data will be of a qualitative or quantitative nature.

Qualitative data is also called nominal data, which exists as discrete, named values without a natural order amongst the values. Examples are different languages (e.g. English, Swahili, and Dutch), different soil types (e.g. sand, clay, peat) or different land-use categories (e.g. arable land, pasture). In the map, qualitative data are classified according to disciplinary insights, such as a soil

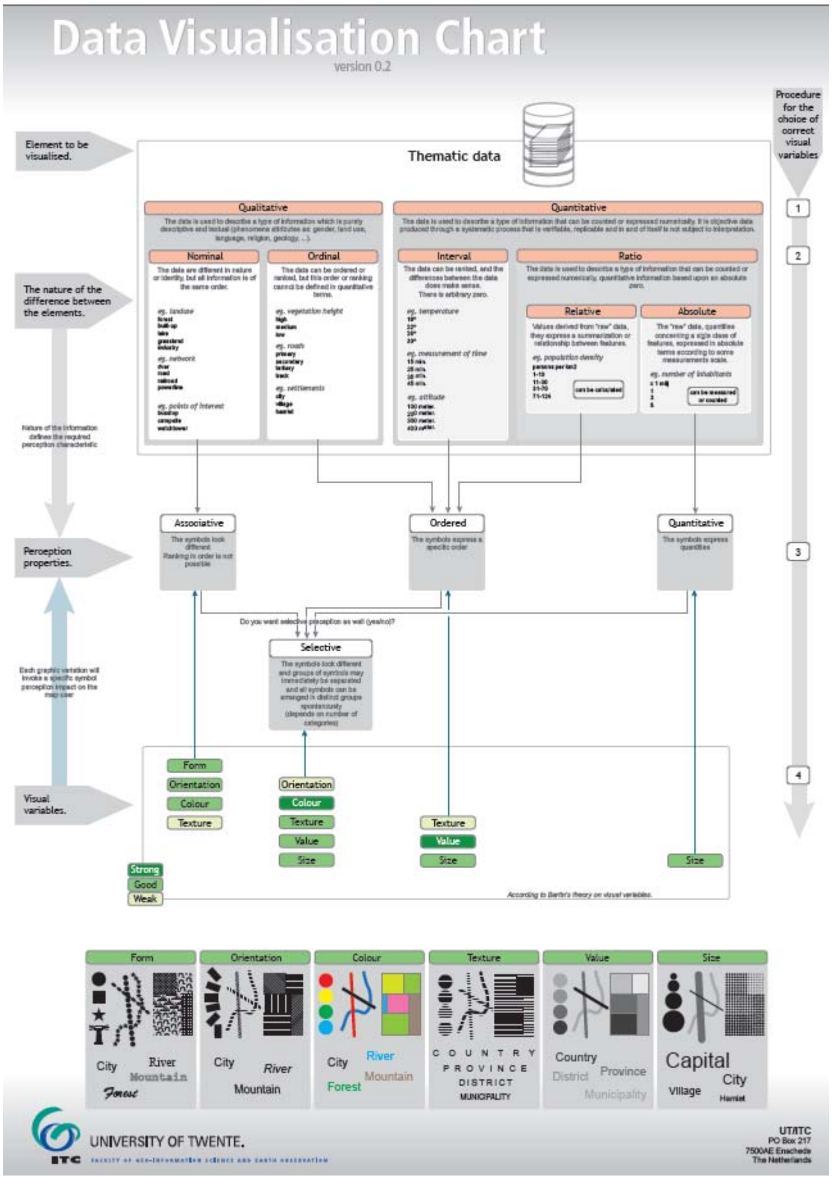
classification system represented as basic geographic units: homogeneous areas associated with a single soil type, recognized by the soil classification.
Quantitative data can be measured, either along an interval or ratio scale. For data measured on an interval scale, the exact distance between values is known, but there is no absolute zero on the scale. Temperature is an example: 40 C is not twice as warm as 20 C, and 0 C is not an absolute zero.
Quantitative data with a ratio scale does have a known absolute zero. An example is income: someone earning $100 earns twice as much as someone with an income of $50. In order to generate maps, quantitative data are often classified into categories according to some mathematical method.
In between qualitative and quantitative data, one can distinguish ordinal data. These data are measured along a relative scale, based on hierarchies. For instance, one knows that one value is 'more' than another value, such as 'warm' versus 'cool'. Another example is a hierarchy of road types: 'highway', 'main road', 'secondary road' and 'track'.

8.4.2 Visual variables

Basic elements of a map, irrespective of the medium on which it is displayed, are point symbols, line symbols, area symbols, and text. The appearance of point, line, and area symbols can vary depending on their nature. Most maps show symbols in different size, shape and colour. Points can vary in form or colour to represent the location of shops or they can vary in size to represent aggregated values (like number of inhabitants) for an administrative area. Lines can vary in colour to distinguish between administrative boundaries and rivers, or vary in shape to show the difference between railroads and roads. Areas follow the same principles: difference in colour distinguishes between different vegetation stands.
Although the variations in symbol appearance are only limited by the imagination, they can be grouped together in a few categories. Bertin distinguished six categories, which he called the visual variables and which may be applied to point, line and area symbols. As illustrated in the figure below, they are: size, value (lightness), texture, colour, orientation and shape.
These visual variables can be used to make one symbol different from another. In doing this, map makers have, in principle, freedom of choice provided they do not violate the rules of cartographic grammar. They do not have that choice when deciding where to locate the symbol in the map. the symbol should be located where features belong. Visual variables influence the map user's perception in different ways. What is perceived depends on the human capacity to see or perceive:

- what is of equal importance (e.g. all red symbols represent danger), saturation differences;
- order(e.g. the population density varies from low to high—represented by light and dark colour tints, respectively);
- quantities (e.g. symbols changing in size with small symbols for small amounts);
- or an instant overview of the mapped theme.

There is an obvious relationship between the nature of the data to be mapped and the ‘perception properties’ of visual variables, see the figure below.



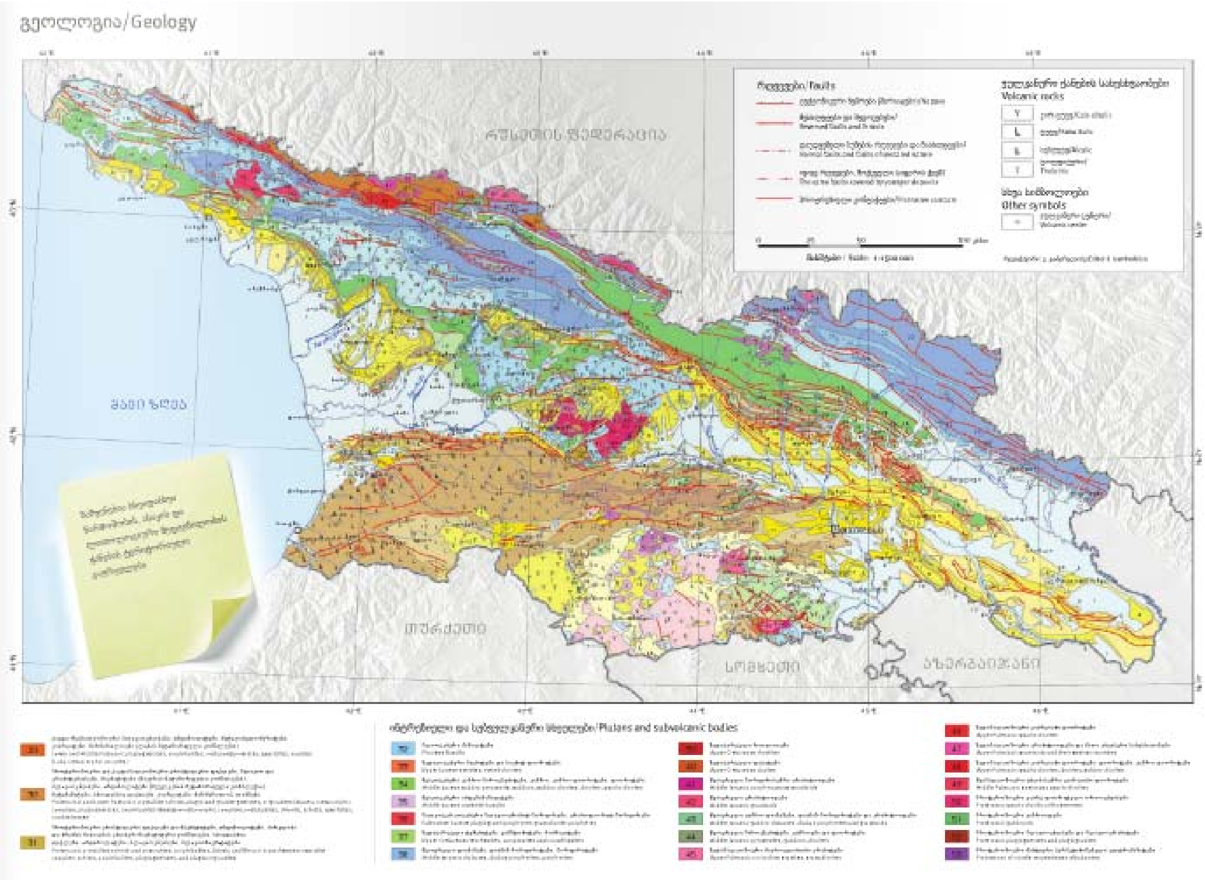
This figure is available as an A3 poster.

8.5 MAPTYPES

A thematic map aims to show the (geo) spatial distribution, quality and/or quantity (and possible relationship) of a specific phenomenon or several phenomena. The division of the thematic map types can be based on a phenomenon oriented division e.g.: Land use map, Soil map, Tourist map etc. or on a cartographic representation oriented division: chorochromatic map, choropleth map, proportional symbol map etc.
The further focus will be on the cartographic representation oriented division.

8.5.1 Chorochromatic map

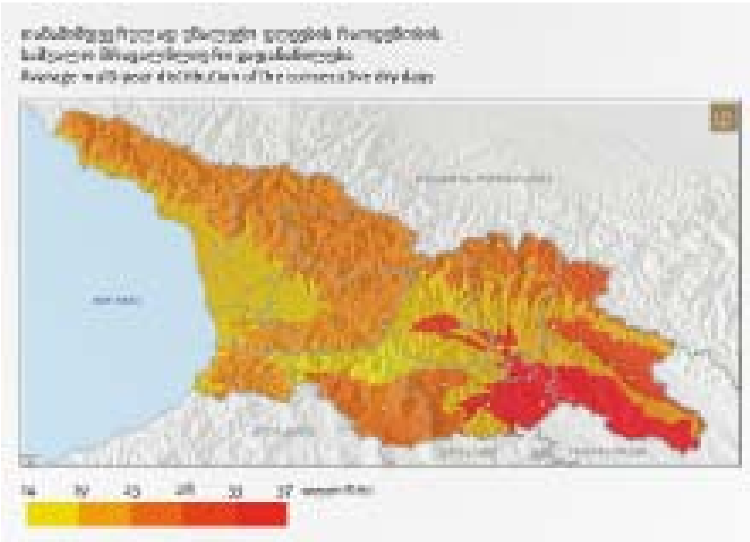
This map type presents descriptive information about the distribution, nature and location of features occupying areas.
The visual variables applied to area symbols are: colour, form, orientation and texture. Examples are e.g.: soil map, district map.



Atlas of Natural Hazards & Risks of Georgia, 2.2.2.Geology

8.5.2 Choropleth map

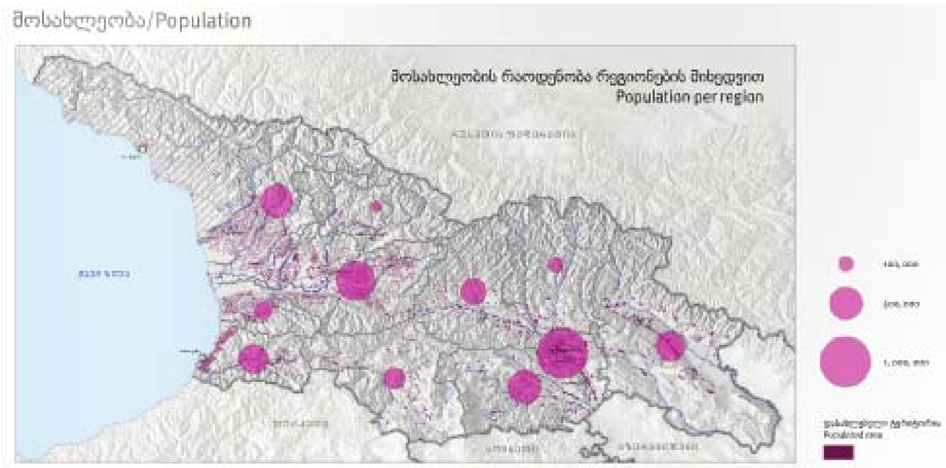
This map type presents relative quantified and interval or ordinal based information on the distribution, nature and location of features occupying areas.
The visual variable applied to area symbols: Value
Examples of this map type are e.g.: population density map, map showing percentages of students per country etc.



Atlas of Natural Hazards & Risks of Georgia, 2.2.5.Precipitation

8.5.3 Proportional Symbol map

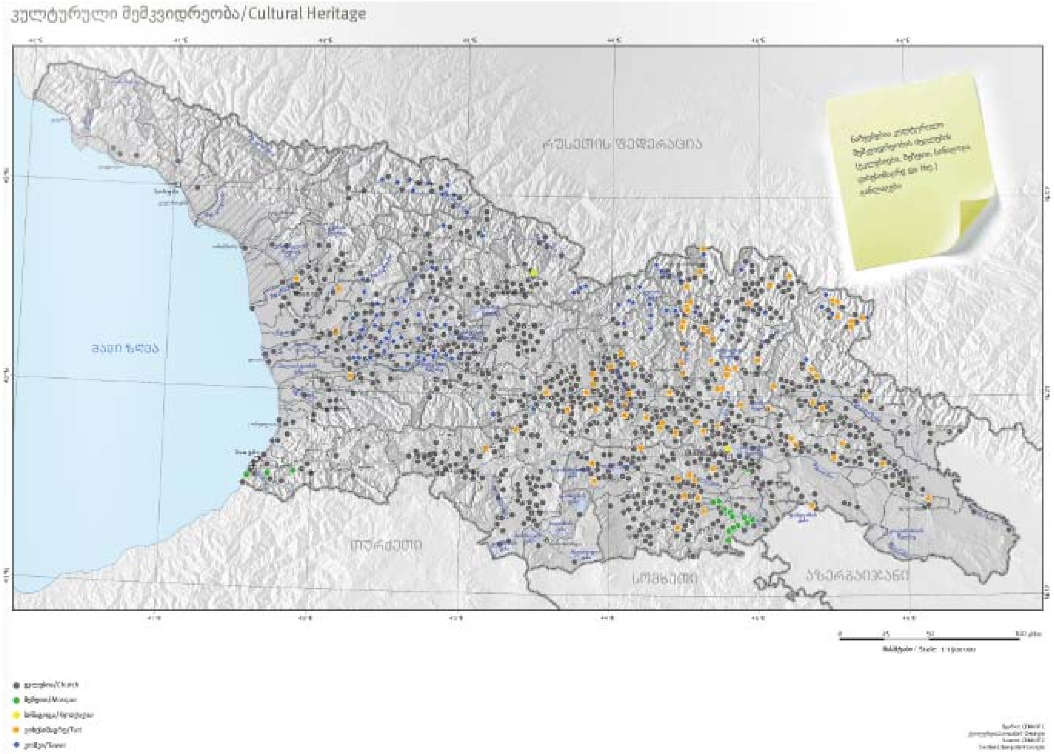
Absolute quantities can be (best) represented by: means of a proportional point symbol of which the size of the point symbol is related to the data values.



Atlas of Natural Hazards & Risks of Georgia, 2.3.5.Population

8.5.4 Dot maps

A dot map is a map type that uses dot symbols to show the presence and spatial distribution of features.

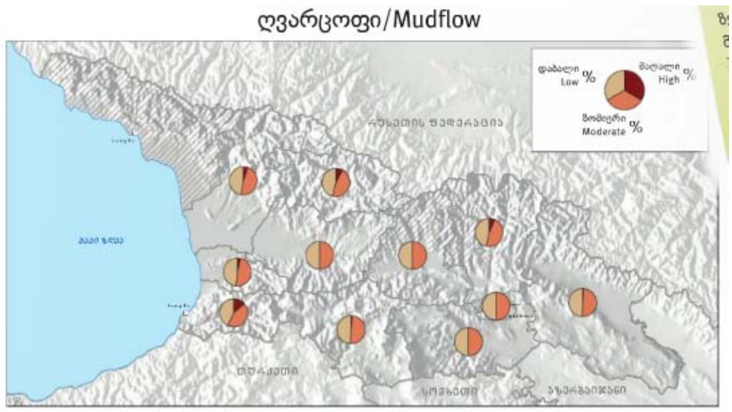


Atlas of Natural Hazards & Risks of Georgia, 2.3.GDP Cultural Heritage

8.5.5 Charts

(Proportional) pie

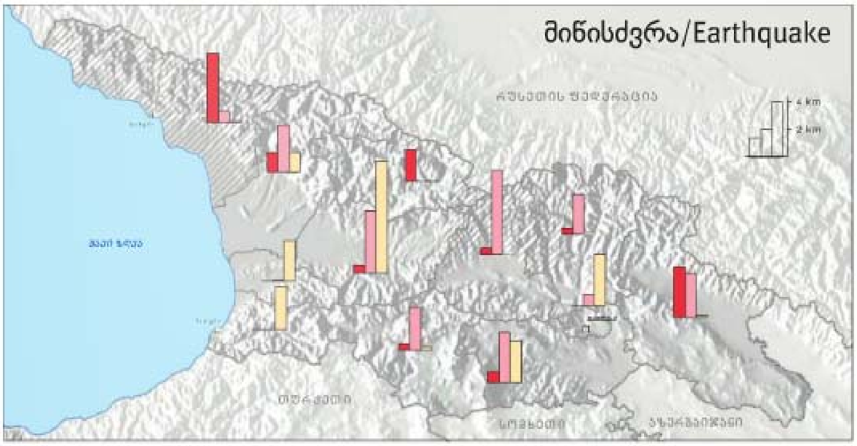
(This map shows proportional circles where their sizes are proportional to the total values.) The circles are divided in sectors, their sizes are proportional to the corresponding % of the total value.



Atlas of Natural Hazards & Risks of Georgia, 4.6.GDP Exposure

8.5.6 Bar

The length of the bars are proportional to the corresponding value.



Atlas of Natural Hazards & Risks of Georgia, 4.5.Road Exposure

Exercise "Symbol design and Map production"

The exercise will be a "hand-on" workshop, the documentation and data will be distributed then.

Base map

Base map production, to be used for thematic layers.

Add thematic layers

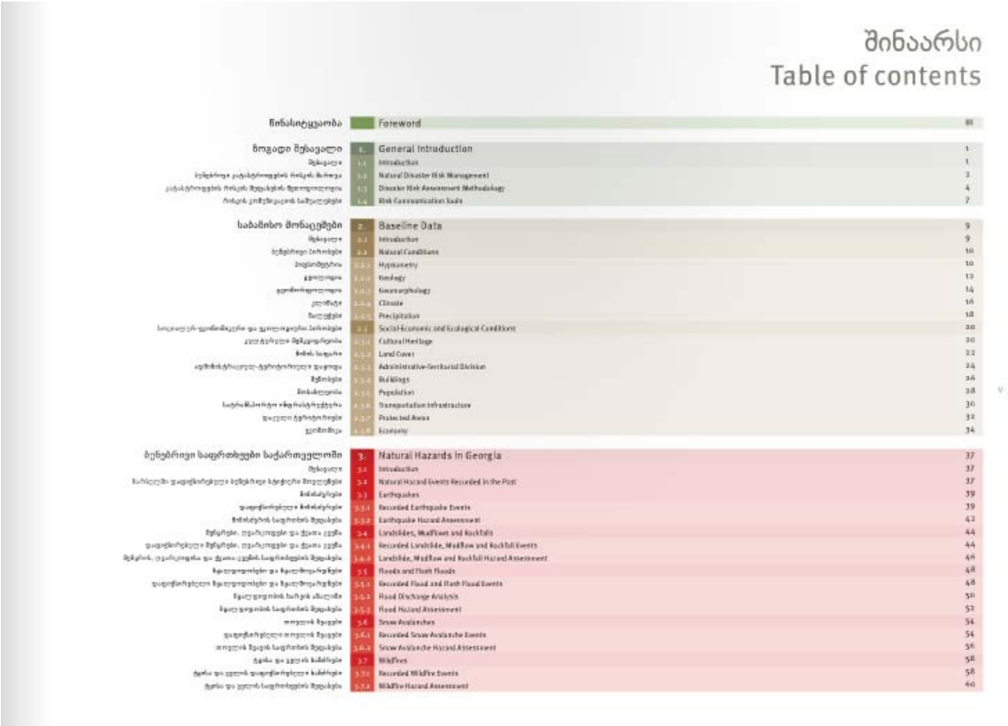
Select correct symbolisation for different Map types and use appropriate visual variables.

8.6 MAPS FOR AN ATLAS

An atlas is a collection of maps mostly accompanied with explanatory text and figures (photographs and/or illustrations), usually joined in a book.

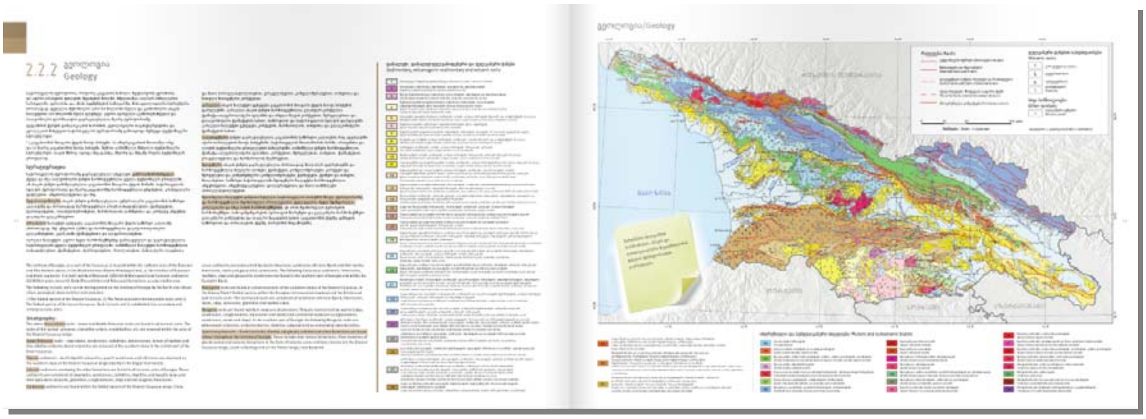
A desk atlas can also feature a variety of different maps of the same place. For example, to reveal more about a particular place, the atlas might include maps showing population, political boundaries, natural resources, topography, religious affiliation, political affiliation, important products, and natural features. A historical atlas may show these topics as they were many years ago or as they change over time. Related material may appear in charts, essays, timelines, or chronologies. [1]

Atlas content



შინაარსი
Table of contents

Before creating an Atlas, the content has to be listed and ordered to get a logic structure. This list will finally be the Table of Content (TOC).



The structure of the TOC is depending on the choice of number and position of maps too. Before the final TOC can be created, the list of maps has to be completed.

[1] http://www.wisegeek.com/what-is-an-atlas.htm

9.WEBMAPPING, WEBGIS

9.1 INTRODUCTION

Web mapping is the process of designing, implementing, generating and delivering maps on the World Wide Web and its product. While web mapping primarily deals with technological issues, web cartography additionally studies theoretic aspects: the use of web maps, the evaluation and optimization of techniques and workflows, the usability of web maps, social aspects, and more. Web GIS is similar to web mapping but with an emphasis on analysis, processing of project specific geodata and exploratory aspects.[1] Often the terms web GIS and web mapping are used synonymously, even if they don't mean exactly the same. In fact, the border between web maps and web GIS is blurry. Web maps are often a presentation media in web GIS and web maps are increasingly gaining analytical capabilities.

A special case of web maps are mobile maps, displayed on mobile computing devices, such as mobile phones, smart phones, PDAs and GPS. If the maps on these devices are displayed by a mobile web browser or web user agent, they can be regarded as mobile web maps. If the mobile web maps also display context and location sensitive information, such as points of interest, the term Location-based service is frequently used."[2]

"The use of the web as a dissemination medium for maps can be regarded as a major advancement in cartography and opens many new opportunities, such as real-time maps, cheaper dissemination, more frequent and cheaper updates of data and software, personalized map content, distributed data sources and sharing of geographic information. It also implicates many challenges due to technical restrictions (low display resolution and limited bandwidth, in particular with mobile computing devices, many of which are physically small, and use slow wireless Internet connections), copyright and security issues, reliability issues and technical complexity. While the first web maps were primarily static, today's web maps can be fully interactive and integrate multiple media. This means that both web mapping and web

cartography also have to deal with interactivity, usability and multimedia issues."[2]
Internet-based GIS systems have been developed in which all the individual layers are separated (multi-tier approach) thus allowing many clients to access and visualize the geo-data at the same time.

A WebGIS is a special GIS tool that uses the Internet as a means to access and transmit remote data, conduct analysis, and present GIS results. WebGIS applications for risk visualization have been developed for different purposes. At the global level, the PREVIEW Global Risk Data Platform is the result of efforts of UNEP, UNISDR, UNDP and World Bank, to share spatial data and information on global risk from natural hazards through the internet. Users can visualise, download or extract data on past hazardous events, human and economical hazard exposure, and risk from natural hazards on a platform compliant with OGC Web Services (OWS). It covers tropical cyclones and related storm surges, drought, earthquakes, biomass fires, floods, landslides, tsunamis and volcanic eruptions (see Figure 9). The collection of data is made via a wide range of partners (UNEP/DEWA/GRID, 2010).

[1] Fu. P and J. Sun, 2010. Web Gis: Principles and Applications. Esri Press

[2] Andreas Neumann Encyclopeida of GIS

1.1 THE USE AND USERS

So you want to make an application! An application like a web map requires a lot of time for design and development and investment in soft- and hardware.
Ask yourself why the product needs to be developed, is there a need? Who will be the audience? What is the aim of the application, what should it do or what should it show? What data do you need, who will provide it? What are the resources, how much time is available and who has the money to pay it? It is obvious that dissemination is via the WWW, but which technology will be used?

Purpose

Too often web applications lack the focus on a clear purpose and visitors are quickly confused. Defining the purpose of your application before you are creating it will ensure that you achieve the required attention.

User requirements

Start with a definition of the target user, general public does not exist. The content you offer has to be adjusted to the targeted audience. Too simple

content will not attract highly educated visitors and too complex makes the application unattractive for e.g. secondary school students.
Also consider the Network connection speed and hardware constraints of the targeted users.

Data requirements

Data not only refers to map content, but also to the images (photo and graphics) to be used and accompanying explanatory text. An exhaustive list is required, as well as an indication who is responsible for acquisition and quality.

Application design

Application usability is enhanced when users know how to operate the User Interface and it guides them through the workflow. Violating common guidelines prevents both.
Usually, applications fail because they
(a) solve the wrong problem,
(b) have the wrong features for the right problem, or
(c) make the right features too complicated for users to understand.
(Jakob Nielsen, 2008)

9.1.1 Functionality

One of the reasons to use a web application is to get information. An application must be designed in such way that such information is easy to find, quickly to access and available for visitors whenever they require it. A good webapp is where you can find what is promised and where tools offered does help the user to find what they are looking for. Functionality concerns easy access to the offered information and the tools you provide.
The tools you include should be:

- functional, the visitor should not be confused or restricted Work fast, reliable, consistent and be to the point
- (preferably) based upon conventions which are easily understood by your visitor.

The graphic design should also be functional, that is to help the visitor to easily find their way to information required.

9.1.2 Sitemap / flowchart

Site design deals with the organisation of files and folders. Web sites have a tendency to expand beyond the original idea, organisation of files used to create the website is an essential part for the design of a website and also web applications.
By drawing a map of your designed website or web application, helps to visually plan and organise current and future development of your work.

A flowchart is a type of diagram that represents an algorithm or process, showing the steps as boxes of various kinds, and their order by connecting them with arrows. This diagrammatic representation illustrates a solution to a given problem. Process operations are represented in these boxes, and arrows; rather, they are implied by the sequencing of operations. Flowcharts are used in analyzing, designing, documenting or managing a process or program in various fields.
Flowcharts are used in designing and documenting complex processes or programs. Like other types of diagrams, they help visualize what is going on and thereby help the viewer to understand a process, and perhaps also find flaws, bottlenecks, and other less-obvious features within it.
(Wikipedia)

9.1.3 Mock-up (graphic design)

cBefore a website or application can be produced, a proper lay-out model (mock-up) has to be designed. Such a Mock-up is by preference produced in a raster editing software (Adobe PhotoShop (Elements, Adobe FireWorks, Picasa (free to download from Google…) etc. However, also graphic software programs such as Macromedia/Adobe FreeHand, Illustrator, CorelDraw or Open Source software as InkScape or GIMP may be used.

Try to design in such a way that the mock-up already reflects its character; professional…, business.., leisure time, tourism by selecting appropriate colours, fonts, symbols, typography etc.

The layout model is made in such a way that it exactly resembles the final result (dimensions (in pixels), colour, fonts and sizes, position of elements etc.).

For the content “fake” elements might be applied, this forces the designer (and your customer!) not to concentrate on possible mistakes in the content but purely on the look and feel of the site or application.
The reason for working in a raster environment rather than in a vector environment is simple; the monitor on which the result is displayed also shows the application by pixels. The resolution of a monitor is low (96 ppi) and this can be perfectly simulated by raster editing software.

Quite often a functional Mock-up is produced, where mouse-over effects are simulated.

The Mock-up is applied to derive all specifications from, like font-sizes, colour, positions, structure etc. On basis of these specifications the web application has to be created.

1.2 EXERCISE BASIC WEB-MAPPING EXERCISES

After design and specifications, the actual creation of the Web application can take place.

Creating a WebMapServer Service

In this exercise you will set-up a WebMapService, using MapServer

OpenLayers & OpenStreetMap

This is the exercise description for creating interoperable web map clients using the OpenLayers Javascript API -- Starting with OpenStreetMap

OpenLayers WMS client

This is the exercise description for interoperable web map clients using the OpenLayers Javascript API -- Adding your WMS to an OSM base map

Web Mash up

Building a Mapping Web Site using HTML5, CSS3 and JavaScript APIs

10. CONCLUSIONS

This guide provided a framework for understanding hazards assessment and disaster-risk management. Spatial data requirements and techniques for multi-hazard risk assessment have been addressed. It should be emphasized that data collection, analysis/modelling, and information production, as part of this process is a complex task, because risk is a dynamic concept and has many facets. This is illustrated in Figure 11. It is evident that the world undergoes rapid changes in terms of population growth, urbanization, economic development and socio-political structures. Furthermore, there is convincing evidence that greenhouse gas forcing may be causing changes in the earth's climate that are expected to lead to an increase in hazardous events due to a hydro-meteorological trigger (IPCC, 2007).

The difficulty in predicting the magnitude of these changes and the frequency of occurrence of extreme events, reiterates the need for a thorough change in our adaptation management of hydro-meteorological risks (EEA, 2004). According to recent European studies, the projected impact of flooding in Europe will increase dramatically in the coming decades. By 2080 it is estimated that between 250,000 and 400,000 people will be affected each year by flooding, and the total annual expected flood damage will range between 7.7 and 15 billion Euros. These values are more than double of those in the period 1961-1990 (Ciscar, 2009). Very limited work has been carried out up to now to include the cascading or conjoint (also called domino) effects in the analysis of future impacts of environmental changes to hydro-meteorological hazards. The exposure of elements-at-risk also increases and therefore the risk of natural hazards is constantly growing. Land-use changes will occur as a result of technological, socio-economic and political developments, as well as global environmental change. The nature and rate of change will strongly depend on policy decisions. Many environmental problems are caused by unplanned urban expansion. By 2050, approximately 70 % of all people will be living in urban areas, while in several countries the proportion will be 90 % or more. Some of the drivers of change to the urban environmental are the global economy, cross border transport networks, large scale societal, economic and demographic changes and differences in national planning laws. As the level of uncertainty of the components used in the risk equation (hazard, vulnerability, quantification of the exposed elements-at-risk) is very high, the analysis of the changes in future risk should incorporate these uncertainties in a probabilistic manner.

Impacts of natural hazards on the environment and on the society are still tackled by mono-disciplinary approaches. The focus is reflected in the domains of scientific research (single approach and tools for each type of hazard), in the existing management tools, and in the legislative basis of these activities. Management tools, models, and local-to-regional technical solutions have been proposed by numerous projects for single hazards. Only a few of them have tackled the issue of risk assessment and management, however, from a multi-hazard perspective, especially including possible combined and domino effects. Probabilistic tools for multi-hazard risk assessment are not available to stakeholders at the local level. Insurance companies and specialized risk-assessment consultants have developed models, but these are not open for public use. The implementation of risk-management measures such as disaster-preparedness programmes, land-use planning, regulatory zoning and early warning systems are considered essential. Fleischauer et al. (2006) conclude that spatial planning is only one of many aspects in risk management and that it is, in general, not properly implemented. Further, multi-risk assessment approaches are not used in planning practice: risk indicators are hardly used and vulnerability indicators are not at all used.

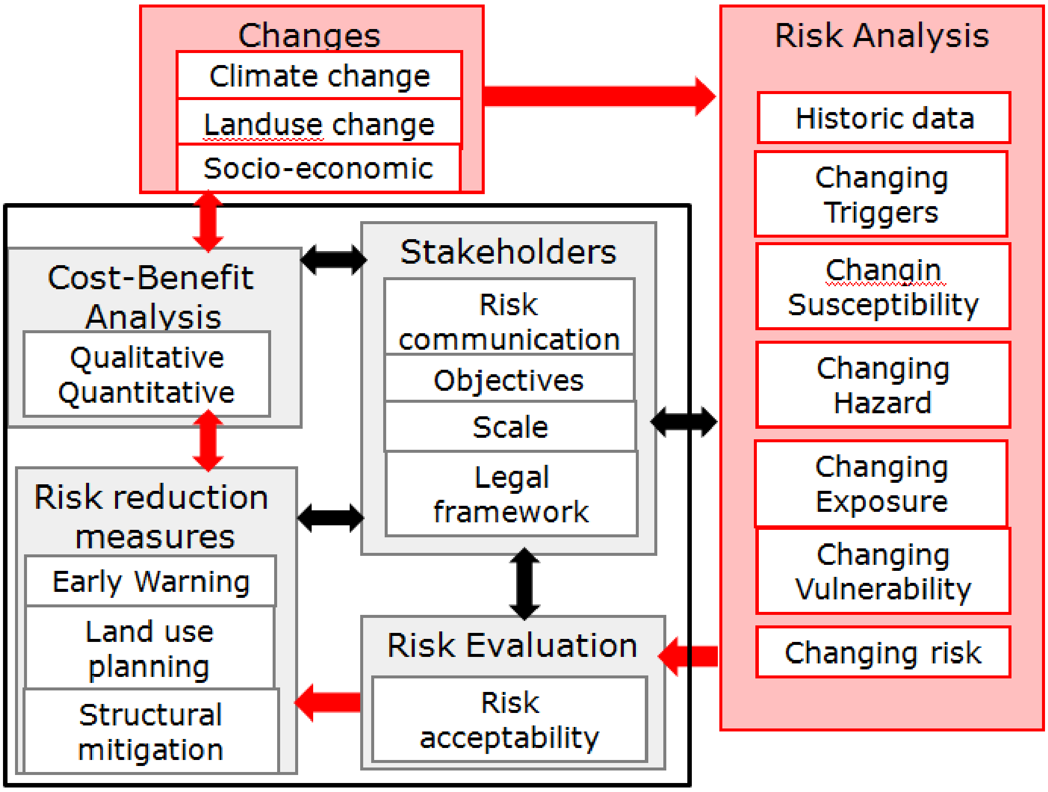


Figure 11: Framework of the implementation of environmental change scenarios in risk management.

Therefore approaches are needed for integrating disaster-risk assessment in long-term resource allocation and land-use planning at all levels of administration. Additionally, scientific advances in hazard and risk assessment and demands of stakeholders/end-users are still not well connected. In many cases, the scientific outcomes remain rooted solely within the scientific community, or new knowledge is not fabricated enough to be implemented by stakeholders and end-users (IRGC, 2005). A key cause of the gap between the science community and stakeholders/end-users is in the complexity of human-environment interactions. This has led to the development of a diversity of approaches, often not easy to implement by the end-user community. There is a need for the development of a harmonized decision-making structure for applying hazard and risk mitigation through spatial planning in risk-prone areas. There is also a need for capacity building in the field of multi-hazard risk assessment, and the transfer of the knowledge from developed countries to developing countries using Open-source software tools and methods adapted to the data availabilities in these countries (Van Westen et al., 2009). 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.

To conclude, it is clear that geo-information science and earth observation have made significant contributions to the understanding of natural hazard processes, and the way these could be monitored and modelled at various scales and using a range of techniques. They are also been used successfully in analyzing the risk to vulnerable societies, and the results have been communicated to stakeholders that have often used them in appropriate disaster risk reduction strategies. However, as both extreme events are expected to increase as well as the number of vulnerable people, much work has to be done in better estimating future hazards and risks. Geomorphologists should further develop their scientific work into practical applications that can be used to save lives and reduce economic losses due to natural disasters.

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12. GLOSSARY:

AAL: Average Annual Loss, or Expected Annual Loss (EAL) is the long term loss rate which can be obtained by summing the product of each discrete loss state with its annual frequency of occurrence over all loss states.

ADPC: the Asian Disaster Preparedness Center (ADPC) is a non-profit organization from Bangkok, supporting the advancement of safer communities and sustainable development, through implementing programs and projects that reduce the impact of disasters upon countries and communities in Asia and the Pacific.

ADRC: the Asian Disaster Reduction Center in Kobe, Japan with a mission to enhance disaster resilience of the member countries, to build safe communities, and to create a society where sustainable development is possible.

AEP: Annual Exceedance Probability is the estimated probability that an event of specified magnitude will be exceeded in any year.

ALOS: Advanced Land Observing Satellite is a land observing satellite launched in January 2006 by Japan Aerospace Exploration Agency (JAXA).

APRSAF: Asia-Pacific Regional Space Agency Forum was established in 1993 to enhance space activities in the Asia-Pacific region.

ArcPad: GIS software developed by ESRI for use on Mobile-GIS devices

ArcGIS: GIS software by ESRI

ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer is a Japanese sensor which is one of five remote sensing devices on board the Terra satellite launched by NASA in 1999. ASTER provides high-resolution images of the Earth in 15 different bands of the electromagnetic spectrum, ranging from visible to thermal infrared light.

AVHRR: Advanced Very High Resolution Radiometer is a space-borne sensor on the National Oceanic and Atmospheric Administration (NOAA) family of polar orbiting platforms.

Capacity: the positive managerial capabilities of individuals, households and communities to confront the threat of disasters (e.g. through awareness raising, early warning and preparedness planning).

CAPRA: Central American Probabilistic Risk Assessment, initiative developed by the Worldbank.

Cartosat: a stereoscopic Earth observation satellite in a sun-synchronous orbit. The satellite was built, launched and maintained by the Indian Space Research Organisation (ISRO)

CLC: CORINE Land Cover. See CORINE

Consequence: The expected losses in a given area as a result of a given hazard scenario.

CORINE: the Corine Land Cover project is a joint initiative of the EU Commission and EU Environment Agency which developed a available database now including orthorectified Landsat 7 ETM satellite images of the European territory, Land Cover and Changes definition maps.

CRED: the Centre for Research on the Epidemiology of Disasters, of the Université catholique de Louvain, Belgium, specializes in the fields of international disaster and conflict health studies, with research and training activities linking relief, rehabilitation and development, and maintains the EM-DAT database.

CVA: the Capacity and Vulnerability Assessment is used as a diagnostic tool to understand problems and their underlying causes, related to the vulnerability and capacity of local communities to natural hazards.

DEM: a Digital Elevation Model is a digital model or 3-D representation of a terrain's surface created from terrain elevation data.

DGPS: a Differential Global Positioning System is an enhancement to Global Positioning System that uses a network of fixed, ground-based reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions.

Disaster: a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.

DNCA: Damage, Needs and Capacity Assessment involves a participatory analysis of the disaster event focussing on the damages caused, the immediate needs and priorities of the affected community, and of the remaining capacities people use to cope with the adverse effects.

DRI: Disaster Risk Index produced a model of factors influencing levels of human losses from natural hazards at the global scale, by the United Nations Development Programme

DSM: a Digital Surface Model is a digital model or 3-D representation of the earth's surface and includes all objects on it.

DRM: Disaster Risk Management is the systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster.

DRR: Disaster Risk Reduction is the concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events

DTM: Digital Terrain Model a digital model or 3-D representation of the bare ground surface without any objects like plants and buildings

EDM: Electronic Distance Measurement is an electronic theodolite integrated with an electronic distance meter to read slope distances from the instrument to a particular point

EFD: European Flood Directive requires EU Member States to engage their government departments, agencies and other bodies to draw up a Preliminary Flood Risk Assessment.

EFFIS: the European Forest Fire Information System supports the services in charge of the protection of forests against fires in the EU countries and provides the European Commission services and the European Parliament with updated and reliable information on wildland fires in Europe.

EIA: an environmental impact assessment is an assessment of the possible positive or negative impacts that a proposed project may have on the environment, together consisting of the natural, social and economic aspects.

Elements-at-risk: Population, properties, economic activities, including public services, or any other defined values exposed to hazards in a given area. Also referred to as "assets". The amount of elements-at-risk can be quantified either in numbers (of buildings, people etc.), in monetary value (replacement costs, market costs etc), area or perception (importance of elements-at-risk).

EM-DAT: Emergency Events Database, the international database on natural hazards, maintained by CRED.

ENVISAT: polar orbiting spacecraft operated by the European Space Agency possessing several instruments used to monitor the earth's environment. Parameters measured include ozone concentration, aerosols, surface stress for earthquake potential, sea level heights, and fires.

EO: Earth observation is the gathering of information about planet Earth's physical, chemical and biological systems, using remote sensing. It is used to monitor and assess the status of, and changes in, the natural environment and the built environment.

ERS: European radar satellite, developed and maintained by the European Space Agency (ESA).

ESRI: the world's largest GIS company that develops geographic information systems (GIS) solutions that function as an integral component in nearly every type of organization.

ETOPO: topographic dataset from the NOAA NGDC, of topography and bathymetry for the entire Earth's surface.

EWS: Early Warning System is the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.

Exposure: exposure indicates the degree to which the elements-at-risk are exposed to a particular hazard. The spatial interaction between the elements-at-risk and the hazard footprints are depicted in a GIS by simple map overlaying of the hazard map with the elements-at-risk map.

FEMA: Federal Emergency Management Agency, the national organisation for disaster risk management in the USA.

Formosat: earth observation satellite operated by the National Space Organization (NSPO) of the Republic of Taiwan.

Frequency : a measure of likelihood expressed as the number of occurrences of an event in a given time.

GeoEye: a commercial satellite imagery company based in Dulles, Virginia, USA.

GDACS: Global Disaster Alert and Coordination System, by Joint Research Center (JRC) of the European Commission.

GEM: the Global Earthquake Model is a public-private partnership initiated in 2006 by the Global Science Forum of the OECD to develop global, open-source risk assessment software and tools.

Geological hazard: a geological process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage

GIS: a geographic information system, or geospatial information system is a system designed to capture, store, manipulate, analyze, manage and present all types of geographically referenced data.

GMES: Global Monitoring for Environment and Security initiative of the European Commission and the European Space Agency (ESA)

G-MOSAIC: GMES services for Management of Operations, Situation Awareness and Intelligence for regional Crises

GMOSS: Global Monitoring for Security and Stability is a project in the aeronautics and space priority of the EU 6th to integrate Europe's civil security research and to develop and maintain an effective capacity for global monitoring using satellite earth observation.

GRUMP: Global Rural-Urban Mapping Project is a project for generation of a gridded model with a grid cell resolution of 30 arc-seconds for global population distribution developed by the Socioeconomic Data and Applications Center (SEDAC).

GPS: Global Positioning Systems is a space-based global navigation satellite system (GNSS) that provides location and time information in all weather, anywhere on or near the Earth, where there is an unobstructed line of sight to four or more GPS satellites.

GSHAP: the Global Seismic Hazard Assessment Project was launched in 1992 by the International Lithosphere Program (ILP) with the support of the International Council of Scientific Unions (ICSU), and produced small scale standardized seismic hazard maps for all seismic regions of the world.

Hazard: A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage

Hazard zoning: the subdivision of the terrain in zones that are characterized by the temporal probability of occurrence of hazardous events of a particular size and volume, within a given period of time.

HAZUS: Hazards U.S. loss estimation software developed by the Federal Emergency Management Agency (FEMA) together with the National Institute of Building Sciences (NIBS).

HVCA: Hazards, Vulnerability and Capacity Assessment is a method that involves a participatory analysis of historical hazard trends and present threats undertaken at the level of the community (hazard assessment). It is combined with an understanding of the underlying reasons why hazards become disasters (vulnerability assessment) and of the available resources an affected community uses to cope (capacity assessment).

Hydrometeorological hazard: process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage

ICG: International Centre for Geohazards, Norway.

IFRC: International Federation of Red Cross and Red Crescent Societies

IKONOS: a commercial earth observation satellite, and was the first to collect publicly available high-resolution imagery at 1- and 4-meter resolution. It offers multispectral (MS) and panchromatic (PAN) imagery.

ILWIS: the Integrated Land and Water Information System is an Open-source combined GIS and image processing software developed by ITC, and maintained by 53North.

InSAR: Interferometric SAR is a radar technique used in geodesy and remote sensing. This geodetic method uses two or more synthetic aperture radar (SAR) images to generate maps of surface deformation or digital elevation, using differences in the phase of the waves returning to the satellite.

IRS: Indian Remote Sensing satellites are a series of Earth Observation satellites, built, launched and maintained by Indian Space Research Organisation. The IRS series provides many remote sensing services to India.

ITC: the Faculty of Geo-Information Science and Observation of the University of Twente is an organization that provides international postgraduate education, research and project services in the field of geo-information science and earth observation using remote sensing and GIS, located in Enschede, the Netherlands.

LANDSAT: the longest running enterprise for acquisition of imagery of Earth from space. The first Landsat satellite was launched in 1972; the most recent, Landsat 7, was launched on April 15, 1999. Landsat 7 data has eight spectral bands with spatial resolutions ranging from 15 to 60 meters; the temporal resolution is 16 days

LiDAR: Light Detection And Ranging is an optical remote sensing technology that can measure the distance to, or other properties of a target by illuminating the target with light, often using pulses from a laser

LIMES: Land and Sea Integrated Monitoring for Environment and Security is is an Integrated Project co-funded by the European Commission within the 6th Framework Programme – Aeronautics&Space/GMES Security.

MARSOP: MARS Crop Yield Forecasting System (MCYFS) carried out by AGRI4CAST and FOODSEC actions within the Institute for the Protection and the Security of the Citizen (EU JRC).

MERIS: Medium Resolution Imaging Spectrometer is is one of the main instruments on board the European Space Agency (ESA)'s Envisat platform, to observe the color of the ocean, both in the open ocean and in coastal zones.

Mobile-GIS: a GIS that is running on a mobile, hand held device, which is linked to a GPD for collecting spatial and attribute data in digital format directly in the field.

MODIS: Moderate Resolution Imaging Spectroradiometer is a sensor launched into Earth orbit by NASA in 1999 on board the Terra (EOS AM) Satellite, and in 2002 on board the Aqua (EOS PM) satellite, designed to provide measurements in large-scale global dynamics including changes in Earth's cloud cover, radiation budget and processes occurring in the oceans, on land, and in the lower atmosphere.

Natural hazard: A potentially damaging physical event, phenomenon or human activity that may cause loss of life or injury, property damage, social and economic disruption or environmental degradation. This event has a probability of occurrence within a specified period of time and within a given area, and has a given intensity.

NDVI: Normalized Differential Vegetation Index is is a simple numerical indicator that can be used to analyze remote sensing measurements, typically but not necessarily from a space platform, and assess whether the target being observed contains live green vegetation or not.

NOAA: National Oceanic and Atmospheric Administration, USA

OneGeology: is an international initiative of the geological surveys of the world, launched in 2007 as a contribution to the International Year of Planet Earth, with the aim to create a web-based geological map of the world.

ORCHESTRA: One of the European Union's major research and innovation projects for risk management, to help national and local governments predict and react to natural disasters by joining up national and local information systems and applications.

OSM: OpenStreetMap (OSM) is a collaborative project to create a free editable map of the world. The maps are created using data from portable GPS devices, aerial photography, other free sources or simply from local knowledge.

PAGER: Prompt Assessment of Global Earthquakes for Response, a tool for the rapid assessment of peoples exposed after an earthquake, developed by the USGS.

PALSAR: Phased Array type L-band Synthetic Aperture Radar sensor on board of the Advanced Land Observing Satellite (ALOS) developed by the National Space Development Agency of Japan (NASDA

PGA: Peak Ground Acceleration is a measure of earthquake acceleration on the ground and an important input parameter for earthquake engineering.

PGIS: participatory GIS is encompassing participatory approaches to planning and spatial information and communication management using mobile GIS.

PML: Probable Maximum Loss is the anticipated value of the largest loss that could result from the destruction and the loss of use of property

Preparedness: the knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions.

Prevention: The avoidance of adverse impacts of hazards and related disasters

PREVIEW: Prevention, Information and Early Warning pre-operational services to support the management of risks

PRISM: Panchromatic Remote-sensing Instrument for Stereo Mapping, on board of the Advanced Land Observing Satellite (ALOS)

Probability: a measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty). It is an estimate of the likelihood of the magnitude of the uncertain quantity, or the likelihood of the occurrence of the uncertain future event.

PSInSAR: Permanent Scatterers Radar Interferometry is a relatively recent development from conventional InSAR, and relies on studying pixels which remain coherent over a sequence of interferograms.

Qualitative risk analysis: an analysis which uses word form, descriptive or numeric rating scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur.

Quantitative risk analysis: an analysis based on numerical values of the probability, vulnerability and consequences, and resulting in a numerical value of the risk.

QuickBird: a high-resolution commercial earth observation satellite, owned by DigitalGlobe and launched in 2001.

RADARSAT: The RADARSAT constellation is a pair of Canadian Remote Sensing satellites. The constellation consists of RADARSAT-1, launched 1995, RADARSAT-2, launched 2007

RADIUS: Risk Assessment Tools for Diagnosis of Urban Areas against Seismic Disasters

Remote sensing: the acquisition of information about an object or phenomenon, without making physical contact with the object. In modern usage, the term generally refers to the use of aerial sensor technologies to detect and classify objects on Earth (both on the surface, and in the atmosphere and oceans) by means of propagated signals (e.g. electromagnetic radiation emitted from aircraft or satellites).

Resilience: the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions

Resourcesat: the Indian Remote Sensing (IRS) P6 satellite operated by ISRO and includes the two remote sensing instruments known as LISS-III and AWiFS

Response: the provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.

Risk: the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between (natural, human-induced or man-made) hazards and vulnerable conditions in a given area and time period.

Risk analysis: the use of available information to estimate the risk to individuals or populations, property, or the environment, from hazards. Risk analysis generally contains the following steps: hazard identification, hazard assessment, elements-at-risk/exposure analysis, vulnerability assessment and risk estimation.

Risk assessment: the process of risk analysis and risks evaluation.

Risk control or risk treatment: the process of decision making for managing risks, and the implementation, or enforcement of risk-mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.

Risk evaluation: the stage at which values and judgements enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental, and economic consequences, in order to identify a range of alternatives for managing the risks.

Risk management: the complete process of risk assessment and risk control (or risk treatment).

Risk perception: the way how people/communities/authorities judge the severity of the risk, based on their personal situation, social, political, cultural and religious background, economic level, their level of awareness, the information they have received regarding the risk, and the way they rate the risk in relation with other problems.

RiskScape: New Zealand software and methodology for multi-hazard risk assessment

Risk transfer: the process of formally or informally shifting the financial consequences of particular risks from one party to another whereby a household, community, enterprise or state authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party.

SAFER: Services and Applications For Emergency Response, an EU GMES Emergency Response Service, with the aim to provide space-based products in support of European decision-makers facing natural and technological disasters.

SAR: Synthetic Aperture Radar is a form of radar whose defining characteristic is its use of relative motion between an antenna and its target region to provide distinctive long-term coherent-signal variations that are exploited to obtain finer spatial resolution than is possible with conventional beam-scanning means. It originated as an advanced form of side-looking airborne radar (SLAR).

SDI: Spatial Data Infrastructure is a framework of spatial data, metadata, users and tools that are interactively connected in order to use spatial data in an efficient and flexible way

SELENA: SEimic Loss EstimatioN using a logic tree Approach, an open risk assessment package consisting of the two separate software tools SELENA (Seismic Loss Estimation using a Logic Tree Approach) and RISe (Risk Illustrator for SELENA), developed by the University of Alicante, NOSAR and ICG.

ShakeMaps: a GIS-based tool for earthquake hazard assessment, developed by the USGS in cooperation with regional seismic-network operators. ShakeMaps provides near-real-time maps of ground motion and shaking intensity after important earthquakes.

SPOT: Satellite Pour l'Observation de la Terre, a high-resolution, optical imaging Earth observation satellite system from France.

SMCE: Spatial Multi Criteria Evaluation, a tool for decision-aid and a mathematical tool allowing the comparison of different alternatives or scenarios according to many criteria, often conflicting, in order to guide the decision maker towards a judicious choice.

Societal risk: the risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental, and other losses.

SRTM : Shuttle Radar Topography Mission (SRTM), an international research effort that obtained digital elevation models on a near-global scale from 56° S to 60° N, to generate a high-resolution digital topographic database of the Earth.

Technological hazard: a hazard originating from technological or industrial conditions, including accidents, dangerous procedures, infrastructure failures or specific human activities, that may cause loss of life, injury, illness or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage

TMPA : TRMM Multi-satellite Precipitation Analysis.

TRMM: Tropical Rainfall Measuring Mission, a joint NASA and JAXA mission to monitor and study tropical rainfall from satellite imagery.

UN-ISDR : United Nations International Strategy for Disaster Risk Reduction

USGS: United States Geological Survey.

Ushahidi: free open-source software for co-ordinating citizen reports on a national crisis

UN-SPIDER: United Nations Platform for Space-based Information for Disaster Management and Emergency Response.

VDV: Virtual Disaster Viewer, a crowdsourcing tool for disaster damage assessment developed by ImageCat.

Vulnerability: the conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. Can be subdivided in physical, social, economical and environmental vulnerability.

WASP: Weighted Anomaly of Standardized Precipitation gives an estimate of the relative deficit or surplus of precipitation for different time intervals ranging from 1- to 6-months.

Web-GIS: is the process of designing, implementing, generating and delivering maps on the World Wide Web with an emphasis on analysis, processing of project specific geodata and exploratory aspects.

WorldView: commercial high resolution panchromatic satellite owned by DigitalGlobe. WorldView-2 provides commercially available panchromatic imagery of .5 m resolution, and eight-band multispectral imagery with 1.8 m (5 ft 11 in) resolution.