Project number: 265138
Project name: New methodologies for multi-hazard and multi-risk assessment methods for Europe
Project acronym: MATRIX
Theme: ENV.2010.6.1.3.4
Multi-risk evaluation and mitigation strategies

Start date: 01.10.2010 **End date:** 30.09.2013 (36 months)

Deliverable: Dictionary of the terminology adopted (D3.2)
Version: Final
Responsible partner: AMRA
Month due: M12 **Month delivered: M20**

Primary authors[(a)]:

ALEXANDER GARCIA-ARISTIZABAL, and WARNER MARZOCCHI **27.01.2012**

Signature Date

([(a)] see the *Acknowledgments* section for a full list of people contributing to this document)

Reviewer:

HEIDI KREIBICH **03.01.2012**

Signature Date

Authorised: **JOCHEN ZSCHAU** **31.05.2012**

Signature Date

Dissemination Level		
PU	Public	
PP	**Restricted to other programme participants (including the Commission Services)**	**X**
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Abstract

A technical glossary of risk assessment language is compiled with the aim of making as uniform as possible the technical and scientific language used in risk assessment practice. The more general terms that may be relevant to all or most of the hazards and risks considered in the MATRIX project are first compiled.

After the introduction, we then focus on more detailed definitions of terms that are relevant to each individual hazard (seismic, volcanic, flood, wildfires, landslides, and meteorological events/hazards). Furthermore, since for quantitative risk assessment it is fundamental to have a clear interface between 'hazards' and 'vulnerability', we include a list of possible interface variables (often known as 'intensity measures').

Keywords: technical glossary, specific hazard definitions, risk terminology

Acknowledgments

The research leading to these results has received funding from the European Community's Seventh Framework Programme [FP7/2007-2013] under grant agreement n° 265138.

Different partners from the MATRIX project have collaborated in the elaboration of this report. For instance, the primary reviews of all the project reports, papers, etc. performed here have been done by many people from different groups. Below we provide a list of people who participated (alphabetical order of institutions):

- AMRA:
  Alexander Garcia-Aristizabal, Warner Marzocchi;

- ASPINALL:
  Gordon Woo;

- BRGM:
  Arnaud Reveillere, John Douglas, Gonéri Le Cozannet;

- CEABN-ISA:
  Francisco Rego, Conceicao Colaco;

- GFZ:
  Kevin Fleming, Massimiliano Pittore, Sergey Tyagunov, Sergiy Vorogushyn;

- NGI:
  Farrokh Nadim, Bjørn Vidar Vangelsten;

- TU-Delft:
  Wouter ter Horst.

Table of contents

List of tables

1. Introduction

A unified technical glossary of risk assessment language in a multi-hazard and multi-risk framework is a basic requirement to minimize misunderstandings and to make the first step towards the homogenization of risk assessments. Different terms and/or different definitions of the same terms are often used in natural and anthropogenic risk evaluation practice. Such a lack of common terminology/definitions remains a challenge to practitioners and scientists working on hazard and risk assessments. This problem becomes more critical when considering different types of hazards and risks in a unified framework.

Given the specific nature of different hazards (and the resulting risks) and the still non-harmonised scientific approaches and methodologies of hazard and risk assessment, a harmonised glossary is indeed an ambitious matter. Many organizations as well as different past European projects have already made significant efforts in producing specific technical glossaries of risk assessment terms.

For the MATRIX project we decided to adopt as much as possible the most general and 'official', well-established definitions existing in the literature and modifying them just when specific considerations make it necessary. The goal is not to provide the "real" definitions, but to improve the discussions and joint understanding of researchers coming from different disciplines. Taking these considerations as a reference, we have finally selected a limited set of terms that were considered as the most important within the multi-risk framework of MATRIX.

The resulting dictionary has come about after consulting different sources (see references), but the general base definitions are those from the glossaries provided by:

- The working paper on "Risk assessment and mapping guidelines for disaster management " of the European Union [(2)];
- The United Nations international strategy for disaster reduction (UN-ISDR)[(3)];
- The ISO guide 73: Risk management – vocabulary [(4)];
- The European Environmental Agency (EEA) multilingual environmental glossary [(8)];
- The glossaries of the NARAS[(1)] and ARMONIA[(5)] European projects.

In section 2 the more general terms that may be relevant to all or most of the hazards and risks considered in the MATRIX project are compiled. In section 3 some specific definitions of terms that are relevant to each individual hazard are highlighted. Furthermore, since for quantitative risk assessment it is fundamental to have a clear interface between 'hazards' and 'vulnerability', in this section is also included a list of possible 'intensity measure' variables.

2. General glossary

- **Cascade (adverse) events:** A series of/or a parallel sequence of adverse events generated by a single or different sources. For example, consider the occurrence of the next (serial) sequence of events: an earthquake that causes ground motion that triggers a landslide in a given area[modified from 1].
- **Consequences (negative consequences):** The negative effects of a disaster expressed in terms of human impacts, economic and environmental impacts, and political/social impacts[4]. It may be expressed quantitatively (e.g., a monetary value), by a category (e.g., high, medium, low) or descriptively[5].
- **Coping capacities:** The ability of people, organizations and systems, using available skills and resources, to face ('cope') and manage adverse conditions, emergencies or disasters. Coping capacities contribute to the reduction of disaster risks [3].
- **Damage**: The amount of destruction or damage, either in health, financial, environmental functional and/or other terms as a consequence of an occurred hazard[5]. It synthesizes the different adverse consequences caused by adverse events and related phenomena. For "tangible" damages, its value can be obtained by multiplying the value at risk by its vulnerability[1]. In earthquake risk studies, for example, the term "damage" is commonly used in the physical (structural) sense, describing the state of affected buildings resulting from an earthquake.
- **Event:** Something that happens (and can be defined) at a given place and time; the term may be extended to a special set of circumstances.
- **Event tree:** A graphical representation of the logic model that identifies and quantifies the possible outcomes following an initiating event. Event tree analysis provides an inductive approach as they are constructed using 'forward logic'.
- **Fault tree:** A top down, deductive failure analysis in which an undesired state of a system is analysed using Boolean logic to combine a series of lower-level events.
- **Hazard:** Is 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 [3]. It can be subdivided into:
  - **Natural hazard:** Natural 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 [3].
  - **Socio-natural hazard:** The phenomenon of increased occurrence (or intensity) of certain (natural) hazard events, such as landslides, flooding, land subsidence and drought, that arise from the interaction of natural hazards with overexploited or degraded land and environmental resources. This term is used for the circumstances where human activity is increasing the occurrence (or the intensity) of certain hazards beyond their natural probabilities. Evidence points to a growing disaster burden from such hazards. Socio-natural hazards can be reduced and avoided through wise management of land and environmental resources [3].
  - **Technological hazard:** A hazard originating from technological or industrial conditions, including accidents, dangerous procedures, infrastructure failure 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 [3].

- **Hazard assessment:** To determine the probability of the occurrence of a given hazard of a certain intensity [2].
- **'Hazard index' or 'Probabilistic hazard':** The probability that a given adverse event of a given intensity will occur in a certain area within a defined time interval. In general, the hazard index is a function of each phenomenon generated by the adverse event and their intensities. Consequently, the hazard index is evaluated by taking into account the characteristics of the risk source, the location it refers to, and the physical process of intensity diffusion from the risk source's location to the investigated area [1]. For quantitative risk assessment purposes, the results of the hazard assessment are often summarized in the form of a 'hazard curve', that relates a given 'intensity measure' indicator with either its occurrence probability (non-cumulative form) or an 'overcome a threshold' probability (cumulative form). For more details about specific hazard definitions of interest to MATRIX project, see Section 3 of this document.
- **Intensity measure:** The measure of the quantity by which a phenomenon is manifested or causes damage. The units of measure are usually expressed in physical quantities defining, for example, the degree of strength of a specific phenomenon per unit area or volume [modified from 1].
- **Loss:** The amount of realized damages as a consequence of an occurred hazard[5].

  Comment: Losses, as consequences of the damage caused by adverse events, are proportional to the damage state and depend on the value of exposed assets (e.g., construction costs, number of inhabitants, functional importance, etc.). The losses are calculated by combining the level of damage and the value of the affected assets and, correspondingly, they may involve monetary losses (due to the damage to buildings and contents), human losses (injuries and fatalities), loss of function, etc.

- **Multi-hazard assessment:** To determine the probability of occurrence of different hazards either occurring at the same time or shortly following each other, because they are dependent from one another or because they are caused by the same triggering event or hazard, or merely threatening the same elements at risk without chronological coincidence [2].
- **Multi-risk assessment:** To determine the whole risk from several hazards, taking into account possible hazards and vulnerability interactions (a multi-risk approach entails a multi-hazard and multi-vulnerability perspective). This would include the events[modified from 2]:

  1. occurring at the same time or shortly following each other, because they are dependent on one another or because they are caused by the same triggering event or hazard; this is mainly the case of "cascading events";
  2. or threatening the same elements at risk (vulnerable/exposed elements) without chronological coincidence.

- **Natech:** A natural hazard that triggers a technological disaster[17].
- **Phenomenon:** One of the forms (many are possible) under which the adverse event causes damages. For this reason it defines a tangible fact, and it is usually measured by the parameter of intensity (intensity measure) [1].
- **Resilience:** The ability of a system, community or society exposed to hazards to

absorb, accommodate to, and recover from, the effects of an adverse hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions [(3)].

Comment**:** Resilience means the ability to “resile from” or “spring back from” a shock. The resilience of a community with respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need [(3)]. In wild fire literature, resilience is specifically considered to be the rate or the capacity of the system to recover to its state prior to the event.

- **Risk:** The combination of the consequences of an event (damage) and the associated probability of its occurrence (probabilistic hazard) [(4, 3, 5)].

  Comment**:** The upper definition follows the definition of the ISO/IEC Guide 73. Other related definitions that can be pointed out are: The non-normalized probability that a negative consequence (that is, a certain type and degree of damage) can occur in a given period of time following a specific adverse event. [(1)]. The probability of harmful consequences or expected losses (deaths, injuries, property, livelihoods, disruption of economic activity or environmental damage) resulting from interactions between natural or human-induced hazards and vulnerable conditions; based on mathematical calculations, risk is the product of hazard, vulnerability, and exposure [(3, 6, 7)]. Expected losses (of lives, persons injured, property damaged and economic activity disrupted) due to a particular hazard for a given area and reference period[(8)]. All these definitions are in accordance to the definition given above.

- **Risk assessment:** The overall process of risk identification, risk analysis, and risk evaluation [(4)]; a methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend. Risk assessments (and associated risk mapping) include: a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability including the physical social, health, economic and environmental dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities in respect to likely risk scenarios. This series of activities is sometimes known as the risk analysis process. [(3)].

  - **Risk identification:** The process of finding, recognizing and describing the risk [(4)];
  - **Risk analysis:** The process of comprehending the nature of risk and to determine the level of risk [(4)];
  - **Risk evaluation:** The process of comparing the results of risk analysis with some terms of reference to determine whether the risk and/or its magnitude is acceptable or tolerable [(4)];
  - **Risk scenario:** Is a representation of one single-risk or multi-risk situation leading to significant impacts, selected for the purpose of assessing in more general detail a particular type of risk for which it is representative, or constitutes an informative example or illustration [(2)]. This also requires a definition for ‘Scenario’: a representation (often only qualitative) of one or more linked adverse events causing and/or caused by threatening phenomena. Several scenarios can or should be identified for each adverse event [(1)].
  - **Risk criteria:** The terms of reference against which the significance of a risk is evaluated [(4)].

- **Risk source**: Anything that can potentially generate adverse events that, consequently, create damage to the population and/or to the natural and built environment. It is therefore a concept related only to the intrinsic characteristics of a substance, a plant or of the physical/geological status of a site [1].

- **Risk management**: The systematic process of using administrative decisions, organization, operational skills and capacities to implement policies, strategies and the coping capacities of societies and communities to lessen the impacts of 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) the adverse effects of hazards [3].

- **Single-risk assessment:** To determine the single risk (i.e., hazard and consequences) of a particular hazard occurring in a particular geographical area during a given period of time [modified from 4].

- **Uncertainty:** This arises when we are not sure about the outcome of a process (like a measure of a physical quantity, or the occurrence of a destructive event). It is usually measured using probabilities or probability functions. Several factors, acting simultaneously or separately, are responsible for the existence of uncertainty; we can group those factors in two groups: those due to the intrinsic stochasticity of the process (the so-called *aleatory* uncertainty)[15], and those due to the lack of or imprecise knowledge of the process (*epistemic* uncertainty) [15].

  <u>Comment</u>: Uncertainty may result, for example, from imprecise knowledge of risk, from model uncertainty which may be related to vague process knowledge, or imprecise data measures, etc. In a risk approach, uncertainty may affect both the probabilities and the assessment of consequences [5].

- **Value (at risk)**: A measure of the total potential loss due to an adverse event in a given area. It can be expressed in terms of human casualties, either in economic or conventional terms (since it is difficult to express heritage or environmental losses monetarily). It depends on the various activities (human, cultural, economic) carried out the referred area, as well as its environmental characteristics[1].

- **Vulnerability**:

  <u>Comment</u>: There is no universal theory or model of vulnerability. The notion of vulnerability has evolved into a concept offering potent explanations for differences in the degree of damage incurred from natural hazards that are manifested for an individual person, a whole community, a city or an entire region. Today, 'vulnerability' is defined, interpreted and applied in various ways, and partly due to the need to work within a specific social and environmental context, partly due to a range of disciplines entering this research field, equipped with their own ontologies, definitions and methods. While this diversity enhances the spectrum for explaining what makes people or communities vulnerable, increasing scientific specialization entails a growing degree of fragmentation and misunderstanding within vulnerability research [9].

  With this comment in mind, for our purposes, 'Vulnerability' may be defined as (MATRIX): the probable damage to an element at risk given a level of intensity of an adverse event (which can be regarded as a 'structural vulnerability' point of view). In probabilistic/quantitative risk assessments, it often expresses the fraction of the total value at risk that could be lost after a specific adverse event[1]. It may also express other losses or damage indicators (e.g. damage grade of a damage classification).

Other definitions that can be highlighted:

- The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard [3, 2].

- The degree of fragility of a (natural or socio-economic) community or a (natural or socio-economic) system towards natural hazards [5].

Within the MATRIX project, more detailed and specific definitions are necessary for specific elements:

- **Physical vulnerability**: Expresses the propensity of a structure to be physically damaged. For instance, it relates the intensity measure of a phenomenon to a probable physical damage grade of a damage classification. It is mostly used, for example, in earthquake and cyclone risk assessment.
- **Functional vulnerability**: This goes beyond the summation of direct losses and considers the interactions between systems and intra-system components in order to capture the total loss impact.
- **Time-dependent (physical and functional) vulnerability**: Considers the evolution of vulnerability with time and with the history of events that have affected a population or structure. The vulnerability evolves due to both physical effects (ageing, corrosion, damage accumulation from past events) and human actions (reconstruction and reinforcement, use changes, population settlement evolution etc.).
- **Social and economic vulnerability**: Refers to the inability of people and of economic activities of a society to withstand natural hazards. It may be based on systemic vulnerability analyses.

3. Definitions for specific hazards

Since different hazards are considered in the project, it is essential to present some specific definitions relevant to each hazard, in particular the possible “intensity measure” variables that should be coincident with those used for the vulnerability curves. In the following, the most important definitions and possible intensity measure variables of the different hazards considered in MATRIX are summarized.

3.1. Earthquake hazard (or seismic hazard)

Earthquake hazards may include: ground shaking, surface faulting and ground failure (e.g., liquefaction, subsidence, slope effects). Each of those phenomena may cause different mechanisms of damage to the elements of built environment. The occurrence and severity of possible seismic effects depends on the complex combination of the earthquake’s magnitude, the distance from the source, and the local geological and geomorphological conditions.

The main cause of earthquake damage is ground shaking. It can be measured by parameters describing ground vibration, including maximum amplitudes.
Table 3.2 summarizes possible “intensity measure” indicators with their respective (physical) units potentially useful for the seismic hazard assessment.

3.2. Volcanic hazards

In the context of volcanic activity, a number of hazardous phenomena are generated. Among the main processes that may produce loss or damage we can consider:

- **Pyroclastic (or tephra) fall:** Refers to the fragments (e.g., ash, tephra, blocks) produced during an explosive eruption that fall to Earth, usually from an eruption column[(5)]. Table 3.1 summarizes possible “intensity measure” indicators with their respective (physical) units that are potentially useful for pyroclastic-fall volcanic hazard assessment.

Table 3.1 Possible intensity measure parameters for volcanic hazard assessment (pyroclastic fall)

Volcanic hazards: Pyroclastic fall	
Possible intensity indicators	**Units of measure**
1. Thickness of ash 2. Static vertical loading	1. cm, m 2. Pa (N/m^2)

Table 3.2 Possible intensity measure parameters for seismic hazard assessment

Seismic hazard	
Possible intensity indicators	**Units of measure**
2.1.1 Peak ground acceleration (**PGA**)	2.1.1 **Acceleration** is measured in **Gal** (**cm/sec^2**) or **g –** the force of gravity (1g = 980 Gal).
2.1.2 Peak ground velocity (**PGV**)	2.1.2 **Velocity** is measured in **cm/sec**.
2.1.3 Peak ground displacement (**PGD**)	2.1.3 **Displacement** is measured in **cm**.
2.1.4 **spectral parameters** (taking into account the frequency content).	
2.1.5 A widely used indicator of seismic influence is **macroseismic intensity**, which represents a classification of the severity of ground shaking based on observed effects in a limited area like a town (considering the effects on humans, objects, nature and damage to buildings). There are different intensity scales in the world, in particular, the European Macroseismic Scale (EMS-98), which has been introduced in a mandatory way for Europe, and moreover is in use on all continents.	2.1.5 According to the EMS-98 the severity of ground shaking is subdivided into **12 intensity degrees**: I. Not felt II. Scarcely felt, III. Weak, IV. Largely observed, V. Strong, VI. Slightly damaging, VII. Damaging, VIII. Heavily damaging, IX. Destructive, X. Very destructive, XI. Devastating, XII. Completely devastating

- **Pyroclastic flows:** These are hot (100-900°C), fast-moving (>100km/h) currents that form ground-hugging mixtures of volcanic particles, rock fragments and gas. Depending on the magma fragmentation dynamics, these currents can be generated by variable mechanisms, leading to a large spectrum of currents that can be generated, mostly characterized by their density. Generally, the most dense currents are called pyroclastic flows, while the most dilute are called pyroclastic surges[5].

  Table 3.3 summarizes possible "intensity measure" indicators with their respective (physical) units that are potentially useful for pyroclastic-flow volcanic hazard assessment.

Table 3.3 Possible intensity measure parameters for volcanic hazard assessment (pyroclastic flow)

Volcanic hazards: Pyroclastic flows	
Possible intensity indicators	**Units of measure**
1. Dynamic pressure 2. Temperature <u>Note</u>: In the case of human losses, the possibility of surviving such an event is practically null. Then, in this case pyroclastic flows may be characterized by a *Boolean* variable '***reach/no reach'*** for a given area, in which the 'reach' state implies total loss.	1. Pa (N/m^2) 2. °C

- **Lava flows:** These are hot streams of molten rock that travel down valleys at velocities ranging from a few m/h up to 60 about 60 km/h. Lava flows generally move relatively slowly along relatively predictable paths, and therefore usually do not threaten human life, although they destroy everything in their path and can cause forest fires[(5)].

  Since lava flows destroy everything in their path, for their "intensity value", they may be characterized by a Boolean variable '**reach/no reach**' for a given area, in which the 'reach' state implies total destruction.

- **Lahars:** This refers to mudflows formed when volcanic particles and debris mix with water. The source of the water may be a crater lake, heavy rain, or melted ice or snow. The loose ash and volcanic fragments are transformed into a dense fluid-rock mixture that rushes down the slopes of a volcano and into surrounding valleys. Lahars are destructive to everything in their path, and the threat from rainfall-induced lahars may last for years after an eruption has ended[(5)]. Table 3.4 summarizes possible "intensity measure" indicators with their respective (physical) units that are potentially useful for lahar volcanic hazard assessment.

Table 3.4 Possible intensity measure parameters for volcanic hazard assessment (lahars)

Volcanic hazards: Lahars	
Possible intensity indicators	**Units of measure**
1. Dynamic pressure 2. Mud depth	1. Pa (N/m^2) 2. m

- **Volcanic earthquakes:** These are characterized by high-frequency seismic signals thought to be generated by the fracturing of rock in response to the intrusion and migration of magma. Volcanic earthquakes almost always precede the onset of volcanic activity, although they do not always culminate in a volcanic eruption. They also often occur in swarms during or after an eruption. In some cases, they may in themselves be energetic enough to cause significant damage, destroying buildings and triggering gravitational mass movements[(5)]. For the possible intensity measure indicators for hazard assessment, see the parameters reported in

- Table 3.2 for seismic hazard.

3.3. Flood hazard

Flood Hazard is defined according to Gouldby et al. (2005)[16] as a physical event, phenomenon or human activity with the potential to result in harm. A hazard does not necessarily lead to harm. Merz et al. (2007)[10] define hazard as the exceedance probability of potentially damaging flood situations in a given area within a specified time period [10].

Flood hazard is characterized by a combination of flood return period associated with the certain gauge and a spatial pattern of a flood intensity indicator. Floods can be generated by various combinations of meteorological and hydrological processes and include pluvial floods, riverine floods, coastal floods, and rising groundwater. Table 3.5 summarizes possible "intensity measure" indicators with their respective (physical) units that are potentially useful for flood hazard assessment.

Table 3.5 Possible intensity measure parameters for flood hazard

Flood hazard	
Possible intensity indicators	**Units of measure**
1. Water depth	1. m
2. Flow velocity	2. m/s
3. Specific impulse/Intensity	3. m*m/s
4. Inundation duration	4. hours, days
5. Rate of water rise	5. m/h, m/day

3.4. Wildfire hazard

The following are typical definitions in the wildfires hazard assessment:

- **Wildfire**: Any unplanned and uncontrolled vegetation fire which, regardless of the ignition source, may require suppression response or other actions according to agency policy[11].

- **High Intensity Wildfires:** These are wildfires where the fire line intensity is higher than 2700 kW/m with a flame length greater than 3 meters[12].

- **Flame length:** The length of flames in the propagating fire front measured along the slant of the flame from the midpoint of its base to its tip. It is mathematically related to fireline intensity and tree crown scorch height[13].

- **Fireline intensity:** Also called Byram's intensity, this is the rate of energy release per unit length of the fire front expressed as BTU per foot of fireline per second or as kilowatts per meter of fireline. This expression is commonly used to describe the power of wildland fires[13].

Extreme wildfires (high intensity >2700 kW/m) are the adverse events that are the focus of wildfire risk analysis. As a consequence of high intensity wildfires, there are different phenomena involved: smoke in the convection column, embers from spotting, and flames in the fire front. These phenomena have different impacts in the various elements at risk (e.g., people, houses, trees). Table 3.6 summarizes possible “intensity measure” indicators with their respective (physical) units that are potentially useful for wildfire hazard assessment.

Table 3.6 Possible intensity measure parameters for wildfires hazard

Wildfire hazard	
Possible intensity indicators	**Units of measure**
1. For the *Smoke* Phenomenon: **Particle concentration**	1. $\mu g/m^3$
2. For the *Fireline* Phenomenon: **Intensity**	2. kW/m
3. For the *Flame* phenomenon: **Flame Length**	3. meters (m)
4. For the Ember phenomenon: **Probability**	4. (dimensionless)

2.5 Landslide hazard

A landslide is the movement of a mass of rock, debris, or earth down a slope, under the influence of gravity(14). In general terms, landslide hazards can be classified as: (1) Rock fall, (2) Earth slide, and (3) Debris flow.

Table 3.7 summarizes possible “intensity measure” indicators with their respective (physical) units that are potentially useful for landslide hazard assessment.

*** Note**: *there is no general consensus on the definition of, and the distinction between landslide magnitude and landslide intensity. Measures of landslide size (i.e. volume and, indirectly, area) are recommended as measures of landslide magnitude by the Joint Technical Committee on Landslides (JTC1).*

Table 3.7 Possible intensity measure parameters for landslide hazard

Landslide hazard		
Kind of landslide	**Possible intensity indicators**	**Units of measure**
1. **Rock fall**	1.1 Volume* 1.2 Kinetic energy	1.1 m^3 1.2 Joule (J = N·m)
2.**Earth slide**	2.1 Volume* 2.2 Area* 2.3 Maximum movement velocity 2.4 Total displacement 2.5 Differential displacement 2.6 Depth of the moving mass	2.1 m^3 2.2 m^2 2.3 m/s 2.4 m 2.5 m 2.7 m
3. **Debris flow**	3.1 Maximum movement velocity 3.2 Depth of the moving mass 3.3 Peak discharge per Unit width 3.4 Kinetic energy per unit area	3.1 m/s 3.2 m 3.3 m^3/m 3.4 J/m^2

2.6 Meteorological events (or meteorological hazards)

Meteorological events (or meteorological hazards in the case that the event itself may cause loss or damage), can be classified in to:

- **Extreme wind speed:** Strong winds occur in association with extra-tropical cyclones (such as winter storms) or thunderstorms, and can sometimes be induced by orographic effects (local wind systems such as the Mistral, Bora or Foehn winds). In general, it is not the mean wind speed but **wind gusts -** a sudden and brief increase in wind speed caused by turbulence – that are responsible for most damage. Strong winds are considered to be damaging at speeds of 62 km/h (34 kn) or above. Table 3.8 summarizes the possible “intensity measure” indicators with their respective (physical) units that are potentially useful for extreme wind speed (hazard) assessment.

Table 3.8 Possible intensity measure parameters for extreme wind speed (hazard)

Extreme wind speed	
Possible intensity indicators	**Units of measure**
1. wind speed	1. m/s, km/h, kn
2. gust wind speed	2. m/s, km/h, kn
3. time duration	3. hours (h)

- **Heavy precipitation:** Heavy rain is related to intense thunderstorms, upper tropospheric forcing, or extra-tropical cyclones. According to the German Weather Service's (DWD) definition, rain is termed as "heavy" if the amount per time period exceeds the following thresholds: >25 mm/1 h, >35 mm/6 h. Snow fall (caused by weather fronts, upper tropospheric forcing, or snow showers) is considered to be heavy if the resulting snow accumulation is of a depth greater than 10 cm within 6 h or >15 cm within 12 h. Snow and rain amounts may be significantly enhanced by terrain. Hail forms in intensive thunderstorms with strong upward motion and is damaging when diameter sizes are >2.5cm. Table 3.9 summarizes possible "intensity measure" indicators with their respective (physical) units that are potentially useful for heavy precipitation (hazard) assessment

Table 3.9 Possible intensity measure parameters for heavy precipitation (hazard)

Heavy precipitation	
Possible intensity indicators	**Units of measure**
1. rain intensity (amount of rain per time)	1. mm/10 min, mm/h, mm/d, (1 mm = 1 l/m^2)
2. hail diameter size	2. cm
3. amount of snow per time	3. cm/h
4. snow depth	4. cm
5. snow load	5. kg/m^2

- **Extreme temperature:** Extreme temperature occurs in association with cold waves or heat waves as a consequence of the persistent blocking of large scale weather conditions over a period of several days or weeks, and intensive transport of cold or hot air masses, respectively, enhanced by radiation processes. The duration of extreme temperature events is decisive. Table 3.10 summarizes possible "intensity measure" indicators with their respective (physical) units that are potentially useful for extreme temperature (hazard) assessment.

Table 3.10 Possible intensity measure parameters for Extreme temperatures (hazard)

Extreme temperature	
Possible intensity indicators	**Units of measure**
1. temperature (daily mean/ maximum/ minimum)	1. °C
2. deviation from monthly mean	2. K
3. time duration	3. days

The definitions of some relevant meteorological terms are given below:

- **Thunderstorm:** A local storm that is always accompanied by lightning and thunder, usually with strong wind gusts, heavy rain and sometimes hail. The intensity and extent of a thunderstorm strongly depend on the weather conditions. Many thunderstorms may be active at the same time, so the area affected by thunderstorm activity may range from the local scale up to the scale of a state (~10 km to 500 km).

- **Extra-tropical cyclones:** Extra-tropical cyclones are low pressure systems in the mid-latitudes. Usually they develop near the polar front as a result of interactions between the lower troposphere and upper troposphere forcing.

- **Winter storms:** A winter storm is a specific type of extra-tropical cyclone occurring during October and March (in the Northern Hemisphere). It brings snow, sleet, freezing rain or rain and in some cases strong winds.

- **Mediterranean cyclone:** A Mediterranean cyclone is a specific type of extra-tropical cyclone that develops over the Mediterranean Sea. Depending on the large scale weather conditions, sometimes it follows a typical route passing the Eastern Alps and the easterly portions of Central Europe, before finally reaching the Baltic States. They often bring large amounts of rain, sometimes causing flash floods.

4. References

(1) Principles of multi risk assessment – Interaction amongst natural and man induced risks (NARAS), FP6 SSA project, Contract 511264

(2) Commission staff working paper: "Risk assessment and mapping guidelines for disaster management", European Commission, Brussels, December 2010

(3) UN-ISDR: UN international strategy for disaster reduction, terminology section, 2009 http://www.unisdr.org/we/inform/terminology (visited 07.2011)

(4) ISO guide 73: Risk management – vocabulary (and ISO 31010: Risk management – Risk assessment techniques)

(5) Applied multi-risk mapping of natural hazards for impact assessment (ARMONIA), FP6 project, Contract 511208: Deliverable 4.1.2 (*Technical Glossary of a Multi Hazard Related Vulnerability and Risk Assessment Language – Final version,* March 2007), and Deliverable 2.1 (*Report on current availability and methodology for natural risk map production*, June 2005).

(6) Integrated Regional Information Networks (IRIN, IRINnews.org), UN Office for the Coordination of Humanitarian Affairs; http://www.irinnews.org/webspecials/DR/Definitions.asp

(7) WHO The World Health Organisation (WHO). The Fifty-seventh Session of the Regional Committee for South-East Asia, Emergency Health Preparedness, Part I

(8) European Environmental Agency (EEA) multilingual environmental glossary, http://glossary.eea.europa.eu/EEAGlossary/ (visited 07.2011)

(9) Hufschmidt, G (2011) A comparative analysis of several vulnerability concepts, Nat Hazards, DOI 10.1007/s11069-011-9823-7

(10) Merz, B., Thieken, A. H., Gocht, M., 2007. Flood risk mapping at the local scale: Concepts and challenges. In: Begum, S., Stive, M. J. F., Hall, J.W. (Eds.), Flood Risk Management in Europe. Innovation in Policy and Practice. Vol. 25 of Advances in Natural and Technological Hazards Research. Springer, pp. 231-251.

(11) Rego, F., Rigolot, E., Fernandes, P., Montiel, C., & Silva, J. S. (2010) *Towards Integrated Fire Management*. European Forest Institute, EFI Policy Brief 4. Joensuu, Finland

(12) Rego, F. C., Colaço, M.C. (in press) Wildfire Risk in *Encyclopedia of Environmetrics Second Edition.* John Wiley & Sons. UK.

(13) Brown, James K.; Smith, Jane Kapler, eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

(14) Cruden D.M. and Varnes D.J., 1996. Landslide types and process. In: Turner A.K., Schuster R.L., (eds.), Landslide investigation and mitigation, Special Report 247. National Research Council, Washington, DC, pp 36-75

(15) Marzocchi, W., Sandri, L., and selva, J. BET_VH: a probabilistic tool for long-term volcanic hazard assessment, Bull. Volcanol. 72: 705-716, 2010.

(16) Gouldby, B., Samuels, P., Klijn, F., Messner, F., van Os, A., Sayers, P. and , Jochen, S., 2005. Language of Risk, PROJECT DEFINITIONS, EU-FLOODsite-Project Report T32-04-01

(17) Cruz, A. M., L. J. Steinberg, A. L. Vetere Arellano, J. P. Nordvik, and F. Pisano. State of the art in Natech risk management, European Commission, EUR 21292, 2004.