Section 42
Governance and Democracy

Guidelines

Risk Analysis – a Basis for Disaster Risk Management

Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ) GmbH

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Deutsche Gesellschaft für Technische Zusammenarbeit
(GTZ) GmbH

Guidelines

Risk Analysis – a Basis for Disaster Risk Management

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Foreword

With increasing frequency, the developing countries and the people living there are being affected by disasters. More and more often, development efforts are being destroyed. The reason for this trend is their growing vulnerability, which in turn is the result of economic and social development processes, such as the expansion of settlements and agricultural land in risk areas. The economic and social consequences of these disasters for the people in our partner countries last for years.

To break and, if possible, reverse this trend, international organisations, governments and NGOs in the developing countries are increasingly upgrading the priority of disaster risk management for policy, and taking concrete preventive measures to reduce the risk to the population. For the GTZ, disaster risk management is an important aspect of its work in Latin America, Africa and Asia. It is accordingly producing concepts, methods and instruments for disaster risk reduction in these regions. One of the most important instruments is risk analysis, as a basis for effective disaster risk management.

The BMZ commissioned the GTZ to produce the present guidelines. Their goal is to help integrate risk analysis into projects and programmes in jeopardised regions, e.g. rural development, promotion of local communities or sustainable resource conservation. Equally important is the use of risk analysis in reconstruction programmes to ensure sustainability in designing a fresh start, e.g. after a flood or an earthquake. In this respect, these guidelines meet the goal of the German Federal government of embedding disaster risk management in development cooperation as a cross-cutting responsibility.

In the present publication the GTZ presents implementation-oriented concepts, instruments and methods for risk analysis which have been tested in projects funded by the BMZ and the German Foreign Office. It is part of GTZ services for disaster risk management, and is aimed primarily at the staff of the GTZ and its partner experts, and experts in national and international institutions and organisations.

We wish to thank particularly the authors Alois Kohler, Sebastian Jülich and Lena Bloemertz for developing the concepts and instruments presented in these guidelines, and Christina Bollin and Mario Donga at the GTZ for producing the present publication. We also wish to thank the staff of the GTZ, partner institutions and other organisations for their cooperation in reviewing experience and their suggestions.

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Acknowledgements

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We also wish to thank the following individuals, whose ideas, comments and expert contributions enriched and even made possible the present document. Christina Bollin, Alberto Aquino, Ralf Kaltofen, Claudia Maier, Eberhard Goll, Elisabeth Mausolf, Wolfgang Stiebens, Rolf Wachholtz, Wolfgang Weinmann, Rosa Sanchez, Ali Neumann, Peter Asmussen and Mario Donga.

The present publication contains the main part of the risk analysis. A CD containing 11 extensive appendices is **available in German** to interested users on request from the sector project "Disaster Risk Management in Development Cooperation" (GTZ Eschborn, disaster-reduction@gtz.de):

The appendices cover the following topics:

1) Remote sensing and geographical information systems in disaster risk management;
2) The "Sustainable Livelihood Approach" (SLA – analysis at household level);
3) ENSO – El Niño Southern Oscillation;
4) Soil and Water Assessment Tool (SWAT);
5) The NAXOS-Praedict early warning system for flood protection;
6) Methods for recording erosion (USLE etc);
7) NOAA approaches (National Oceanic and Atmospheric Administration);
8) Tasks and activities in carrying out a risk analysis;
9) Selected organisations and contact persons for risk analysis;
10) Risk analysis – methods for assigning relative values, using the example of landslides, PGRSAP-GTZ-Wachholtz Survey Ltd, 2003;
11) Interactive CD-ROM "Digital information pool on natural disasters and disaster risk management".

The guidelines were started within the framework of a BMZ-funded study and expert fund and completed in the sector project "Disaster Risk Management in Development Cooperation".

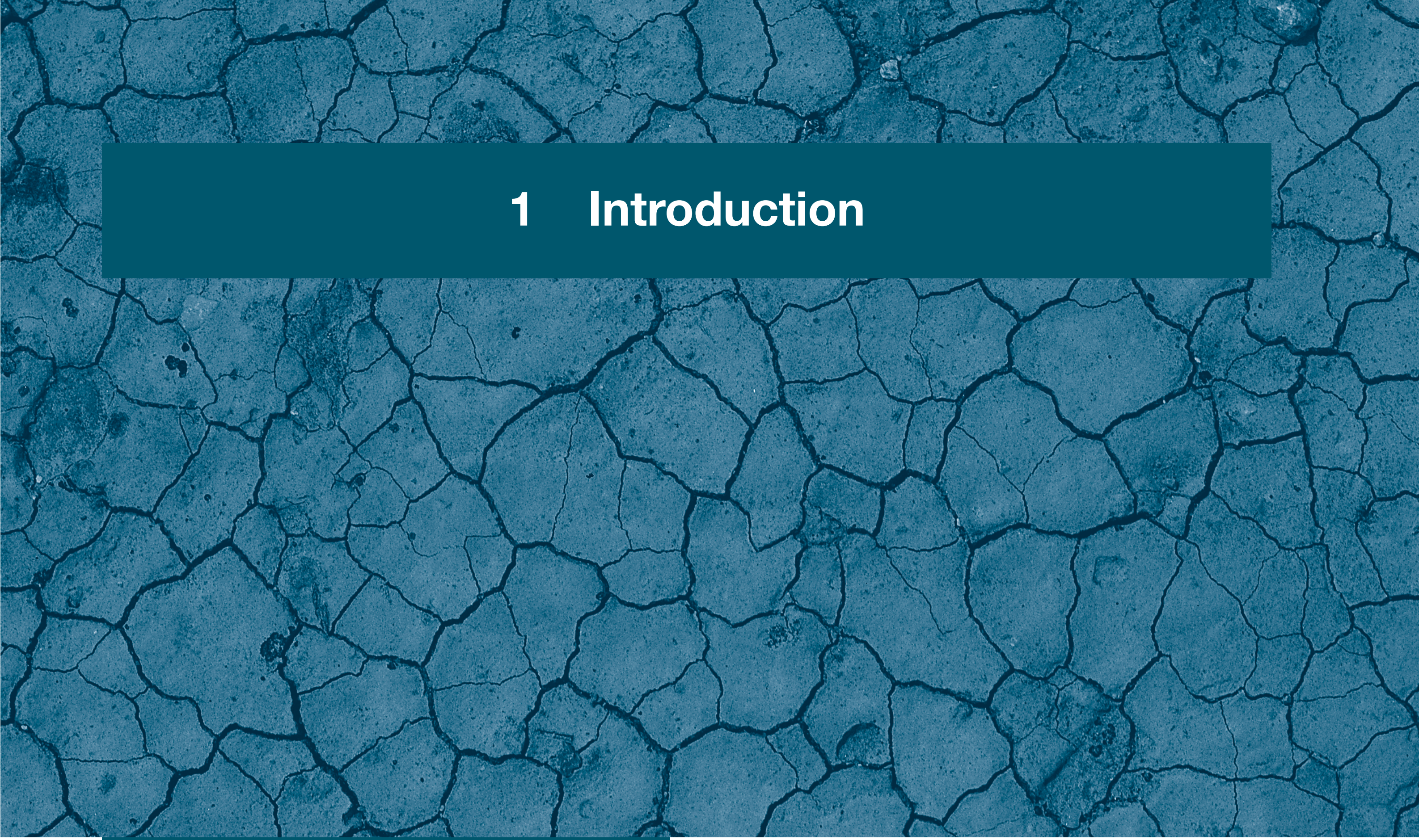
We hope that our readers and users will find these guidelines interesting and helpful, and we look forward to your feedback.

The authors

Contents

List of abbreviations

AA	German Foreign Office
APELL	Awareness and Preparedness for Emergencies on a Local Level (UNEP)
BMZ	Federal German Ministry for Economic Cooperation and Development
CREAMS	Chemicals, Runoff and Erosion from Agricultural Management Systems
DC	Development Cooperation
DG	GTZ International Services
DKKV	German Committee for Disaster Reduction
DEA	Development-Oriented Emergency Aid
DR	Disaster Reduction (=DRM)
DRM	Disaster Risk Management (=DR)
ECHO	European Community Humanitarian Office
ENSO	El Niño Southern Oscillation
EPC	Emergency Preparedness Canada
FC	Financial Cooperation
FEMA	Federal Emergency Management Agency, USA
FSP	Food Security Programme
GIS	Geographical Information System
GL	Guideline
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit GmbH
HIRV	Hazard, Impact, Risk, and Vulnerability (Model)
IDNDR	International Decade of Natural Disaster Risk Management
IFSP	Integrated Food Security Programme
IFRC	The International Federation of Red Cross and Red Crescent Societies
ISDR	International Strategy for Disaster Risk Management
LUP	Land Use Planning
MAMUCA	Mancomunidad de los Municipios del Centro de Atlántida (Honduras)
MUSLE	Modified Universal Soil Loss Equation
NAXOS	Precipitation-Runoff Model for X Operations Systems, TU Braunschweig
NDVI	Normalised Difference Vegetation Index
NGO	Non-Government Organisation
NOAA	National Oceanic and Atmospheric Administration (U.S. Department of Commerce)
OT	Ordenamiento Territorial (= spatial planning)
PRA	Participatory (Rapid) Rural Appraisal
P-RA	Participative Risk Analysis
RA	Risk Analysis
RRA	Rapid Rural Appraisal
RM	Resource Management
SLA	Sustainable Livelihood Approach
SP	Spatial Planning
STC	U.N. Scientific and Technical Committee, responsible for operationalising the International Decade of Natural Disaster Reduction
SWAT	Soil and Water Assessment Tool
TC	Technical Cooperation
UN	United Nations
UNEP	United Nations Environment Programme
UNHCR	United Nations High Commissioner for Refugees
USLE	Universal Soil Loss Equation
WEPP	Water Erosion Prediction Project
WFP	World Food Programme



1 Introduction

1.1 The approach

The present guidelines are based on cooperation with staff at GTZ Eschborn, and particularly the section "International cooperation in the context of conflicts and disasters" and with various projects of bilateral German development cooperation in partner countries in Latin America, Africa and Asia. In addition, an extensive body of literature in German, English and Spanish was reviewed and consulted, together with relevant documentation from projects, workshops and meetings. In developing the methodology, we incorporated both concrete experience from practice and the information from our review of the literature. Technical Cooperation (TC) projects also provided important feedback from practice at the workshops in Piura (Peru, 3–5.6.03) and Cochabamba (Bolivia, 22–23.9.03)

The approaches, concepts, methods and terminology for disaster risk management and risk analysis found in the reports and other literature are very diverse, in some cases contradictory[1], mostly lacking in precision and often very academic in their presentation. In the case of risk analysis in particular there are virtually no documents with clear presentations at the level of concrete implementation. The present guidelines on risk analysis were developed for this reason, and to meet the needs of the projects of (German) development cooperation.

The guidelines are based on the GTZ working concept "Disaster Risk Management", which has been available at the GTZ since December 2001.

1.2 What and who is it for?

These guidelines on risk analysis became necessary as a result of the new demands posed by the increasing number of disasters and resulting increase and change in requirements in DC. These requirements include specifically

- more elaborate and complex coordination due to the increase in number and diversity of donors and organisations;
- closer links between humanitarian aid, emergency aid, reconstruction and development (TC) and securing the transition from emergency aid to reconstruction and TC;
- given the growing scarcity of resources, increasing pressure to show that a) emergency aid measures restore the conditions for sustainable development and b) investment in disaster risk management leads to reduced vulnerability.

[1] For example, the name "risk maps" is applied to maps showing different information, and the same goes for hazard maps.

The GTZ has responded to these new requirements by developing the concept of **"development-oriented emergency aid (DEA)"** which includes and links the components of emergency aid, rehabilitation and reconstruction, disaster risk management and crisis prevention, laying the basis for structural development (TC). Methods and instruments are needed to make this linkage possible. One of these basic instruments is risk analysis, which lays the foundation for developing the strategies for deploying the various components of DEA. Risk analysis shows whether there is a need for reconstruction and TC after a brief period of emergency aid, and if so, how these can be configured.

The guidelines are intended to be useful and applicable in the case of not only **emergency aid** and humanitarian aid, which generally have a planning horizon of 6–12 months, but also the other components of **DEA**, such as reconstruction measures and food security programmes in the context of disasters. They are also intended to be useful for **TC projects** which are being implemented in regions threatened by natural hazards or which contain components of disaster risk management.

These TC projects (rural development, community promotion, resource management, etc) and projects following the DEA concept have so far had different experience with various approaches to **disaster risk management** (DRM). Risk analysis as an element of these is often treated as a secondary priority, or even neglected altogether. Alternatively, it is developed and carried out within a specific project, requiring extensive inputs.

The context for the present guidelines is **bilateral and multilateral development cooperation** which assists and advices projects in disaster risk management (DRM) and disaster response as well as projects in various sectors with components of DRM. Due to their economic situation and sociopolitical conditions, the developing and transition countries do not have the financial strength or knowledge to prepare appropriately for individual hazards and plan and implement fundamental social measures to reduce and cope with disasters (early warning systems, protective structures, disaster protection organisations, insurance systems).

These guidelines are also intended to provide assistance where the **basic data** required for the use of hi-tech models in geographical information systems (GIS) is not available. This is generally the case in projects operating in the context of poverty, where there are no qualified experts and institutions, but where it is still necessary to develop solutions for the population affected.

The use of risk analysis is intended to enhance the importance and priority of disaster prevention and preparedness and make them more effective, as a way of reducing damage and losses from extreme natural disasters and reducing the need for emergency aid.

1.3 Some definitions

A **hazard** is a natural physical phenomenon which can lead to a loss of life or damage to objects, buildings and the environment. The hazard is measured and defined by its nature (type of hazard), location and extent, scope and intensity (damage potential) and its probability of occurrence, duration and frequency (repetition cycles). Examples: floods, earthquakes, droughts, landslides, etc.

Vulnerability expresses the level of possible loss or injury or damage to humans, objects, buildings and the environment which can result from the natural hazard. Vulnerability expresses the susceptibility and predisposition to be affected or suffer injury or damage. It also captures people's inadequate options or ability to protect themselves against possible damage or recover from the consequences of natural phenomena without outside help. Vulnerability always relates to a concrete hazard. It arises out of the interaction of social, economic, physical and environmental factors.

The level of vulnerability of a society to a specific extreme natural phenomenon (hazard) is determined by the potential damage caused by the natural phenomenon.

There is just **one vulnerability**, which depends on and is influenced by various factors, and not specific sectoral vulnerabilities, such as economic, political or institutional vulnerability, as described in numerous publications. In addition to these "specific vulnerabilities", the specialist literature also often uses the term **"ecological vulnerability"**. This refers to the vulnerability of the environment (soil, water). However, "ecology" covers more than just the environment. Ecology in these guidelines is used to refer to the science dealing with the relationship between nature and society, and not just one of these two components.

Vulnerability factors: vulnerability and its severity depend on a range of factors. In these guidelines, vulnerability factors are allocated to the following four categories: physical, environmental, economic and social. The vulnerability factors to be identified and researched depend on the particular **hazard type** and **location**. They are explained in detail in sections 3 and 7.

Risk is defined as the product of hazard and vulnerability (R=HxV), or – to put it another way – risk as the probability of an encounter between a specific hazard and an element vulnerable to this is interpreted as the probability of occurrence of loss of life or damage to objects, buildings and the environment as the result of an extreme natural phenomenon with a specific strength or intensity.

Disaster risk management (DRM): the terms **disaster reduction** (DR) and **disaster risk management** (DRM) are used as synonyms in the present guidelines. However, DRM is preferred, as this conveys a stronger sense of direct local initiative. In addition to risk analysis, DRM also includes prevention and preparedness for disaster. By contrast, disaster management (DM) consists of DRM as well as disaster response.

Risk analysis is used here as a synonym for **risk assessment**. However, many authors and documents distinguish between these. Where this is done, risk assessment is taken as also including risk evaluation, socioeconomic cost-benefit analysis, prioritisation of measures, establishing acceptable risk levels, developing scenarios and measures[2]. **Risk analysis** (RA) is used in these guidelines to refer to a method of determining the quantitative or qualitative degree of risk. The term "risk analysis" has the underlying concept of **"participative risk analysis"** (P-RA). This means that the affected target population are involved in the various stages of a risk analysis, and adopt the DRM as their own.

[2] From: ISDR (2002): Living with Risk: A global review of disaster reduction initiatives. Preliminary version July 2002, p.66

2 Growing disasters and new demands on development cooperation

2.1 From emergency aid to prevention

In development cooperation (DC), more and more money is being spent on disaster and emergency aid, in both absolute terms and as a share of DC financing. Given the general shortage of funding, this is at the expense of spending on Technical Cooperation (TC), which aims at sustainable structural measures. This is a result on the one hand of the increase in extreme natural events and phenomena, primarily of climatic or meteorological origin (such as floods, storms and droughts) and on the other hand of the dramatic increase in vulnerability due to population growth, weak institutions, poverty, and inadequate and uncontrolled use of natural resources.

To a considerable extent, the increase in vulnerability is due to the growth in poverty in many countries and regions, which leads to settlements and productive activities increasingly relocating to and expanding in areas which are at risk (traditional flood areas, steep and unstable hillsides, wet areas, forest areas with vulnerable ecosystems, etc). Other causes are dysfunctional disaster protection, missing or inaccurate precautionary planning (risk analysis, disaster prevention) and a lack of strategies for water catchment area management and rural development.

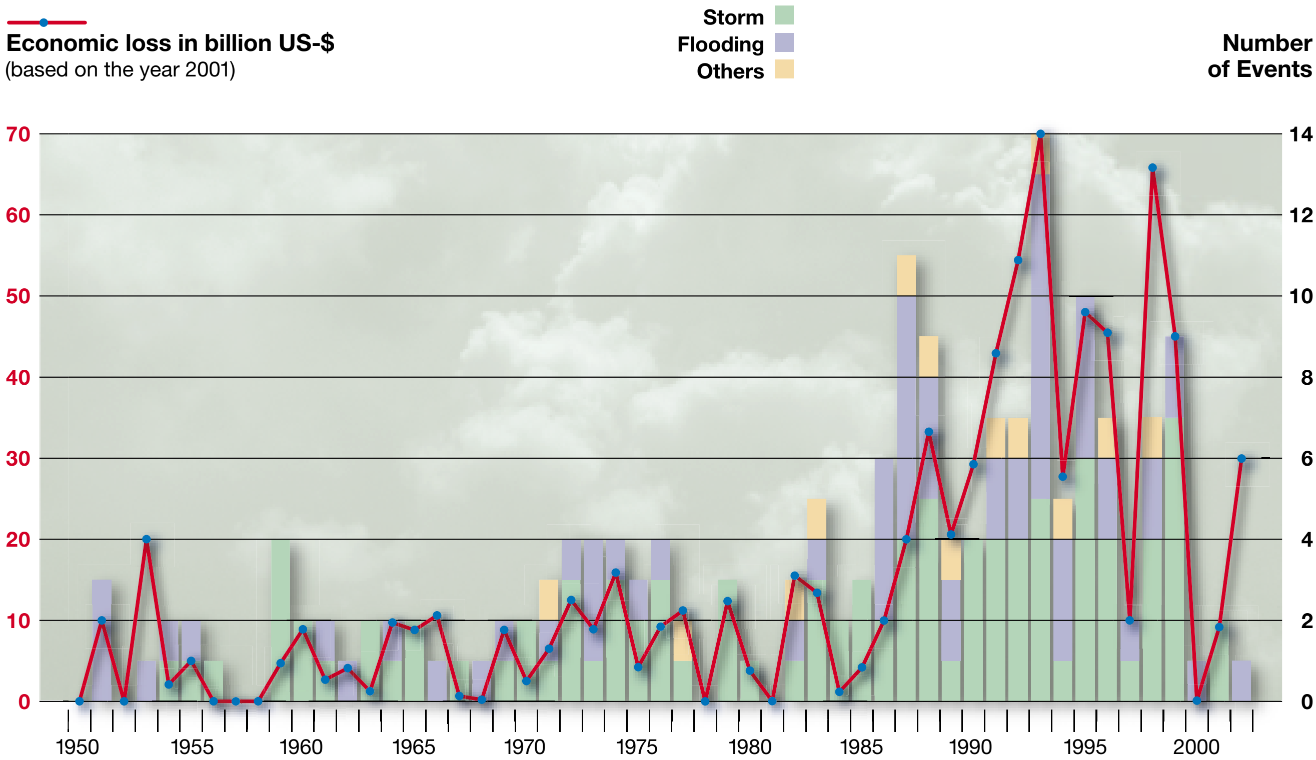
The extensive neglect of rural development is one of the most important reasons for the rapid and uncontrolled growth of urban population centres which are particularly vulnerable to extreme natural events.

Disasters lead to increased poverty. In many hazardous regions, there has been a dramatic rise in the number of starving people after natural disasters, e.g. in Honduras and Nicaragua after Hurricane Mitch and in El Salvador after the earthquake. The German Federal Government and the GTZ are trying to counter this trend towards growing demand for emergency aid through increased efforts aimed primarily at strengthening disaster prevention and preparedness. This includes improved coordination and linkage between the various components of DEA and with TC. However, emergency aid has also been faced by changing demands in recent years as a result of these developments. New coordination mechanisms were needed to coordinate the large number of organisations involved in supplying aid. Planning has to include the interfaces with other aid services and must facilitate the transition to reconstruction and structural DC, to ensure that emergency aid has lasting positive effects. Another important quality criterion is the contribution towards conflict reduction.

The German Federal Ministry for Economic Cooperation and Development (BMZ) is responding to the growing number of conflicts and disasters by redirecting budget item 68708[3] "Food security programmes

[3] Primarily used in the past to combat structural hazards to nutrition.

Figure 1: **Major weather-induced natural disasters, 1950–2002** (source: Münchener Rück)



(FSP)", which is used specifically to finance programmes directly related to the rising number of crises, conflicts and natural disasters. This item is supplemented by item 69725 "Food, emergency and refugee aid". The "emergency aid budget item" is used more for short-term interventions, while the '08 item supports measures with medium-term, multiyear orientation towards reduction, reconstruction and emergency aid following the "continuum" concept (emergency aid, reconstruction and development as elements of an overall strategy covering elements of both time and space) FSP bridges emergency aid and DC. In future, it is intended to use it (among other purposes) in increased preventive work for disaster risk management.

Improved disaster risk management (DRM) is being used to help reduce the impacts of extreme natural events and phenomena.

As the subject of various areas of policy and work (domestic policy, environment protection, agriculture, rural and regional planning, construction, land use planning, etc), **disaster risk management** (DRM) is recognised today as an important **cross-cutting task** in DC. **For this reason the BMZ has commissioned the GTZ to carry out the sector project "Disaster Risk Management in Development Cooperation": this started work in October 2003 on developing instruments and methods needed in disaster risk management.** In addition, the project has the job of formulating clear *implementation strategies* for integrating DRM more closely and definitively in the various sectors of DC.

The focus in promoting DRM within DC is on promoting local disaster protection structures (as part of decentralisation) in developing and transition countries, and integrating DRM into the various sectors of DC. Other priorities – as elements of the *implementation strategies referred* to earlier – are the development and formulation of instruments, methods and guidelines, in order to ensure efficient implementation of DRM and disaster response measures within the framework of DC.

2.2 Project types and linking short term and long term measures

Where natural disasters pose an acute hazard to the survival of the population and TC measures are not (yet) possible because of the urgency and lack of basis, the GTZ executes projects in "development-oriented emergency aid (DEA)". Emergency aid measures are an important element in DEA. They ensure supplies to people in acute emergencies and lay the foundation for subsequent reconstruction and structural development measures based on recommendations derived from risk analyses. For emergency aid measures lasting one year or less, risk analysis is carried out in parallel with the emergency aid or reconstruction measures. The results provide a basis for the decision whether support should be continued, and for which measures (reconstruction, TC), in order to reduce vulnerability – e.g. during reconstruction – and to secure DRM measures sustainably. These short-term measures are often carried out in a context of existing bilateral projects, in order to respond quickly while ensuring long-term assistance to the affected population.

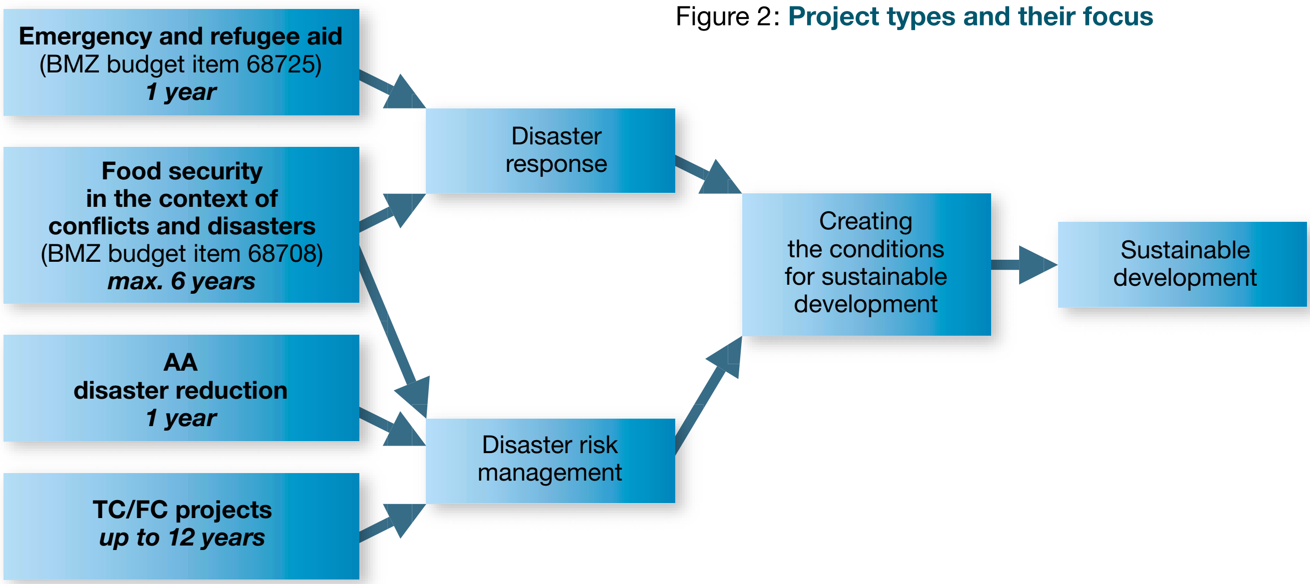
Risk analyses also help with project identification, providing information on whether under certain circumstances short-term activities under emergency aid measures are more efficient and effective, whether aid measures should be aimed more at longer term structural (TC) measures, or whether a combination of the two is needed.

In practice, many different possible combinations are conceivable – often, the follow-up to disasters is an emergency aid measure, as this can provide a faster and more flexible response than normal TC[4]. Often, these disaster risk management measures (generally lasting one year) by the BMZ, German Foreign Office (AA) or European Union (EU/ECHO) are repeated once or more (examples: FAM-Amdecruz, Bolivia; La Masica/MAMUCA, Honduras) or are replaced by food security measures (FSP) or technical and financial cooperation measures (TC, FC). Another possibility is to start aid measures with FSP (examples: San Pedro, Bolivia; Arequipa, Peru), starting with risk analysis and concentrating on reduction and preparatory measures. In other cases measures are also carried out in cooperation with nongovernmental organisations (NGOs) and international organisations (UNHCR, WPF, IVRC, etc).

In regions threatened by disasters, disaster risk management measures are often integrated into TC measures (programmes or projects) as cross-cutting themes, e.g. in projects of rural regional development, rural development, resource and water catchment area management or decentralisation and community promotion. Risk analysis is then part of project preparedness and planning, and is carried out in the framework of instruments such as problem analysis, organisation or potential analysis, ROPP (Regionally Oriented Programme Planning) or land use planning.

[4] Emergency aid and FSP measures are not tied to country quotas, government negotiations and exchanges of notes, and can accordingly be used at short notice.

Figure 2: **Project types and their focus**



Depending on the constellation and the course of the project, risk analysis can also be carried out in such projects during other phases of the project cycle. A distinction needs to be made here between normal TC, where projects can have a duration up to c. twelve years, FSP with terms of at most six years, and the emergency aid or disaster risk management projects (BMZ, AA) referred to above, which normally have terms of a year or less. In the latter case, there is no preparatory phase, and the conditions and time for a detailed risk analysis are lacking. In this case, risk analysis must be seen as a rough estimate, with the analysis focusing on general conditions in order to arrive at an assessment of the value, usefulness and type of follow-up measures.

Development oriented emergency aid (DEA) with its interlinked components of emergency aid, rehabilitation and reconstruction, disaster risk management and crisis prevention is intended (among other things) to prepare the way for structural development (TC). **Risk analyses** are essential in making possible this interlinkage and also in creating a bridge to structural TC. Risk analyses are a necessary basis for developing adequate and efficient strategies for implementing the various components of DEA and moving on from both emergency aid and reconstruction measures to less vulnerable and more sustainable development measures. Risk analysis can show whether reconstruction and TC are useful and necessary after a brief period of emergency aid.

Typical phases in a disaster:
emergency aid (medical services, tents, water, waste water disposal, medication) ➜ food aid ➜ rehabilitation and reconstruction based on risk analysis ➜ disaster risk management (risk analysis, prevention, spatial planning and preparedness) ➜ rural regional development, promotion of agriculture and employment, community development and decentralisation.

The nature and scope of risk analyses and the measures based on these can vary extensively, depending on the hazard and whether they are concerned with the national, regional, village or household level.

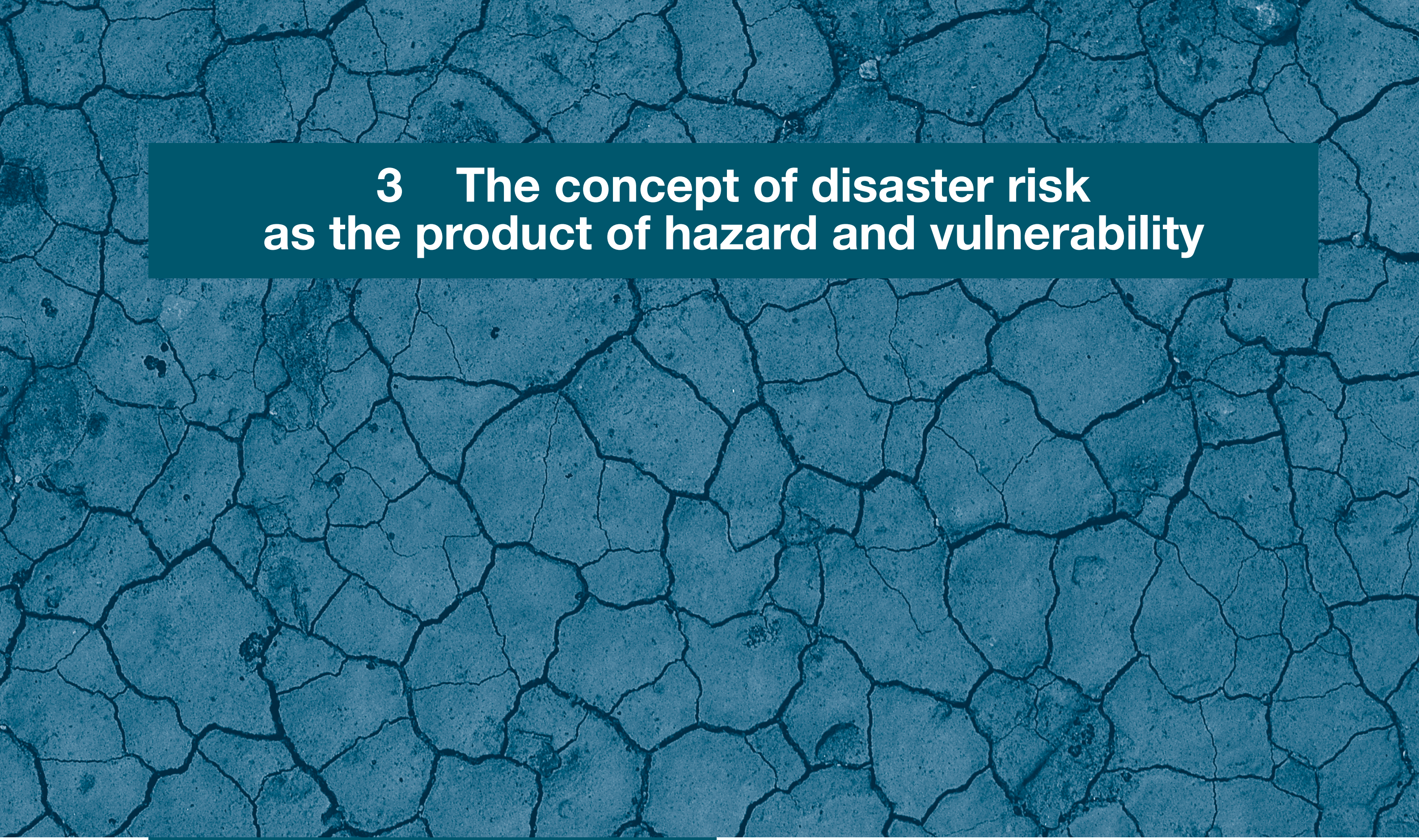
2.3 Disaster risk management as part of other planning

The projects supported by the GTZ are the result of processes of negotiation and the expression of both international and binational agreements and national policies. Since "Rio 92" the Federal Republic of Germany has been just as committed to the **paradigm of sustainable development** as the governments of the partner countries (Rio Declaration, Agenda 21, Convention on Biological Diversity, Framework Convention on Climate Change) which the German Federal Government cooperates with.

One of the GTZ's goals is accordingly *"to promote the formation of viable partnerships for sustainable development by supporting learning and negotiations processes which lead to a balance between the economic, social and ecological dimensions of development in the interests of present and future generations"*[5].

The specific anchoring of the projects supported by the GTZ a) in the paradigm of sustainable development and the development policy principles of the German Federal Government, b) in the development efforts of the partner countries, and c) in the mostly short-term expectations and needs of the target groups leads to a situation where the diverse interests, necessities and needs have to be coordinated and negotiated. This process of negotiation is often charged with conflict, and risk analysis is the only way to provide competent support and advice. Risk analysis also supplies a foundation for a) detailed formulation of an efficient DRM and b) concrete linkage of the DRM with other planning or integration into a national development strategy. The DRM must be or become an element of a national development strategy in order to be successful and contribute to sustainable development.

[5] From: Burger/Happel: "Das Leitbild nachhaltiger Entwicklung – handlungsleitende Orientierung der GTZ?" Diskussionspapier 3/97.



3 The concept of disaster risk as the product of hazard and vulnerability

3.1 The concept of disaster

Natural disasters are the result of the impact of an extreme natural event on people and their vulnerable goods and infrastructure, and cause loss of life and damage to goods and the environment. A disaster is the disruption of the functioning of a society to an extent which exceeds the ability of the society to cope with it from its own resources. The extent of the disaster depends on both the intensity of the event and the degree of vulnerability of the society[6]. A natural disaster always consists of two elements, an (external) event (the hazard) and the impacts of this hazard on a vulnerable social group exposed to this hazard.

A powerful earthquake in an unpopulated area is not a disaster, while a weak earthquake which hits an urban area with buildings not constructed to withstand earthquakes, can cause great misery. Extreme natural events only become disasters if they impact vulnerable people, who often expose themselves to natural hazards through carelessness or poverty, or who contribute to or aggravate the events by intervening in nature.

Although reducing the risk of disaster can be done by both restricting the hazard and reducing vulnerability, DC mainly tries to reduce vulnerability, since reducing the hazard is usually very difficult or even impossible. Vulnerability, by contrast, is easier to influence by strengthening human response, planning and protective capabilities.

Disasters can be seen differently in other cultures. Whether those affected see an event as a risk or as a disaster, or whether they assess the risk as high or low depends on the value system they feel bound by. Perception of risk – or, more accurately, lack of perception of risk – is the most important factor in vulnerability.

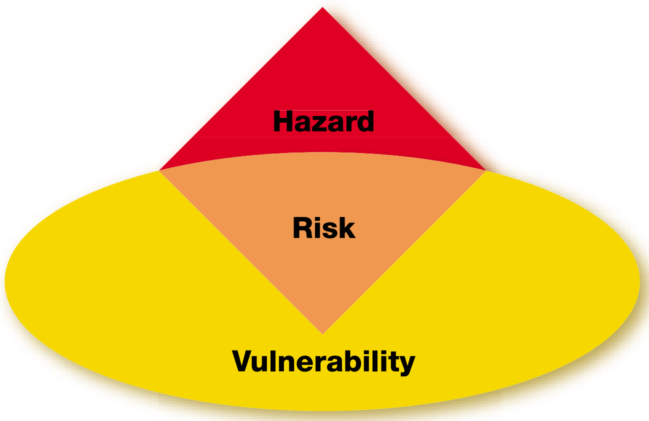
3.2 The nature of risk

Risks have always been part of daily life for humans. Life without risk is neither possible nor conceivable. However, both the level of acceptance and the perception of risk varies from one individual to another. One person will take a sharp bend at 50 km/h, another at 80 km/h, depending on their assessment of risk. Perception also varies between regions, societies and cultures. For example, there are countries who support nuclear power plants without reservation, while others see the risk as too great.

There is no universally valid definition of risk, precisely because perceptions differ between individuals

6 From: BMZ Spezial Nr. 082/Juni '97: Entwicklungspolitik zur Vorbeugung und Bewältigung von Katastrophen und Konflikten – Konzeptionelle Aspekte und deren entwicklungspolitische Implikationen.

Figure 3: **The concept of risk**



Explanation of fig. 3: Locations and populations in the yellow region are characterised by certain types of vulnerability, those in the red and orange regions are threatened by natural events. However, risk only arises in the orange area, where hazard and vulnerability coexist.

and cultures. In the context of disaster risk management, the following definition has been "agreed":

Risk is the probability of a harmful occurrence with a specific force at a specific location and at a specific time. Risk relates to humans or objects at risk from natural events.

To perceive, understand and assess risk requires experience with or knowledge about risks, i.e. experience of something in the past.

Risk is something which has not happened yet, something which is projected into the future. If a risk is perceived as too great, there are two possibilities: eliminate the risk, or reduce it as far as possible.

However, with growing poverty there are more and more situations in which the affected population accept a high level of risks and locate in urban population centres, steep slopes or flood areas. There are also those who e.g. live near industrial zones or atomic power plants, and do not want to move away because they would lose their job or other benefits. How high the risk is judged to be also depends on the available information about possible hazards. Adequate provision of information relating to hazards helps increase awareness and perception of risks.

3.3 The elements of hazard and vulnerability

These two elements – hazard and vulnerability – are essential in risk assessment: hazard, as the probability of occurrence of a harmful natural event, and vulnerability as susceptibility to injury or damage if the event occurs, and the ability to protect yourself against it. This leads to risk as the product of the two, expressing the probability of occurrence and the magnitude of the possible damage – in other words, the probable loss or injury.

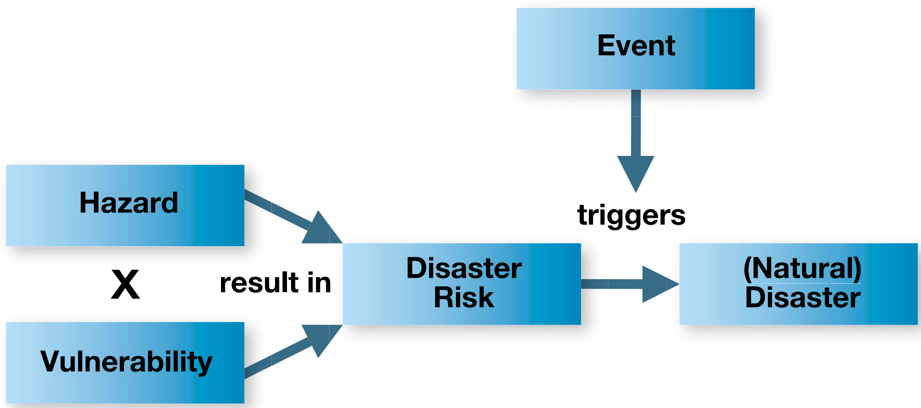
The BMZ and GTZ use the basic equation

risk = hazard x vulnerability.

However, it is important to remember that a large part of the vulnerability can be reduced through human

Figure 4: **Disaster risk as the product of hazard and vulnerability**

(revised following "Working Concept Disaster Risk Management", GTZ)



capability for prevention or self-protection ("coping strategies"). The absence of coping strategies is part of vulnerability, and has to be taken into account in the vulnerability analysis.

Hazard and vulnerability must be simultaneously present at the same location to give rise to risk, which then becomes a disaster if the event actually occurs. A society may be vulnerable to floods, but not to earthquakes (and vice versa). Vulnerability can only be identified and studied with reference to a concrete hazard. Vulnerability to a specific type of hazard varies, depending on the sector and context: for example, in housing areas, vulnerability arises out of the poor quality of buildings and basic infrastructure, in health it arises out of a lack of reserves of medication and first aid equipment, in economic activities like agriculture it arises out of a shortage of stockpiles, etc.

The vulnerability of a population or an ecosystem involves very different and often interdependent factors, which have to be taken into account in determining the vulnerability of a family, a village or a country. It is like a spider web in which physical factors are linked to economic, cultural, political, institutional, ecological and other factors.

Hazards have impact chains which can vary in length. Torrential rain as an extreme natural event can, for example, cause damage to poorly constructed (and hence vulnerable) roofs (direct impact), but for the most part the direct physical hazards and causes of damage are the consequences of the torrential rain, i.e. floods, landslides, erosion etc (longer impact chain).

The subject of hazard analysis comprises the direct physical hazards as part of what may be a longer impact chain. A direct physical hazard is the hazard which the affected population group perceive as such. In the above example, it would not be the torrential rain, but the floods, landslides and erosion.

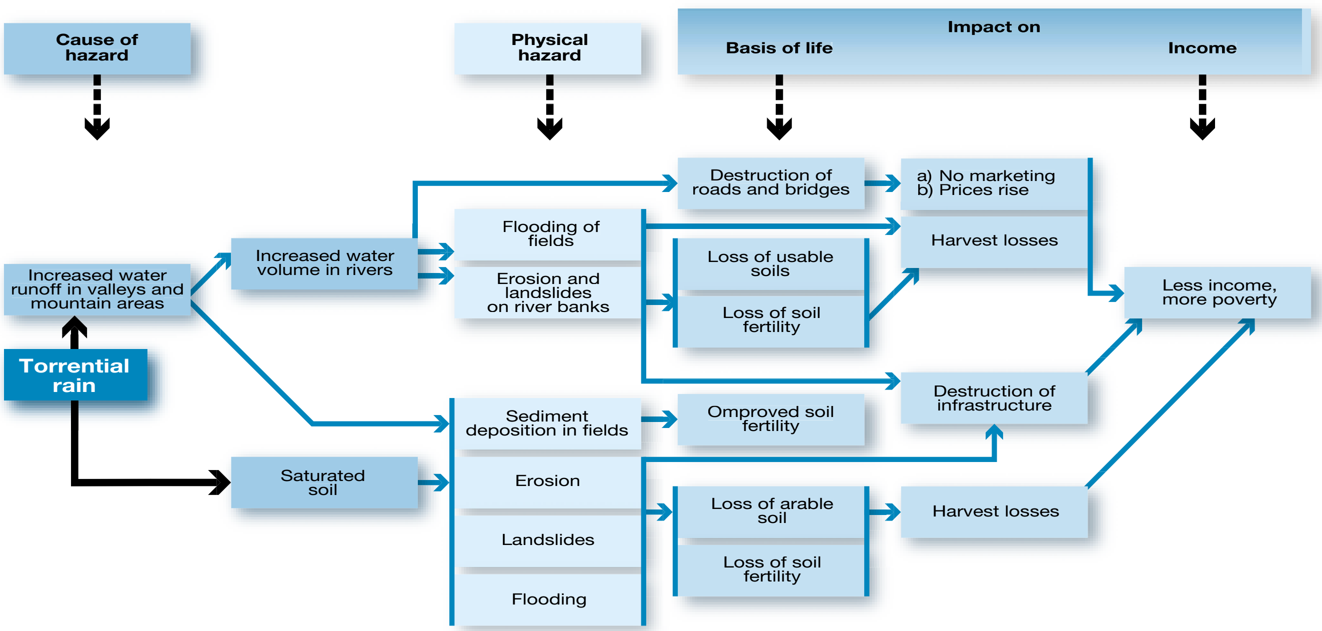
However, this depends in turn on whether the torrential rain actually leads to such secondary extreme events as floods, landslides and erosion as a result of the given characteristics of the location (water catchment area, steep slopes, lack of vegetation cover, soil infiltration rate) and vulnerability factors, and whether there are elements present which are vulnerable to these secondary hazards, e.g. roads or fields on slopes, settlements in low-lying areas etc (= vulnerability factors).

How far a natural event represents a hazard also depends on the location under consideration: torrential rain in the mountains poses no hazard to a settlement in the lower lying areas – at worst, the hazard comes from the flooding which can result from the rain, and even then only if the settlement is vulnerable to floods. In the case of an unprotected road on a slope, the hazard comes from landslides caused by the heavy rain.

Whether the torrential rain poses a hazard in the higher lying region where it falls depends on whether there are elements vulnerable to it there, e.g. the early stages of salad and vegetable cultivation.

How much damage e.g. agriculture as an important source of income suffers from torrential rain depends

Figure 5: **Impact chain for agriculture and income of torrential rain**



on a series of processes, impacts and vulnerability factors, as illustrated in figure 5, showing the **impact chain** of torrential rain for agriculture. Here, the impacts of torrential rain are transformed into physical hazards and thus causes of damage, such as landslides, flooding and erosion.

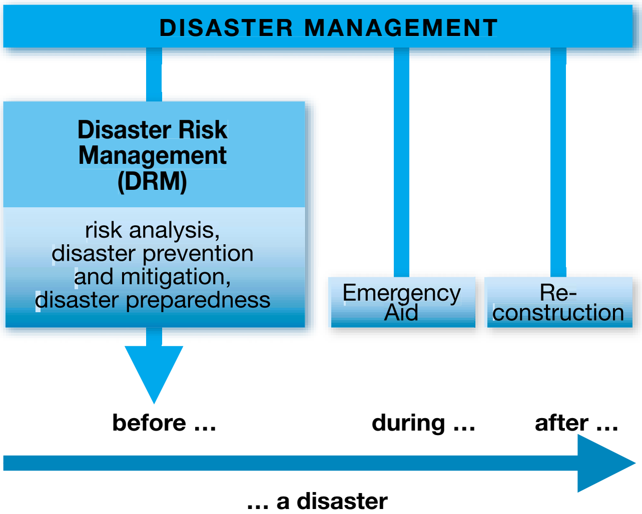
Extended impact chain:
torrential rain > floods > landslides, erosion, loss of soil fertility > diminished utility of soils > lower agricultural output > increasing poverty > clearing of new agricultural land which is often inappropriate for the location > inadequate land use > soil compacting > lower soil infiltration rate > greater surface water runoff during next torrential rain > more flooding > more landslides and erosion > etc.

4 Disaster risk management – concept, areas for action and components

4.1 Disaster risk management – concept and areas for action

Disaster management (DM) includes measures for **before** (prevention, preparedness, risk transfer), **during** (humanitarian aid, rehabilitation of the basic infrastructure, damage assessment) and **after** disaster (disaster response and reconstruction). Emergency aid is followed by longer term (development oriented) emergency aid, often summarised as disaster aid. Reconstruction measures form the third leg of disaster management, together with emergency aid and disaster risk management. Disaster **risk** management (DRM) in this context relates to reducing vulnerabilities as an area amenable to influence, and to developing risk transfer mechanisms.

Figure 6: **Disaster risk management as part of disaster management**



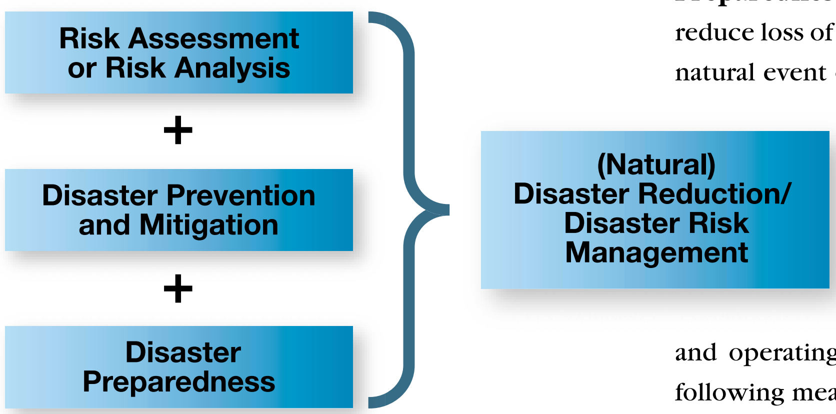
4.2 Disaster risk management (DRM) and its components

Disaster risk management (DRM) is part of disaster management, focusing on the *before* (risk analysis, prevention, preparedness) of the extreme natural event, and relating to the *during* and *after* of the disaster only through risk analysis. DRM is an instrument for reducing the risk of disaster primarily by reducing vulnerability, based on social agreements resulting from risk analysis.These social agreements are the result of a complex social process in which all social strata and interest groups participate.They are a necessary basis for resisting the future effects of extreme natural events (prevention, preparedness). The primary area of action of a DRM is reducing vulnerability and strengthening self-protection capabilities.

The DRM takes into account and links technical, social, political, socioeconomic, ecological and cultural

Figure 7: **Areas of action for disaster risk management**

(revised following “Working Concept Disaster Risk Management”, GTZ)



aspects. This involves networking the various DRM components and the various aspects listed above to form an integrated system. This integration is what enables the DRM to reduce the risk to a level which a society can cope with. The components of the DRM are risk analysis, prevention and preparedness.

Risk analysis (RA) consists of hazard analysis and vulnerability analysis, together with analysis of protective capabilities. Some authors treat the analysis of the protective capabilities of the local population (coping strategies) as part of vulnerability analysis, others as a third component of RA, others see it as an additional chapter, and as such a component of risk assessment and not risk analysis. Here, the analysis of self-protection capabilities is treated as part of vulnerability analysis.

Disaster prevention includes those activities which prevent or reduce the negative effects of extreme natural events, primarily in the medium to long term. These include political, legal, administrative, planning and infrastructural measures.

The GTZ “Working Concept Disaster Risk Management” lists the following priorities:

1) Spatial and land use planning, urban development planning, building codes;
2) Sustainable resource management and river basin management;
3) Establishment of social organisational structures for preventive measures and to improve the response to extreme natural events (disaster risk management structures);
4) Training and upgrading for population and institutions;
5) Infrastructural improvements.

Preparedness for disasters is intended to avoid or reduce loss of life and damage to property if an extreme natural event occurs. The participating institutions and the population at hazard are prepared for the situation that might arise, and precautions are taken. In addition to increasing the alert level, mobilising the self-help resources of the population for the emergency and operating a monitoring system, this includes the following measures:

1) Participative formulation of emergency and evacuation plans;
2) Coordination and deployment planning;
3) Training and upgrading:
4) Infrastructural and logistical measures, such as emergency accommodation, etc and stockpiling food and drugs;
5) Establishing and/or strengthening local and national disaster protection structures and rescue services;
6) Disaster protection exercises;
7) Early warning systems.

Preparedness and prevention measures also include designing and implementing risk transfer concepts.

Figure 8: **Measures to reduce the risk of disaster, using flooding as an example**

	Hazard reduction	**Vulnerability reduction**
Prevention (to reduce risk)	spatial planning (e.g. to protect against landslides); settlement planning sustainable resource management; polders dams protective/containment walls drainage to reduce landslide impact; afforestation	spatial and settlement planning: sustainable agriculture; diversification of seed and economic activities; consciousness raising, training and advanced training, building codes; organisational promotion; dams integrate DR into sectors; risk transfer; insurance; promotion of local economy; drainage to preserve roads; information management; capacity building;
DRM **Preparedness** (residual risk)	DRM dam reinforcement and raising establishing flood protection brigades (e.g. logistical planning, etc)	DRM early warning systems; evacuation plans; organisation for emergency situations; training and upgrading for emergency situations; bridge building for evacuations

Explanation of figure 8:
The diagram is an attempt to assign the various measures for reducing disaster risk to the DRM categories of "prevention" and "preparedness" and to reducing hazard and vulnerability. The arrows pointing from preparation to prevention are meant to show that DRM can help strengthen prevention, which in turn reduces the burden on preparedness.

5 Risk analysis: concept, goal and products

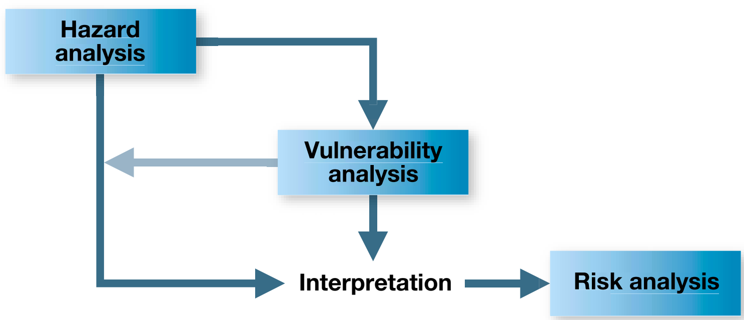
Risk analysis is based on the recognition that risk is the result of the link between hazard and vulnerability of elements affected by the hazard. The goal of risk analysis is to use this link to estimate and evaluate the possible **consequences and impacts** of extreme natural events on a population group and their basis for life. This involves impacts at the social, economic and environmental levels. Hazard and vulnerability analyses are parts of risk analysis, and are inseparable activities – vulnerability analysis is not possible without hazard analysis, and vice versa.

Once it is established that the people and bases for life potentially impacted by an extreme natural event are vulnerable to this, making the extreme natural event a hazard, risk analysis investigates the potential loss.

5.1 The concept of risk analysis

Besides nature as the cause of disasters, increasing attention is being paid to analysing the role of societies, their mode of production and living, and their development model as possible causes, and integrating the results of this analysis into the various protective strategies. In most parts of the world, disasters are no longer accepted simply as acts of god or nature. This means that vulnerability is increasingly understood as the result of economic and social development processes, which needs to be documented and reduced on the basis of comprehensive analysis. **Risk analysis** is a basic instrument of disaster risk management which is used to study the factors of disaster risk and provides the basis for planning and implementing measures to reduce risks and impacts of disasters.

Figur 9: **The concept of risk analysis**

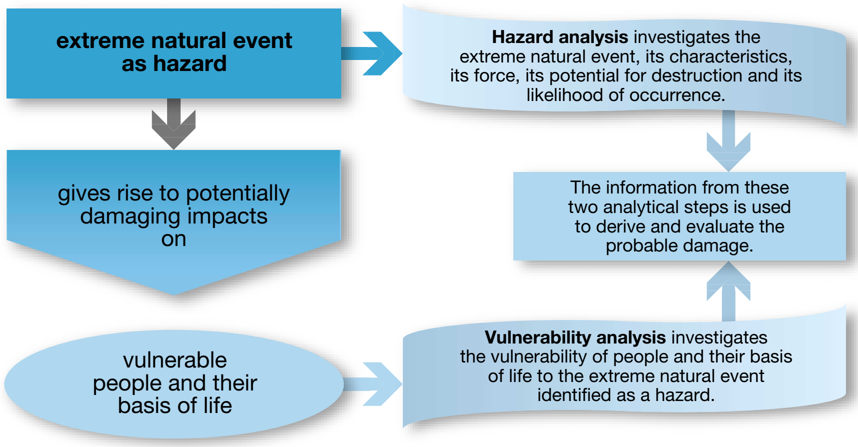


Hazard analysis

A hazard analysis investigates, identifies and documents natural hazards (drought, floods, landslides, earthquakes, etc.), their causes and impact chains. In hazard analysis, natural disasters (droughts, floods, landslides, earthquakes etc) and their causes and the resulting impact chains are identified, analysed and documented. Knowledge of the types of hazard is essential for analysing and assessing risks. The resources required for an analysis depend on the situation. A simple analysis with modest data input may be sufficient, or comprehensive investigations and elaborate studies may be required to document hazard potentials.

To be able to estimate and evaluate the degree of risk and the characteristics and scale of possible loss from extreme natural events, it is necessary not only to estimate the probability of occurrence but also to investigate the force and duration of the event. However, before this detailed study it is necessary to establish how far population groups and their bases for life are potentially affected by the event, i.e. how susceptible they are to the event and how vulnerable they are to this hazard. If there are no vulnerable populations or elements at the site of the hazard, no hazard analysis is required, as in this case the extreme natural event does not constitute a hazard. These are the first steps in vulnerability analysis, and they are needed before any detailed hazard analysis. Hazard analysis is not a linear sequence of analytical steps relating to the hazard: it is constantly being interrupted by steps in the vulnerability analysis, and supplemented by the learning loops and results generated by this. This leads to the procedure presented in figure 10.

Figure 10: **Assessment of impacts as the goal of risk analysis**



The most important tasks and steps in hazard analysis are:

1) The first stage in hazard analysis is to identify the types of hazards. There are many ways to classify hazard types, e.g. natural events occurring suddenly or gradually, of an atmospheric, seismic, geological, volcanic, biological and hydrological nature[7] while others summarise mass movements under the heading of "geomorphological hazards"[8]. In these guidelines, we use the classification shown in the box below.

Main hazard types

A. Meteorological causes and origins

a) Floods caused by torrential rain and tropical storms
b) Storms and torrential rain > damage caused by storms, e.g. damage caused by tropical storms, tornados and cyclones, hurricanes and tidal bores
c) Droughts have a particularly high damage potential if they cause extensive crop destruction and famine or forest/bush fires
d) Hail and frost, if they lead to extensive crop destruction; lightning
e) Mass movements (e.g. landslides as a result of heavy and intensive rainfall) caused among other things by 1) flooding in mountainous regions 2) heavy and intensive rain 3) rivers changing courses
f) Erosion, soil degradation caused by water and wind
g) Forest fires

B. Geological causes

h) Earthquakes and the secondary consequences such as tsunamis, tidal waves and mass movements
i) Volcanoes and the secondary consequences such as lava and mudflows
j) Mass movements caused by large-scale tectonic movements, slow mountain building and shifting. The resultant changes to the angles of slopes can cause mass movements

C. Other

k) Epidemics, animal and plant diseases and pests

2) Depending on the types of hazard identified, the process may need to be continued on a separate basis for each type of hazard or group of hazard types. Earthquakes, for example, require different instruments and specialisations for analysis than e.g. landslides or floods. The analytical methodology must be adapted for the hazard types and data available.
3) Identification and characterisation of hazard prone locations.
4) Identification and determination of the probabilities of occurrence on an ordinal scale (high – medium – low).
5) Estimate or calculate the scale (strength, magnitude) of the hazardous event, also on an ordinal scale.
6) Identify the factors influencing the hazards, e.g. climatic change[9], environmental destruction and resource degradation, major infrastructural facilities such as dams etc.

In the case of hydrometeorological hazards, there is a close connection between weather and floods. The weather determines the precipitation, which in turn determines the runoff of the waters. Floods are determined by the specific characteristics of the catchment area, and also by regional climatic factors. If these climatic factors change, the vegetation also changes, which modifies the runoff behaviour of the waters and ultimately the scale of flooding.

Hazard analysis describes and assesses the probability of occurrence of an extreme natural event at a specific place, at a specific time, and with a specific intensity and duration, for a vulnerable population and their vulnerable basis for life. It describes and evaluates the degree to which the population, animals, structures and goods would be at risk.[10]

[7] Guidelines "Katastrophenvorsorge und Ländliche Entwicklung", GTZ 2002 (draft)
[8] Zschau, J., A. N. Küppers (2003) "Early Warning Systems for Natural Disaster Reduction", Hans Kienholz "Early Warning Systems related to mountain hazards", p. 556.
[9] Climatic data studies for 1961–1990 in Switzerland, for example, showed a rise in temperature of just under one degree. Even if this period is too short for reliable interpretation of secular climatic changes, we can nevertheless expect a general warming with more extremely hot days and fewer extremely cold days. This warming reinforces the hydrological cycle, and various models indicate more intensive rainfall and more extreme events involving rain. The German Federal Government's Council of Scientific Advisers on Climate (1996) expects a rise in sea level in German coastal regions of c. 1 m by the end of the century, caused by global climate change. Worldwide, c. 15% of the world population is threatened by a rise in sea level. However, overall the increase in strength and frequency of extreme events is seen as more serious.
[10] Hazard analysis is defined as follows in ISDR's "Living with Risk": "Identification, studies and monitoring of any hazard to determine its potential, origin, characteristics and behaviour".

Analysis of vulnerability[11] and self-protection capability

Vulnerability analysis studies the ability of a system (or element) to withstand, avoid, neutralise or absorb the impacts of hazardous natural events.

Before starting an analysis of the vulnerability of a population group and its bases for living, the extreme natural events and the locations they threaten must be identified and studied. Without extreme natural events as a hazard, there are no vulnerable elements, and hence no hazard. Conversely, without threatened locations with vulnerable elements, there is no risk, and hence no need for either hazard or vulnerability analysis.

The vulnerability of a group of people or region is inseparably linked to the social, cultural and economic processes developing there and the agricultural and ecological transformation of the region. Vulnerabilities are created, they are the product of social development or faulty development; they reflect deficits, shortages or disruptions within social development.

Vulnerability is assessed by the potential loss resulting from a natural event. It expresses the degree of possible loss or damage to an element threatened by a natural event of specific force. Damage can be to the population (life, health, wellbeing), material assets (buildings, infrastructure) or natural assets (woods, forest, agricultural land).

The most important tasks and steps in vulnerability analysis are:

1) Identification of potentially vulnerable individuals or elements (e.g. agricultural production, buildings, health, agricultural land and waters). In this, basic data is collected on population (age, density, gender, ethnic structure, socioeconomic status), location (buildings, important facilities such as schools, hospitals, emergency centres, environment, economy, structures, history), self-protection capability in terms of capacities for disaster preparedness – emergency response capability, training, prevention programme, early warning systems[12].
2) Identification and analysis of factors influencing or resulting in vulnerability = vulnerability factors for

[11] Vulnerability or susceptibility is understood here as possible damage or loss from the occurrence of an extreme event. Damage, on the other hand, is something actually suffered.
[12] Modified classification from Pearce, Laurence Dominique Renée (2000), "An Integrated Approach for Community Hazard, Impact, Risk and Vulnerability Analysis", HIRV, University of British Columbia, Vancouver.

each hazard type. Analysis of risk perception and the factors determining this (e.g. education, access to information, poverty) and investigation of the vulnerability factors and their linkage and interdependencies.

- **Physical vulnerability factors:** location, technical construction type and quality of the settlements and buildings, population growth and density.
- **Social factors:** education, legal reliability, human rights, participation of civil society, social organisations and institutions, legal framework, statutes, politics, corruption, gender aspects, minorities, dependent population (old, young, sick), traditional knowledge systems, power structures, access to information and social networks.
- **Economic factors:** socioeconomic status, poverty, food insecurity, lack of diversity of seed and economic activities (e.g. monoculture in agriculture), lack of access to basic infrastructure (water, energy, health, transport), lack of reserves and financing.
- **Environmental factors:** arable soil, usable water, vegetation, biodiversity, land under forest (logging, land degradation), stability of the ecosystems.

3) Development and identification of indicators for identifying vulnerabilities and estimating the degree of vulnerability (quality and location of buildings and basic infrastructure, education, access to information, diversity of agriculture and seed, preventive infrastructure etc).

4) Analysis of self-protection capabilities: identification of indicators to show or measure capacity for preparedness (protective and preventive infrastructure, early warning and forecasting systems, etc). Here, strategies and measures are identified and investigated at the various levels (family, village, community, district, province, country). The following indicators provide information on the existence or degree of strength of coping strategies:

- monitoring and early warning systems
- traditional forecasting and early warning systems
- plans for disaster reduction
- plans and fund for disaster protection
- insurance policies
- construction standards
- maintenance of basic infrastructure
- preventive structures, protective infrastructure
- land use planning, spatial planning, zoning
- organisation and communication (emergency committees)
- stability of settlement, social structures
- local knowledge (of hazards)

5) Estimate of accepted risk (risk level) and hence residual risk. Preventive measures are taken to reduce the risk to a socially and culturally accepted risk.

Examples of vulnerability factors

Economic factors force poor population groups to settle at threatened locations (steep slopes, flood areas), mostly on the edge of major cities. Others settle close to volcanoes because of the fertile soil. Besides location as a risk factor, poverty and the lack of diversification of income are vulnerability factors. • A well informed and organised population (**social factors**) is less vulnerable to extreme events than a poorly organised one. • **Political factors** which make a society more vulnerable include lack of disaster protection, corruption, lack of participation of civil society in (spatial planning) decisions. • Examples of **environmental factors** which result in increased vulnerability are logging and overgrazing on steep slopes or destroyed water catchment areas.

Risk analysis as a combination of the two analytical stages

Risk is understood here as the expected value of the loss of human life or damage to objects, infrastructure and the environment. Determining the disaster risk as a result of the risk analysis is analytically based on documenting and assessing the hazard, followed by valuation of the vulnerability of a population or region to this hazard. In determining the overall risk, all the elements at risk (e.g. population, property, infrastructure, economic activities, etc) are taken into account with their specific vulnerability.

Risk analysis involves estimating damage, loss and consequences arising out of one or more disaster scenarios. It attempts to estimate the probability and magnitude of damage and loss caused by extreme natural events. Its results are conventionally presented in risk maps created manually or using geographical information systems (GIS).

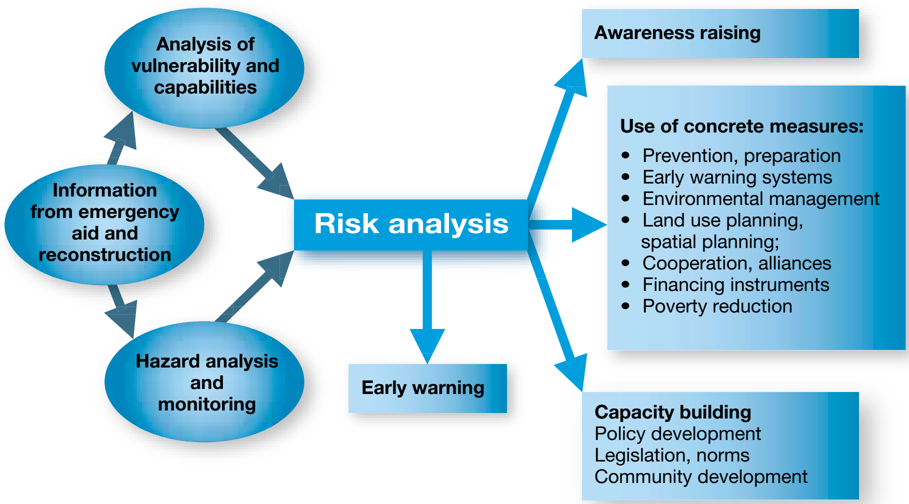
As already indicated at the beginning of this section, the two analytical stages are not separate procedures, but rather interactive steps. At theend we get the products described in the next section – risk maps, scenarios, forecasts, risk assessment tables, etc.

5.2 Goal and products of risk analysis

Risk analysis consists of hazard analysis and vulnerability analysis, together with analysis of self-protection capabilities. This also takes into account knowledge from prior emergency aid measures.

Risk analysis is not a static one-time process, but rather a dynamic process which is constantly adjusting to changing vulnerabilities, hazards and risks.

Figure 11: **"Inputs" and "outputs" in risk analysis**



The goal of risk analysis:

- To identify participative possible hazards and vulnerabilities of population groups to natural events, to analyse these and to estimate and assess both the probability of occurrence and the possible potential damage of such natural events; to identify and study possible weaknesses and gaps in existing protective and adaptive strategies.
- To formulate realistic recommendations for measures to overcome weaknesses and reduce the identified and assessed disaster risks, and to agree these with those affected. It is particularly important here to identify and improve existing capacities as well as protective strategies.
- To ensure and enhance the feasibility, effect and efficiency of protective measures by working from the risk analysis to a) balance the various interests, b) consider the reasonability of measures and c) make possible social agreements on strategies and measures to reduce disaster risks.
- To contribute to meeting the recommendations of the "World Conference on Natural Disaster Reduction" (Yokahama, 1994) and realising the goals of Agenda 21. In the latter, the following sections are specifically addressed: section 7 "Promoting sustainable human settlement development", Programme Area F; section 13, "Managing frail ecosystems: sustainable mountain development", Programme Areas A and B; section 17 "Protection of the oceans, all kinds of seas, ..." Programme Areas A and G.

Risk analysis is also expected to contribute to the following:

- Other planning, and specifically spatial and land use planning.This makes it possible to take into account the risks of natural hazards in land use and other activities with spatial impact, including development and zoning plans of communities, agencies and specialist institutions which are formulated using the information from risk analysis and whose implementation contributes to reducing disaster risks.
- Planning for emergency aid measures, by making it possible to create the conditions for sustainable reconstruction work and development measures.
- Efforts to improve coordination and linkage between the various components of DEA and with TC.
- Efforts to integrate DRM into the various areas of development.

Expected products of risk analysis

In the context of risk analysis, highly advanced technologies for remote sensing and geographical information systems (GIS) have in recent years led to the development and improvement of numerous instruments and methods for hazard mapping and analysing the physical aspects of vulnerability. By contrast, the integration of social, economic and environmental variables into GIS models, risk maps and risk analysis generally still remains a challenge.

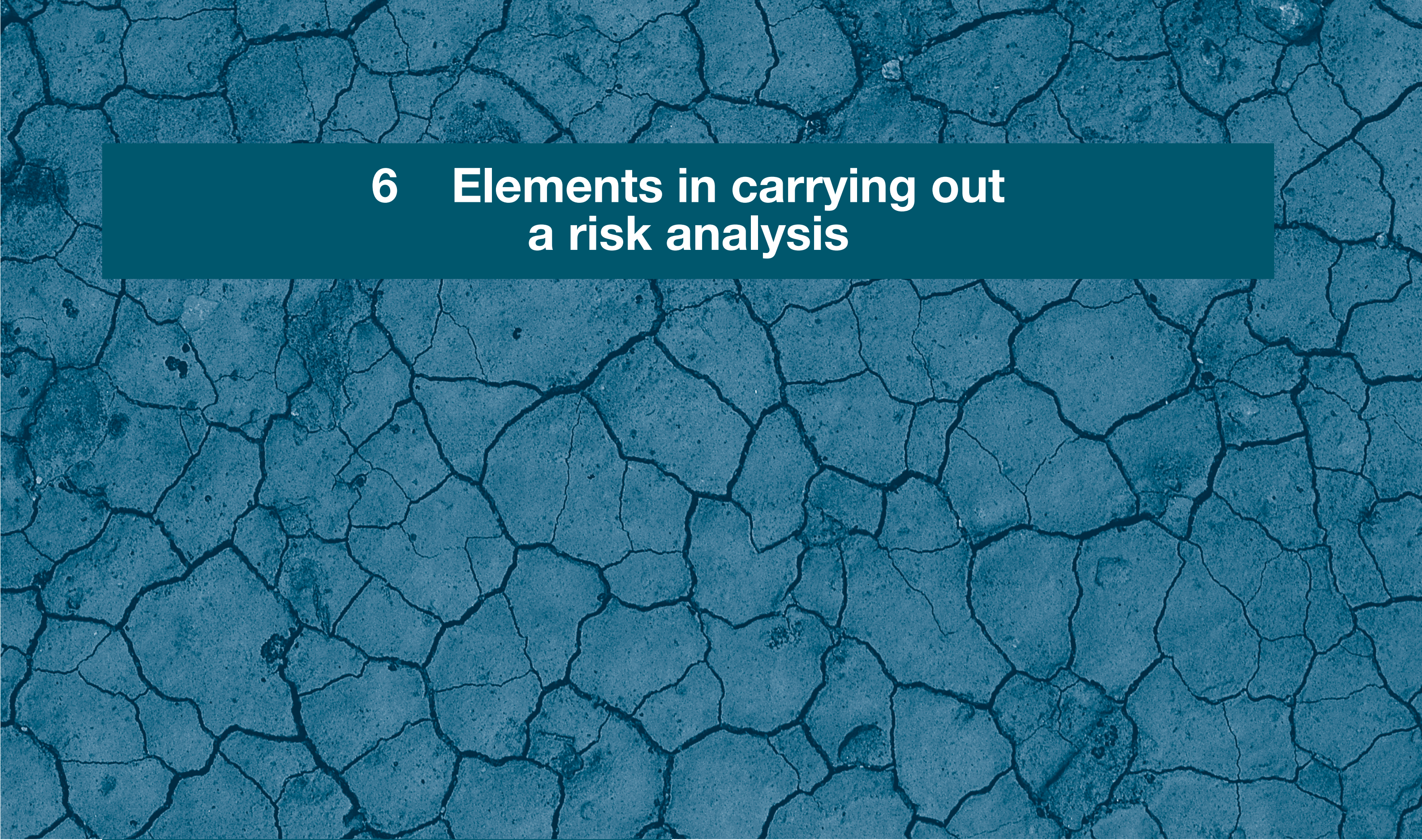
The products most frequently created in risk analyses include hazard maps and so-called risk maps. Different authors and regions use different names for risk or hazard maps. They also have different levels of data accuracy, and can be subdivided into three categories:

- Hazard maps: these are maps which give qualitative and quantitative information on natural hazards, e.g. by presenting the expected danger or maximum level of danger or the event, e.g. slopes at risk from landslides.
- Risk zone maps: these provide information on the probability of occurrence (in the case of earthquakes, the contain the building standards needed for disaster reduction). They are generally the result or product of a hazard analysis.
- Risk maps are risk zone maps which also contain quantitative information on the risk and the impacts on people, property, environment, etc. Typically, they take into account the physical aspects of vulnerability, but not the social, economic and political aspects.

Other products:

- Information from various analytical methods and techniques (e.g. “Livelihood analyses”, FEMA) and simulation models (e.g. NAXOS, SWAT, USLE) is presented in text and diagrams. Generally, this information is allocated to either the hazard or vulnerability analysis or both. References on the methods and models cited are contained in the appendices to these guidelines, available from the sector project “Disaster Risk Management in Development Cooperation”.
- Assessment tables and risk assessment matrix.

6 Elements in carrying out a risk analysis



6.1 Criteria for determining the methods and instruments in applying risk analysis

In carrying out a risk analysis and determining the methods and techniques to be used in this, certain *conditions* must be met and the following *criteria* must be taken into account.

Before carrying out a RA, the following questions should be explored or settled.

- Is there the political commitment to DRM? Are preventive measures politically acknowledged? Or do emergency aid measures do more for the institutional image and political career?
- Is there financing for implementing the measures derived from the risk analysis.
- Does a cost-benefit assessment indicate a positive social benefit? Or is RA more expensive than possible damage from a natural event?
- Is the starting point an emergency aid measure, are there follow-up measures (DEA, TC)?
- Is there an institutional and statutory basis for DRM and RA? Are there developing and/or poverty reduction strategies which take into account disaster risks?
- Is the affected population motivated and interested in self-help?

1) The existence of **political commitment** to active DRM is an absolute prerequisite. Just as important is the existence of defined institutional responsibilities for disaster reduction and disaster response. The political framework should permit democratic consultation processes and cooperation between and with institutions.
2) There must be a realistic chance that the **results of the RA** can be implemented and applied, i.e. there must be resources available or capable of mobilisation. The results must be taken into account e.g. in spatial and land use planning.
3) **Cultural acceptability** of the innovations (e.g. methods and techniques) must be taken into account in the interests of project sustainability. In addition, promotion of self-organisation by the affected population and consideration of traditional and local knowledge are of fundamental importance for sustainability.
4) Besides the problems already referred to in the transition from emergency aid to normal TC, there is often a further difficulty in the fact that experience shows that the emergency aid instruments used (aid shipments, food aid) often hinder **"ownership" and personal initiative** among those affected. However, both of these are basic elements of TC, which primarily works with participative analysis and planning instruments. To deal with this problem, a dual

strategy should be pursued during emergency aid which combines aid contributions with promotion of "ownership" and personal initiative.

5) Experience in DC has shown that it is easier to reach a consensus between technicians, politicians and the local population if highly visible protective measures are involved (which are often expensive and do not always do much for disaster reduction) than if less spectacular but possibly more effective measures are involved. One example of this is ineffective protective walls against landslides instead of adequate water management in uplying regions. This is a question not only of **different interests** but also of **different perceptions** of hazards. To achieve optimal solutions in consensus with all participants, measures such as transparent information management, disclosure and discussion of the various interests and clarification of the various roles are important and useful.

6) Risk analyses can be applied at **various levels and in different contexts**. When deciding on the approach, it is necessary first to investigate or clarify a) whether the aim is to reduce disaster risk at local, regional or national level, and b) whether the product is intended for a community (implementation), technical agency (research, analysis), financial institution (cost-benefit analyses, profitability) or insurance company (tariffs). The comments in the present guidelines focus on the local level for strengthening local structures, and are oriented towards implementation.

7) Even with experienced planners and specialists, there is still a tendency apparent to give too much emphasis to **inputs for data collection** and analysis, leaving too little time and resources for evaluation of data and formulation of solidly-based planning statements, and particularly for their agreement with actors and subsequent implementation. Often, vast quantities of data are collected which cannot be used later or have to be aggregated after being collected in too much detail, and which cannot be used to derive any direct statements for planning. It is accordingly important to clearly define and agree the concrete goals for the risk analysis and the data required.

Based on analysis of these questions and criteria, the methods and instruments for the risk analysis must be identified, modified or developed.

Because the data available differs very widely in quantity and quality in the various countries and project locations, methods always have to be adapted.

Participative approach

German TC has extensive and varied experience with participative approaches and the use of participative instruments for analysis and planning. These participative instruments are mostly based on the RRA[13]/PRA[14] approaches and further developments of these methods. RRA is a sociological approach developed in DC at the start of the 80s in which a multidisciplinary team uses nonstandardised simple methods and incorporates the knowledge of the local population in order to rapidly collect, analyse and evaluate information about rural life and rural resources which is relevant for action. PRA methods are indicated if it is a question of a rapid, action-oriented assessment of local knowledge, needs and potentials. PRA stresses a proactive role in problem analysis and planning for those affected, with outsiders playing the role of "facilitators". Today, the emphasis in these approaches is on "participatory", while "rapid" is less important. PRA as an internationally established term and concept is understand here in the sense of "participatory appraisal", with the emphasis shifted from "analysis" and "rural" to *planning* and active *problem solving*, both in a rural context and elsewhere.

The basis for the increased importance of participative instruments and thinking, which has set the tone in many projects, is the acknowledgment that the conventional (top-down) planning approaches have produced little success, despite high costs. The participatory approach is tied to the goal of enhancing the planning competence, autonomy and organisational capacity of previously disadvantaged (target) groups, and to integrating excluded and marginalised groups. A central aspect of applying participative planning methods is mutual learning on the part of those involved.

In developing countries, the weak public structures for disaster protection mean that people are particularly dependent on self-help. This gives rise to the challenge of meshing state-organised disaster protection with private aid organisations and self-help activities by the citizens. Disaster protection and prevention measures – where present at all – are mostly managed at

13 RRA = Rapid Rural Appraisal
14 PRA = Participatory Rural Appraisal

community level from remote head offices with external labour.

It goes without saying that risk analysis is carried out with the participation of the affected target groups and in cooperation with the responsible institutions and political decision-makers. The term “risk analysis” as used in the present guidelines has the underlying concept of **“participative risk analysis”** (P-RA).

Participative risk analysis is viewed here as a socio-technical method which takes into account sociocultural values, integrates subjective perceptions and sensitivities, helps evolve existing knowledge and potentials, builds capacity and promotes self-help. Wherever possible and expedient, it gives priority to participatory working methods and the use of participative instruments, and promotes access to information and knowledge for the affected population.

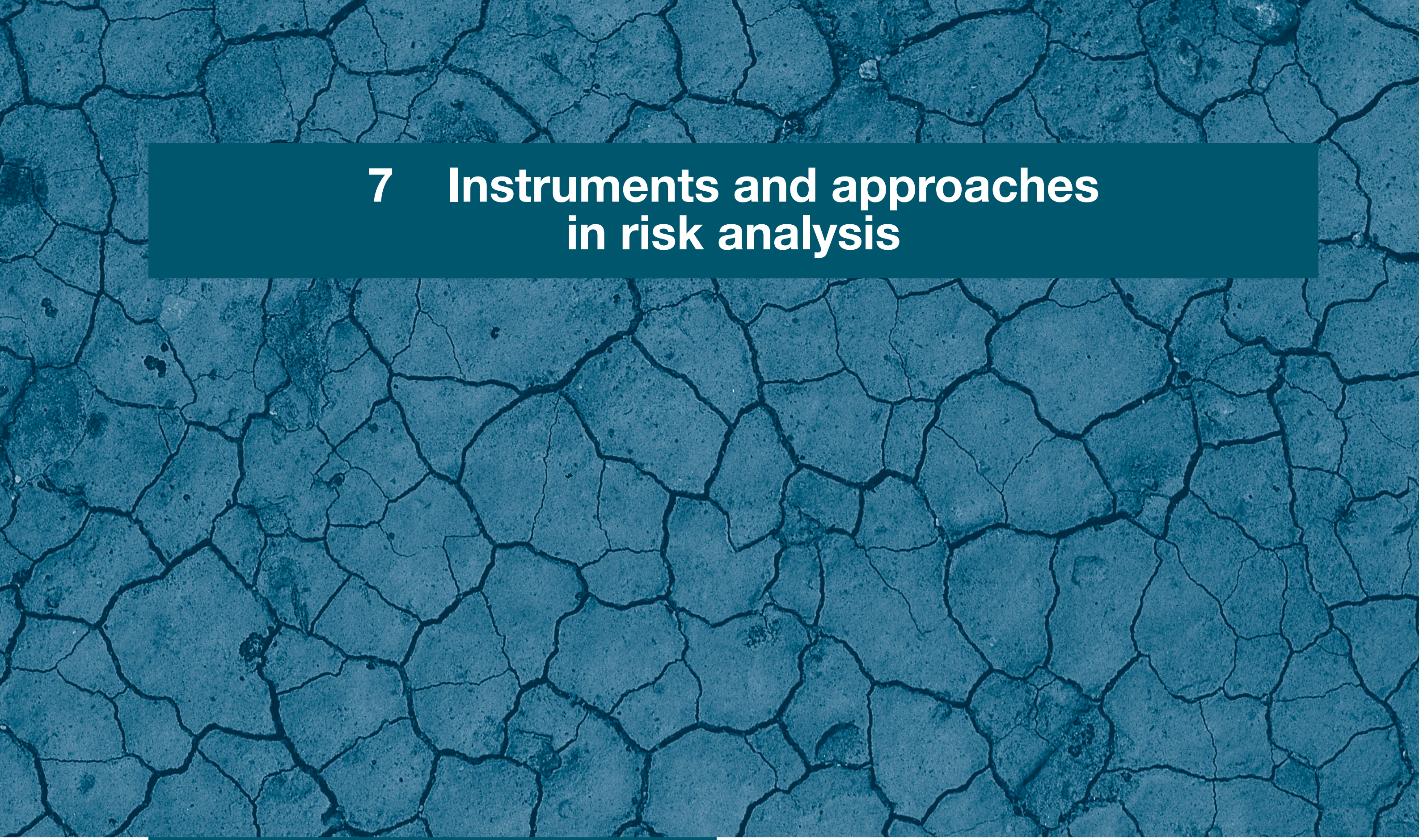
It is a process of negotiation between partners, which actively includes those affected in the solutions to problem and which practises teamwork. It supports the development of the social and institutional basis for successful disaster risk management.

6.2 Elements in implementation

In carrying out RA, the structures and elements shown in figure 12 are the basis:

Figure 12: **From risk analysis to DRM measures**

Hazard analysis	Vulnerability analysis		Disaster prevention and mitigation	Preparedness for disaster
Geographical analysis: • Location • Extent **Temporal analysis:** • frequency • duration • probability of occurrence **Dimensional analysis:** • scale • intensity	**Identification of elements and people potentially at risk** **Identification of vulnerability factors and analysis of causes:** • physical • economic • social • environmental **Assessment of possible damage/loss**	**Analysis of self-protection capabilities** **Development of strategies and measures at different levels:** • family • village • community	**Planning measures** **Physical preventive measures** **Capacity building, creating institutional arrangements**	**Emergency plans** **Early warning systems** **Evacuation plans**



7 Instruments and approaches in risk analysis

7.1 Overview

The previous section covered the "what" and "why" of risk analysis, and this section goes on to look at the "how" and "what with" aspects. The breakdown of risk analysis into hazard analysis and vulnerability analysis is itself an analytical tool, and this separation is not reflected in the reality of practical risk analysis. In practice, steps in hazard analysis and steps in vulnerability analysis alternate and interact.

After identifying the hazard type, **hazard analysis** becomes a matter of identifying and investigating the hazard location and its geographical extent, strength (scale, magnitude, intensity) and the probability of occurrence of the extreme natural event identified as a hazard.

There are many methods and instruments available for hazard analysis. Most of them operate on the basis of available scientific data. We distinguish between qualitative and quantitative methods. While quantitative methods are more precise, they are often not enough simply because of the difficulty with obtaining data that is often encountered. Qualitative methods by contrast offer greater depth of focus, more participation and better understanding of relationships. They are strongly based on experience and observations in the area affected. In the context of DC, a combination of both methods is recommended. Qualitative methods should be supplemented or supported by quantitative techniques.

In analysing the various hazards, a classification into **three analytical categories** has proved useful:

- spatial analysis (location, extension);
- temporal analysis (frequency, duration, probability of occurrence, trends);
- dimensional analysis (strength, scope, intensity, scale, magnitude).

There are various analytical approaches for and experience with **vulnerability analysis**, but to date no standardised approaches have emerged. Besides methods for assessing physical vulnerability (i.e. quantifying the expected damage to buildings and infrastructure), there are many individual studies which have developed methods as needed or assembled them by combining elements of existing instruments. This is particularly true in situations involving social factors in vulnerability. There is no uniform approach to investigating vulnerability or any agreement on what constitutes appropriate indicators. We are accordingly unable to present or recommend any standard methods as "best practice" here. In addition to the individual studies, there are various conceptual approaches which have led to "social vulnerability studies".

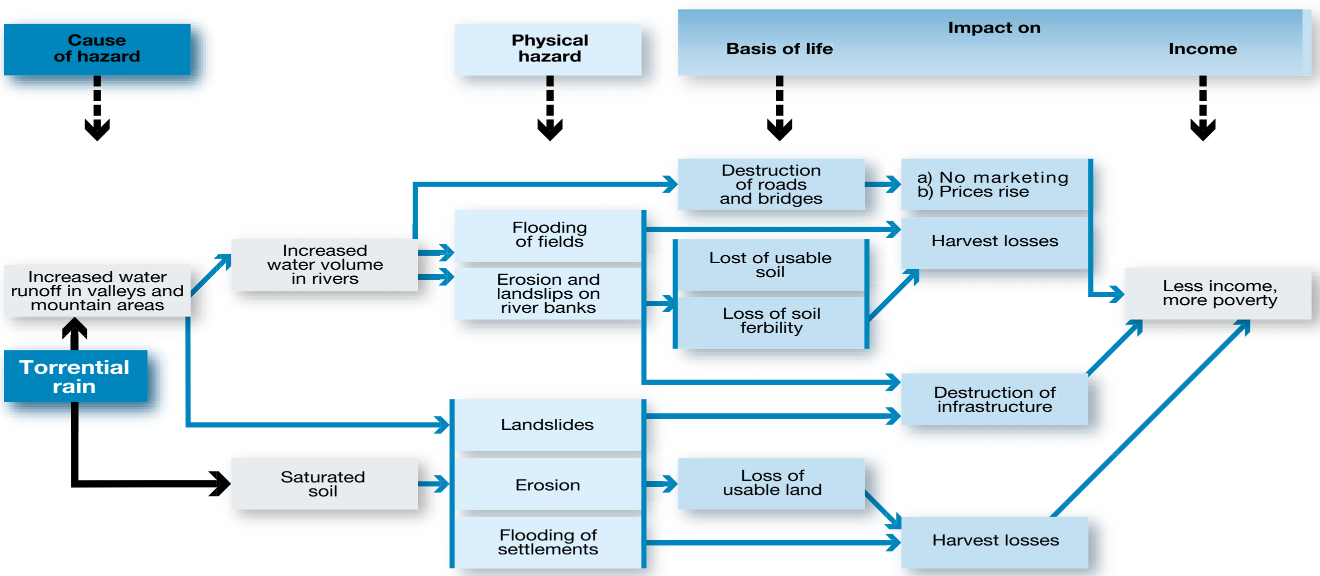
The approaches to analysing vulnerability come from a range of research perspectives. Several are more concerned with analysing vulnerable groups, partly inspired by poverty reduction strategies, while others are based on analysing the actual living situation at village and household level (e.g. the UK Department for international Development (DFID) and its "Sustainable Livelihood Approach (SLA)"). Morrow (1999) describes a community-based approach to analysing the vulnerability of a community. The "Sustainable Livelihood Approach (SLA)", which is often used for vulnerability analysis at household level, is described in detail in appendix 2, available from the sector project "Disaster Risk Management" (GTZ). A common feature of all approaches is that they assume that vulnerabilities differ depending on the type of hazard and change over the course of the day, season and year.

7.2 Hazard and vulnerability analysis, using the example of flooding

After identifying flooding as the relevant type of hazard and direct physical hazard from the point of view of the local population, the following questions are used to continue and deepen the analysis. To identify the direct physical hazard and resulting consequences, analysis using impact chains or grids has proved useful.

The **direct physical hazard** is the hazard within the impact chain which the affected population group perceive as such. In the present example, this is flooding rather than the torrential rains. If the project working area covers an entire water catchment area, it is necessary to distinguish the direct physical hazard to upstream and downstream populations. For the former, the problem may not be flooding, but landslides and erosion caused by the torrential rains. Impact chain analysis is also helpful in identifying the causes and the impacts on the relevant basis of life of the direct physical hazard. The impact chain can be drawn up and analysed for each relevant area of the basis for life, if detailed exploration of possible hazard manifestations is required. The literature includes the following areas in the *basis of life:* basic infrastructure (energy/electricity, water/waste water disposal, roads/bridges, communications), settlements and buildings, and – depending on the context – agriculture/fisheries and/or trade crafts and industry, health. The social and political institutional sector and the environmental sector also form part of this, although they have received little attention in the literature.

Figure 13: **Impact chain to identify the direct physical hazard and its causes and impacts**



Key questions

The following sections explain and explore the individual steps in risk analysis by means of key questions. The questions are used to present the instruments to be used, and in some cases to illustrate their use with the help of examples. The abbreviations stand for hazard analysis (HA), vulnerability analysis (VA) and risk analysis (RA). HA 1 means step 1 in hazard analysis, VA 1 means step 1 in vulnerability analysis, and so on.

HA1 HA1 = step 1 in hazard analysis;

VA1 VA1 = step 1 in vulnerability analysis;

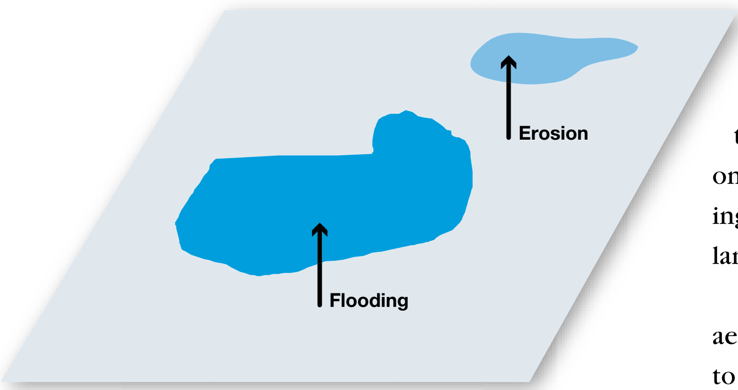
RA1 RA1 = step 1 in risk analysis (HA x VA = RA)

HA1 Which locations and areas are threatened by flooding?

(spatial analysis)

To identify the areas potentially affected (i.e. the locations threatened), records and registers are analysed, where available. These are supplemented by analysis of aerial and satellite images and surveys among the population affected. In the case of very extensive flooding areas (e.g. Mozambique), the hazard prone areas are documented using satellite images (Landsat TM). The collected data is entered manually or using GIS on topographical maps to a scale of 1:20,000 to 1:100,000 or larger.

Figure 14: **Mapping threatened locations**



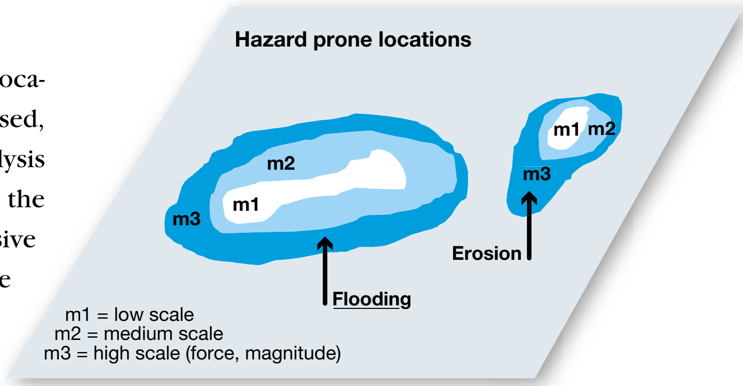
Where are the areas which are potentially threatened?

This map of the locations potentially at risk is the basis for the further steps in the analysis, which look at the characteristics of the threatened areas and their environment, and at the factors affecting and determining the scale (force) of the flooding (hazard factors). Detailed knowledge and analysis of the hazard factors affecting the hazard type "flooding" (precipitation, current land use, soil infiltration capacity, as derived from soil type and ground cover, slope, shape of the water catchment area) is needed to estimate the force (scale, magnitude) and probability of occurrence of the expected flooding, along with trends and tendencies.

Once the various scales of flooding are known, a location map might look like this:

Figure 15: **Example of a map of hazard locations with different scales m1 – m3**

(1:20,000 – 1:100,000, using a digitised basic map)



Depending on the hazard type, more or less intensive use is made of satellite and aerial images as a data source together with GIS as an analytical instrument.

The satellite images most frequently used to analyse flooding are Spot XS, Spot PAN, Landsat TM and Radar. The aerial images are obtained for various years as required, particularly if it is a question of determining the frequency of flooding, mostly on a scale of 1:15,000 to 1:30,000 (for small-scale flooding), and possibly supplemented with NASA and/or landscape photos.

For **participative analysis** with village populations, aerial images are particularly suitable, as they are easier to interpret than maps, the realism of the objects provides a high degree of recognition and accuracy, and requires less ability and experience with abstraction. The aerial photos have proved particularly useful in participative analysis of cause-impact relationships. If specific types of territory, vegetation characteristics or traces of past natural events (landslides, flooding, erosion) are identifiable in the aerial image, this makes possible systematic mapping of hazard areas (hazard maps). Joint interpretation of an aerial image is a useful means of communication for localising the various natural hazards jointly with the village population, and reconstructing their history and past disasters with the extent of resulting damage. A comparison with hazard maps drawn by the analysts themselves can prove particularly interesting. The differences can make clear where the local population's perception (of risk) diverges from reality.

Identification of hazards and vulnerable elements together with the local population
In the project "Disaster reduction and food security in San Pedro, Bolivia" the basis of life vulnerable to erosion, landslides, drought, and hail and frost was jointly identified and analysed with the local population using enlarged aerial images. In the process the enlarged aerial image was covered with transparent film and the vulnerable elements and hazards were drawn in on the film with a felt-tip pen. Another aid in this analysis was the pictures drawn by the village inhabitants showing hazards and vulnerable elements, which were put up on pinboards.

The use of technical aids in spatial analysis and mapping the results of analysis depends on the context and size of the area at risk and the expected damage. Sophisticated technologies are not always necessary. In simple hazard scenarios with relatively little anticipated damage, spatial analysis can be done using drawings and maps made by local inhabitants and put up on pinboards, or representations of the landscape scratched into the ground.

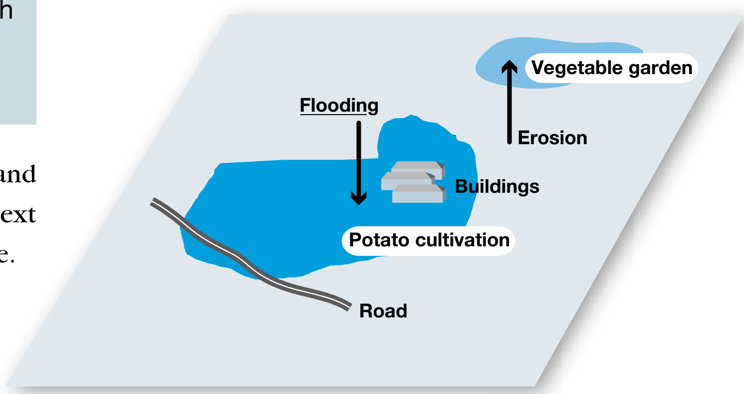
A detailed description of the use of remote sensing and GIS in risk analysis is given in appendix 1 to these guidelines.

VA1 Are there vulnerable people and bases of life? Who and what is affected and threatened? Which are the important bases of life? What is produced? What does the local population make its living from?

To identify the elements (i.e. people and their bases of life) vulnerable to flooding, maps and settlement plans (where available) are analysed and/or aerial and satellite images are reviewed and analysed and supplemented through surveys or using participative workshops with the affected population. As described above, aerial images have proved their value as a basis for identifying the threatened elements. Local knowledge generally provides sufficient information about what the local population is vulnerable to.

It is important to establish in this analysis which elements and activities constitute the basis of life – is it agriculture, craft trades, or jobs in manufacturing industry or mining? What role do markets and roads and bridges play for access to markets and communications? What role does the drinking water supply and waste water disposal system play? The collected data is entered manually or using GIS on topographical maps to a scale of 1:20,000 to 1:100,000. In the present example (figure 16), the following elements were identified as vulnerable to flooding and erosion: potato cultivation, roads, buildings, vegetable garden

Figure 16: **Mapping hazard locations and vulnerable elements**



HA1

Scale and frequency?

When and how often are future floods to be expected? Seasons? Cycles? Frequency? With what intensity and duration (= scale, force)? Past damage? *(Temporal and dimensional analysis)*

Here we are looking for answers to these questions – how high will the water rise at the threatened locations? When and how often is there flooding? What factors affect the flooding and its frequency and scale?

The **scale** of flooding is a combination of intensity and duration, where the intensity is the measure of water speed and volume. The **scale** (force) of the flooding is derived from past events (e.g. flooded area in km?, volume in m? and depth of water in m) and from analysis of the hazard factors (e.g. expected precipitation) or calculated and predicted using models, modelling and simulation.

Identification and analysis of the hazard factors to determine scale (force, magnitude)

What factors affect flooding? To estimate the **scale** it is necessary to investigate the factors (hazard factors, local characteristics) which affect extreme natural events. In the case of flooding, these are:

... Hazard factors:

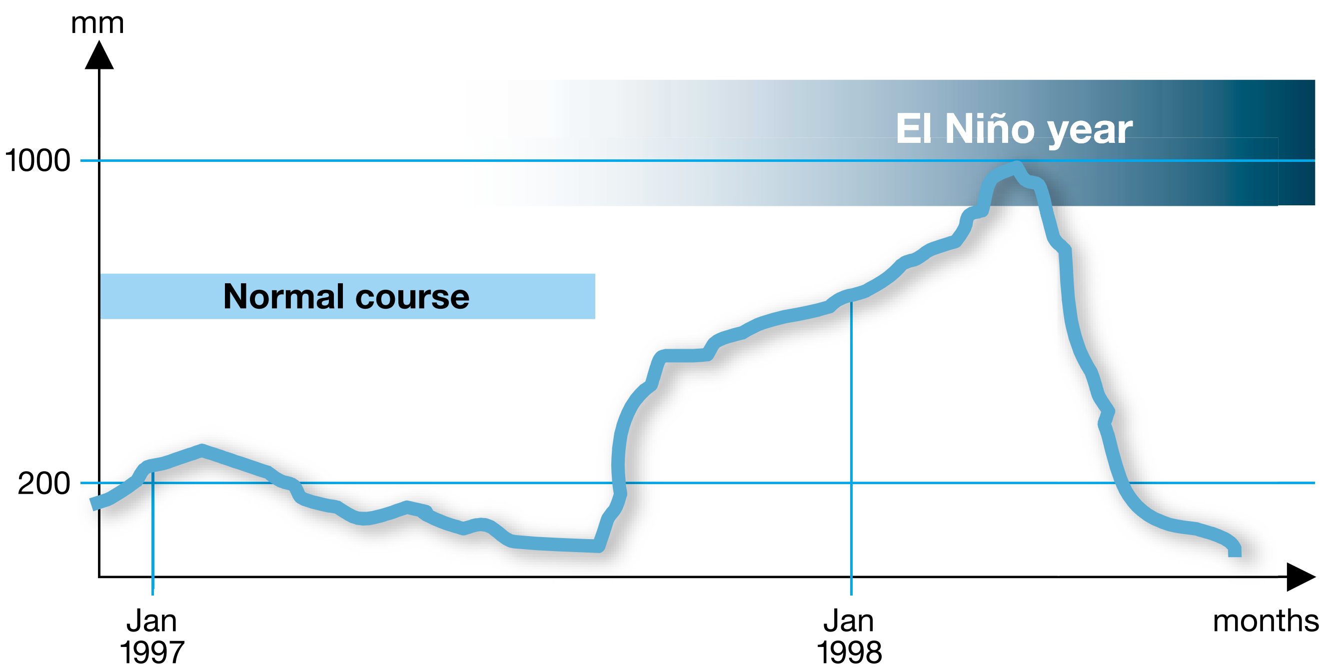
1) Precipitation (temporal and spatial, ENSO);
2) Shape and size of the water catchment area (including slopes);
3) Soil type;
4) Ground cover (including land use);

Precipitation is a factor affecting flooding which is not amenable to human influence. Its contribution to flooding depends on its spatial and temporal distribution and the total volume of rainfall. In many regions in the world which are affected by flooding, the phenomenon El Niño/La Niña (ENSO)[15] is an important factor which has more or less influence on rain and flooding, depending on the region.

Among the *characteristics of a river catchment area* the slope and length of incline play an important role in flooding, together with the shape and size of the catchment area. The steeper and longer the slope, the greater the speed of the surface water runoff will be, as the rain will have little time to seep into the soil. The rate of seepage of the water into the soil also depends on the infiltration characteristics and storage capacity of the soil (soil type). Finally, the speed and volume of surface water runoff depends not only on the three factors cited above, but also on the type and extent of ground cover.

[15] For an explanation of ENSO (= El Niño Southern Oscillation) see appendix 3, available from disaster-reduction@gtz.de

Figure 17: **Changes in precipitation during El Niño (Milagro – coast of Ecuador)**



This consists of plants, harvest residues or geological structures or possibly buildings.

To **identify the scale of flooding** it is necessary to establish indicators which can be used to quantify and evaluate the hazard. In analysing precipitation as a hazard factor, both the temporal and spatial distribution and total volume per unit of time must be taken into account and determined.

Hazard factors	Hazard indicators
1) Precipitation	1.1 Spatial and temporal distribution of precipitation 1.2 Volume of precipitation
2) Water catchment area	2.1 Slope inclination 2.2 Shape and size of water catchment area
3) Soil type	3.1 Soil infiltration characteristics 3.2 Soil absorption capability
4) Ground cover	4.1 Type of ground cover (plants, other) 4.2 Percentage share of ground cover

This makes it possible to derive or reconstruct the probability of occurrence to a certain extent, even where historical data is lacking (e.g. through analysis of precipitation data).

Apart from studies of flooding, the same hazard factors are particularly important in the hazard types of erosion, landslides and frost. They may be supplemented by additional factors, for example geology in the case of landslides.

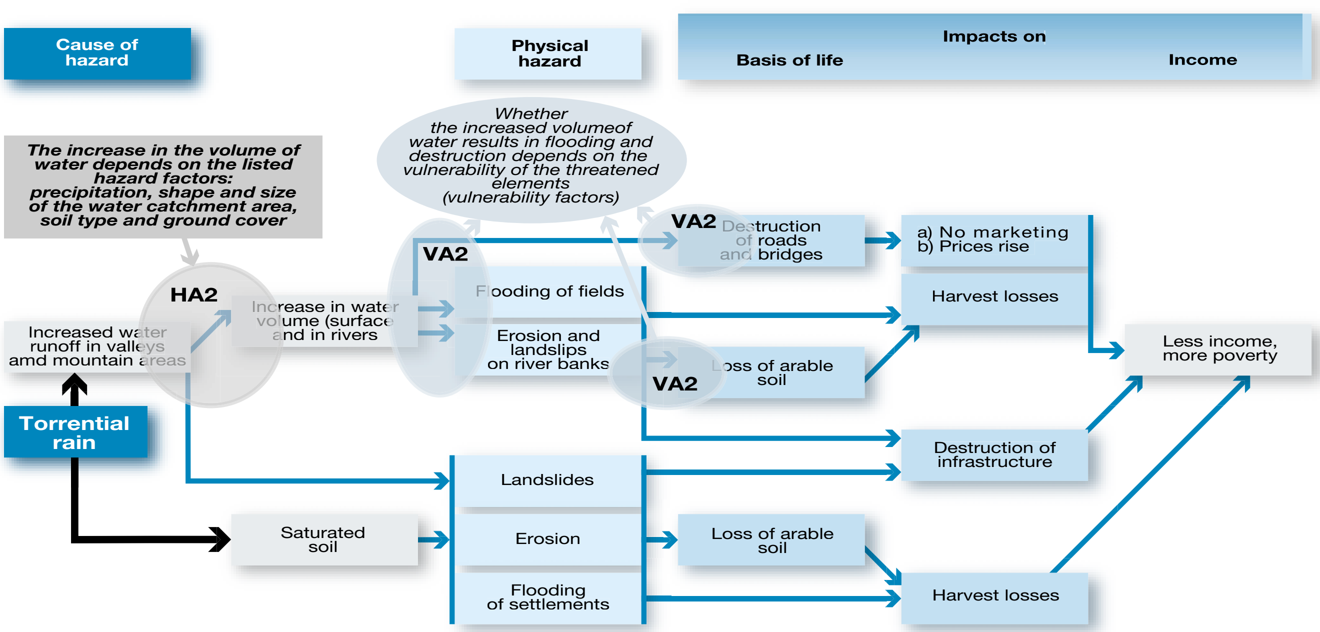
In estimating the hazard of flooding and drought, it is also necessary to investigate what role (if any) global climatic change and the El Niño/La Niña (ENSO) phenomenon play in the affected locations.

To present precipitation and its temporal distribution (of particular interest to populations with agricultural focus) and to determine the water budget for a region, the "water balance" diagrams[16] (figure 25) shown on page 43 under key question AA2 can be used to visualise periods of water surplus and water deficit. This requires data on precipitation, temperature and evaporation.

In studying the hazard factors and their effects on the scale of flooding, the influence of the local population must also be taken into account. This is particularly true of the hazard factor of ground cover, which is

[16] Based on Walter's climate diagrams.

Figure 18: **Dependence of the scale of flooding and damage on hazard and vulnerability factors**



affected by logging and agricultural use. Soil type and slope (e.g. terraces) can also be influenced by humans. In many places, these depend on agricultural practices. Overall, the vulnerability of regions and populations to extreme natural events such as flooding, storms and landslides is considerably increased by destruction and degradation of natural resources (logging, overgrazing, erosion, loss of biodiversity, etc). In the literature hazard and vulnerability factors are often consolidated and shown as risk factors. Location is treated as a typical **risk factor**, as this is where hazard and vulnerability come together.

In (participative) analysis of the effect of hazard and vulnerability factors on the scale of flooding and the damage done, the following impact diagram is helpful, as the key questions in the analytical process can be assigned to the relevant location.

Detailed knowledge and analysis of the hazard factors is necessary for estimating the various scales of flooding or simulating it with the help of digital topographical models. Figures 15 and 21 show how the various scales of flooding can be shown on maps.

Each scale or force category has an associated probability of occurrence p. This shows the frequency.

When and how often? – estimating the probability of occurrence

In estimating the **probability of occurrence** the most important sources of information apart from the precipitation data are the registers (records, recollections, maps etc) documenting the history of extreme events. These are the natural events and disasters that have already happened. The historical data can be used to infer and model future events. To assess and quantify the probability of occurrence of flooding on a specific scale, information on the number and force of past floods is essential. A fundamental part of this is analysis of the precipitation data.

The literature frequently talks of **cycles of recurrence** or intervals of recurrence (intervalo de recurrencia) between natural events, in order to show the **frequency** showing the average time between events. This is an important statistical concept for quantifying the probability of occurrence of natural events.

Analysing the hazard and estimating the probability of its occurrence means predicting the natural event. We distinguish here between short-term (between several minutes and several days), medium-term and long-term forecasts. For short-term forecasts in particular, it is useful to study the traditional systems of the local population, as they often have (bio)indicators based on observations which often go back for centuries. Medium-term and long-term forecasts are mainly based on information from the historical records.

Extensive and detailed hazard analyses are normally carried out by technical and scientific institutions in specialisations such as geology, hydrometeorology and the like. The results range from detailed analysis to general estimates, from elaborate technical studies to simple **hazard maps**. The latter include zones showing homogeneous areas and areas with the various hazard classes (1:2,000 to 1:50,000). For floods, the threatened zones (recurrence cycles of 50, 100 and 500 years) are shown, for landslides, volcanoes and earthquakes, the maps not only show the hazard prone locations but also the level of susceptibility/vulnerability (susceptibilidad) in terms of high, medium and low. These maps are an essential basis for spatial planning and planning protective measures.

Depending on the requirements, hazard maps are produced on a scale from 1:2,000 to at most 1:50,000. hergestellt.

Traditional forecasting systems[17]

- A particular species of bird nests in the reeds of Lake Titicaca (Peru, Bolivia) at a higher level in years of expected flooding than in years of "normal" precipitation. This observation helps the local population to predict floods.
- Developing hurricanes in Mozambique are spotted by farmers in the interior of the country hours and days before arrival because a certain species of spider angles its web towards the coast.

[17] A detailed study of traditional forecasting systems with corresponding indicators was carried out as part of a masters thesis by Frederik Pischke at the start of 2003 in the project in San Pedro, Bolivia. "Traditional risk prediction and prevention strategies in the San Pedro catchment area, Potosi – Bolivia", thesis by Frederik Pischke, Brandenburg Technical University Cottbus, July 2003.

HA3 How can the assessment of hazards be visualised?

Hazard maps and assessment tables are important instruments for presenting the results of hazard analysis.

Hazard assessment is expressed as an assessment of the probability of occurrence. This can be on a scale between 0 and 1, 1 and 100 or some other range. A figure of 0 would mean it is very unlikely that a natural event such as an earthquake of a given intensity will occur at a specific place, a figure of 1 that it is absolutely certain. The probability of occurrence is shown as a function of force (scale), i.e. based on the three different scales for floods, the probability of occurrence is defined for each of the three.

In the following pages, a number of diagrams and tables are shown to illustrate the wide range of possibilities for presenting hazard assessments.

A flood assessment can be shown as follows:

m = scale, force, magnitude
i = value of scale (1, 2 or 3)
p = probability of occurrence
mi indicates the probability of occurrence showing the scale of flooding with the corresponding value (magnitude, force):

Example of determining the scale of flooding

scale	low 1	medium 2	high 3
water speed	x	xx	xxx
volume, level	y	yy	yyy
duration (week)	1	2	3
magnitude/ force (i)	m1	m2	m3

If the analysis concludes that it is *very likely* (p = high = 3) that a flood will occur in the next 10 years, this is expressed as follows on an annual basis: there is a 10% probability of a flood in one year. In this case the cycle of recurrence is 10 years. If the cycle of recurrence is 100 years, this means that there is a 1% probability that a flood will occur in a year, and the probability of occurrence in the next 10 years is low.

Probability of occurrence of floods of scales (magnitudes) m1, m2 or m3

Based on experience that floods have different scales (force, magnitude) with different cycles of recurrence, and that we are assuming three different scales here, the probability of occurrence can be shown as follows for each of the three individual scales (m1, m2, m3).

Example of presentation of three different probabilities of occurrence

magnitude, scale (m)	probability of occurrence p(m)	example
m1 (= low)	p(m1) = 3 (high)	> 33 %
m2 (= medium)	p(m2) = 2 (medium)	5–33 %
m3 (= high)	p(m3) = 1 (low)	< 5 %

Transferred to a coloured chart, the table looks like this:

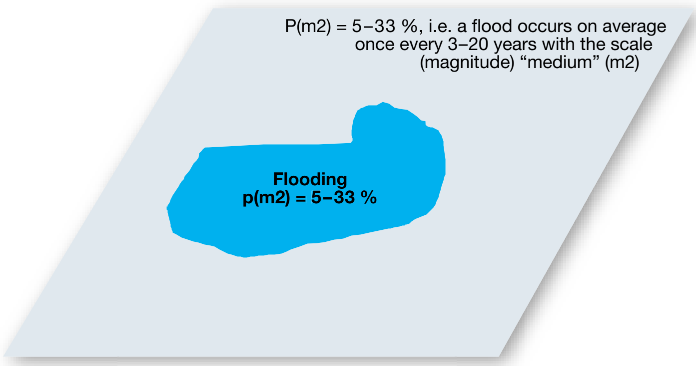
Figure 19: **Probability of occurrence (p) for different scales (m1–m3)**

SCALE (m)	
high m3	**(p) = low = (1) p(m3) = < 5 %**
medium m2	**(p) = medium = (2) p(m2) = 5–33 %**
low m1	**(p) = high = (3) p(m1) = > 33 %**

p(m1) = > 33 % (or:3) means that on average flooding on a minor scale will happen at least every 3 years.
mi = magnitude (force, scale): high = m3, medium = m2, low = m1
p(mi) = probability of the event in % per year: e.g. 33% = flooding every three years, 5% = flooding every 20 years.

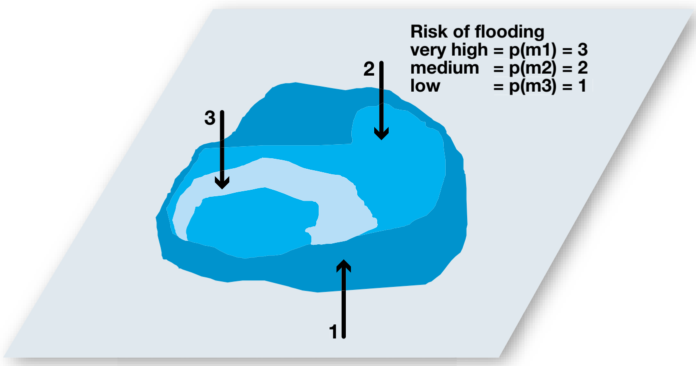
The colours in the chart show different hazard levels, which can be transferred to hazard maps.

Figure 20: **Hazard map with scale (m2) and associated probability of occurrence (p)**



The different scales of flooding (m1-m3) with the figures for the corresponding probabilities of occurrence can be shown on a map as follows:

Figure 21: **Hazard map with probability of occurrence (p) for three different scales (m1–m3)**



Depending on the requirements, hazard maps are produced on a scale from 1:2,000 to at most 1:50,000.

Other presentations for determining probability:

Probability	
rating	probability in 50 years
high	82 % – 100 %
medium	40 % – 82 %
low	0 – 40 %

Cycle of recurrence	
cycle of recurrence in years	rating
1 – 30	frequent
30 – 100	medium
100 – 300	rare

Resources for data

Depending on the methods used, more or less resources can be needed for data. For precise estimates, large volumes of data are required for all approaches. To carry out the analysis for the three categories referred to above **(temporal: when? how often?; dimensional: scale?, spatial: where?)** the following basic data is required: locations with local names and coordinates; scale and date of past floods; quantitative damage assessment: dead, injured, damage sufferers, destroyed or damaged buildings, damage to roads, bridges, agriculture, etc, length of damaged or disrupted road, oil/gas pipelines, water and electricity lines; area affected; qualitative damage assessment: social imbalances and disruptions, disruption of communications networks, cultural losses (schools, etc), interruption of water, energy, health services; isolated zones.

Resources and time

The process of hazard analysis can take between one and 12 months, depending on the size of the community, project area and nature and complexity of the hazards. However, the maps produced are also used in other steps (e.g. vulnerability analysis) and for other purposes. The time required depends critically on whether the maps are available in digital form and can be processed, or whether they need to be drawn manually for each update.

Scale and probability of occurrence can (as already noted above) also be calculated and predicted using models, modelling and simulations. Due to the high level of complexity of physical systems, modelling is only approximately possible. Precise modelling and reproduction is not possible due to the complexity of natural systems.

AA2 What impacts do the floods have on the vulnerable elements?

Vulnerability expresses the degree of possible loss or damage to an element threatened by a natural event of specific force. In this case the natural event is flooding, which is perceived as a direct physical hazard at local level. Often, perception of events differs depending on the extent to which people are affected, the degree of poverty, income and property, social role, etc. National disaster protection institutions in the capital perceive a local event differently to institutions at regional or departmental level, and these in turn differ from the local population directly affected by the event. Often, however, an extreme natural event is part of normal life for a local population which has become accustomed to it or perceives and explains it as an "act of god". An important step in vulnerability analysis is accordingly to investigate the different perceptions and the factors influencing these.

Vulnerability factors and indicators for determining vulnerability

Here the questions are, how much water will penetrate into the houses, and how much damage will it cause? How severely will the remaining infrastructure be damaged by the flood? How many fields will be flooded, how badly, and how much farming land and harvest will be lost? What consequences will the floods have for agriculture? For health? For the organisations of the population and institutions? For families living in poverty?

Following the logic of the impact scheme, the grey-edged area relating to the physical elements ("physical vulnerability") is investigated. Social factors, e.g. vulnerable institutions, are ignored at this point. All that matters at this point are the vulnerable physical elements (buildings, roads, bridges, farming land, basic infrastructure) and the impacts and degree of damage to these elements.

After identifying the vulnerable elements, the vulnerability factors are determined. Vulnerability factors are the factors which influence the vulnerability of a population group and their basis of life or result in vulnerability. They increase (or reduce) vulnerability to hazardous natural events. To evaluate vulnerability or

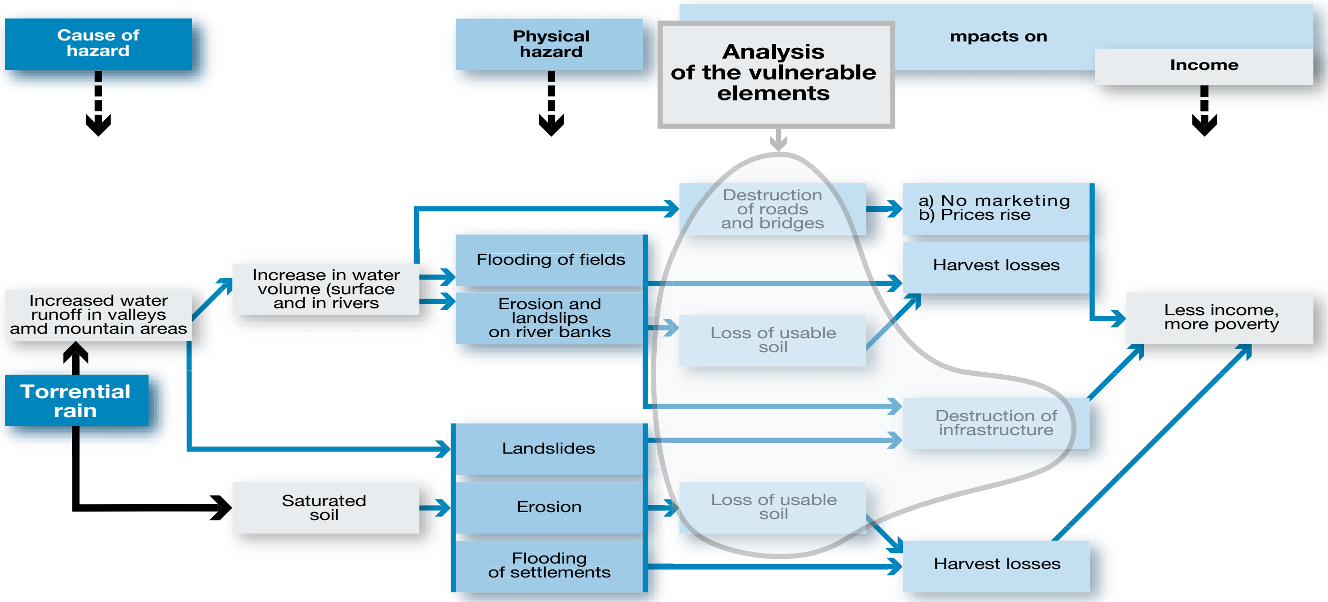
Models and simulations:

use of models and simulations in hazard assessment

Simulation of damage scenarios is becoming increasingly important in the practice of disaster reduction. The development of GIS has made it possible to process large volumes of data and superimpose various forms of data in a geographical framework. This in turn makes it possible to develop various models, primarily with the aim of protection against flooding. Well-known examples are the precipitation-runoff models like NAXOS and SWAT, and (for erosion) USLE, whose use is justified at key locations with great potential for damage, if sufficient data (e.g. digital topographical models) is available. These permit calculation of the scale and probability of damage from natural events such as flooding, silting and erosion.

When using models for flooding and silting, the transformation of the initiating event (torrential rain) into runoff is captured using hydrological models, permitting an assessment of the level of hazard. Such simulation models can calculate both the probability of occurrence and amount of damage. The necessary data is collected in surveys, studies, measurements and with the help of satellite and aerial images. Three of these simulation models (SWAT, NAXOS, USLE/MUSLE) and details of remote sensing and GIS are described and explained in detail in the appendices to these guidelines. SWAT and NAXOS are used (among other purposes) to predict flooding, while USLE/MUSLE is used mainly for simulating erosion.

Figure 22: **Study of the impacts on vulnerable elements**



estimate the relevant degree of vulnerability, it is necessary to define indicators. Indicators for determining vulnerability depend very strongly on the regional and national political, social and economic environments. This is why they have to be developed from scratch in each new project context. In addition, experience has shown that measuring and estimating vulnerability at different scales (local, regional national) involves different problems and challenges, so that the indicators can also differ depending on whether they are defined for the (local) micro, meso or macro level. In the present guidelines, the focus is on the local and meso levels.

The literature uses various classifications for vulnerability factors. The classification used here (see figure 23) is a modification of the one used by the UN and ISDR (source: "Living with risk", 2002, p. 47). Reproduction of this system used by the UN does not imply any evaluation or suggest that it is the only logical and useful classification. However, it is used by many authors, and modified to meet prevailing conditions. There are also many other possible classifications, but it is not the purpose of the present guidelines to evaluate these[18]. In every risk analysis, identification and classification of the vulnerability factors should be agreed on the basis of the specific circumstances, the goal and the constellation of problems in the region to be studied.

As in hazard analysis, vulnerability analysis also has complex interrelationships and some long impact chains with direct relevance to vulnerability to disaster. For example, there is a direct negative aspect in the form of increased erosion if growing fodder exports (e.g. soy) to Europe result in extensive clearing of the primeval forest in many of South America's river catchment areas, in order to use extractive and soil destroying methods of large scale production of fodder. Besides erosion, this also leads to landslides and/or steppe degradation, desertification and pesticide pollution.

Taking the example of flooding (figure 16, page 33), the "vulnerable elements" were identified as potato cultivation, buildings and roads, and these were supplemented in figure 24 by various other elements which reflect many typical situations in projects, and indicators were identified for "measuring" vulnerability.

The study of self-protection capabilities[19] ("coping strategies") is part of vulnerability analysis, and is expressed in the following indicators: building codes, stability of settlement and stable social structures, main-

[18] For example, Anne-Catherine Chardon, Manizales, Colombia, uses the following classification in her paper "Un enfoque geográfico de la vulnerabilidad en zonas urbanas expuestas a amenazas naturales" (pp. 77 et seq): natural factors (past experience, erosion, slope, intensity of the 1979 earthquake, artificial landfill e.g. former refuse dumps, flood areas, geotechnical protective structures), socioeconomic factors (population density, socioeconomic stratum etc).

[19] The literature distinguishes between a) coping strategies as short- to medium-term strategies for dealing with acute crises in concrete instances; b) adaptation strategies as long-term fundamental behavioural changes resulting from changes in the social, economic and ecological environments; c) risk-reducing strategies for reducing crisis risk, which represent a form of internal crisis prevention; d) seasonal coping strategies to overcome seasonal recurring food shortages (from: Report on the German Contribution for the World Vulnerability Report of the UNDP, by ZENEB and the AA, February 2002).

tenance of basic infrastructure, local knowledge of hazards, organisation and communication (emergency aid committees), land use planning, zoning, protective infrastructure, monitoring and early warning systems, disaster prevention plans, disaster protection plans and funds, traditional forecasting systems.

Taking agriculture as an example of a threatened area, the study of indicators for determining vulnerability poses the following questions:

a) *Type and diversity of seed:* Is the lack of sufficient seed due to lack of knowledge or lack of resources, organisation, services? How long is the growing period of the various crops? At what point in the growth cycle are floods to be expected? Are there varieties which ripen earlier, before the time of flooding? Or later? Is the seed resistant to moisture buildup?

b) *Type of cultivation:* Do the types of cultivation (rotation, mixed cultivation, monocultures, soil treatment practices, technology) promote vulnerability of agriculture to flooding?

c) *Diversity of sources of income:* Is the producer or affected local population dependent solely on agriculture, or do they have other sources of income? Which?

In analysing agriculture as the most important basis of life of a local population, it is useful to superimpose water balance diagrams and agricultural growing and

Figure 23: **Classification of vulnerability factors**

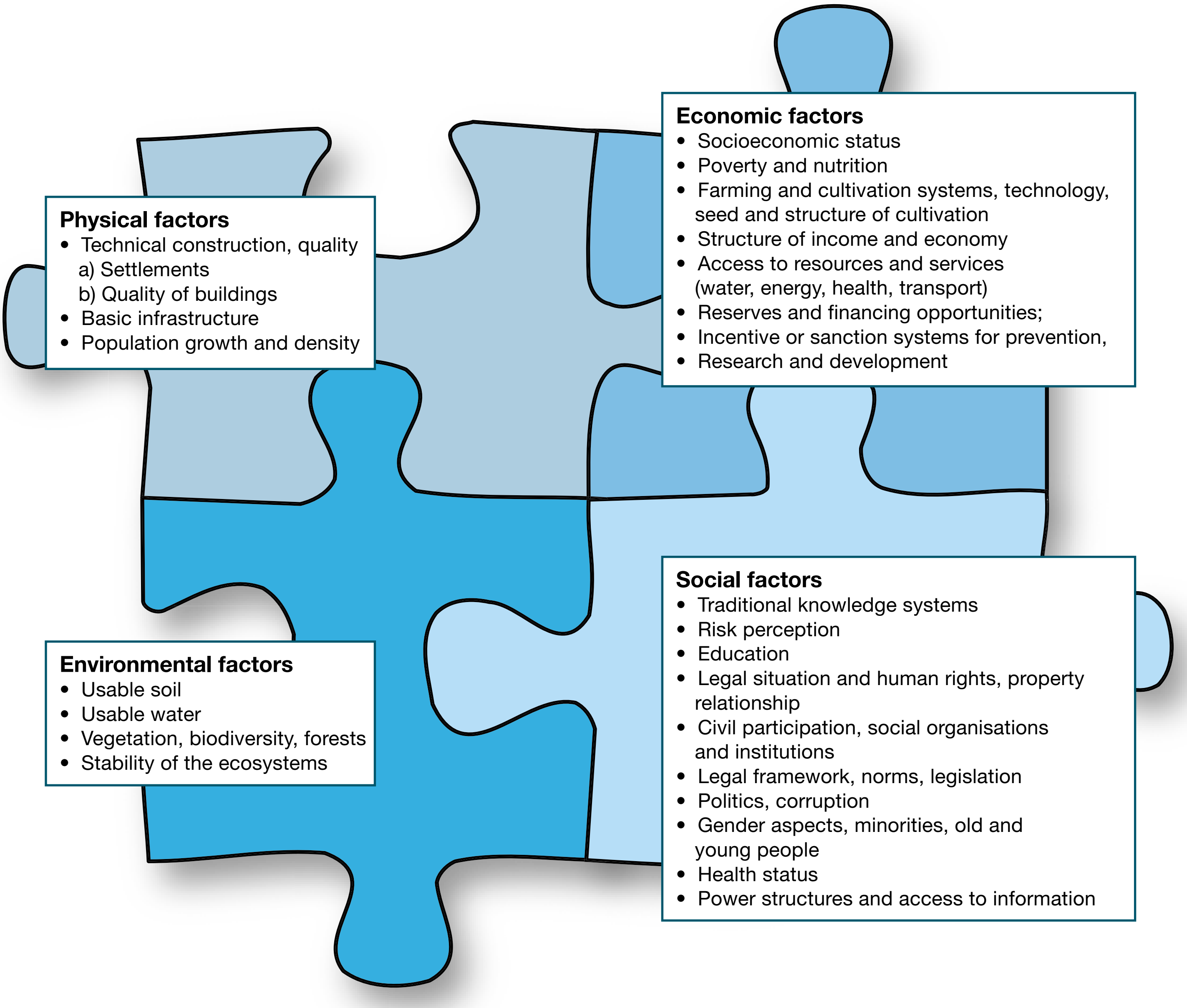


Figure 24: **Example of an indicator table for identifying vulnerabilities in DC projects**

Areas and elements at risk	Vulnerability factors	Indicators
	1) Economic vulnerability factors	
agricultural production	seed structure of cultivation ownership	type and diversity of seed diversity and technology of cultivation type of cultivation volume of agricultural production, % of income from agriculture unequal distribution of ownership income (amount, diversity)
	2) Physical vulnerability factors	
buildings settlements basic infrastructure	buildings settlement infrastructure energy, water, roads	quality and location of buildings (construction standards), spatial planning; access to water, energy, …
population	demographic factors	rising population growth, growing rural exodus, settlements near coast and rivers, population density
	3) Social factors	
population organisations institutions	education	length of schooling, absence rate literacy
	income access to information risk perception social and political organisations social and age structure social stability, peace, security power relationships, corruption decentralisation, citizen participation	% of population below poverty line early warning and prediction systems government disaster reduction protective and disaster reduction infrastructure spatial planning measures social disparities statutes on decentralisation and participation, % of national budget for local governments weakening of traditional security systems
health	nutrition, diseases hygiene	child mortality, % of population with access to water and health services;
	4) Environmental factors	
nature natural resources	vegetation soil water	level of ground cover and logging erosion, degradation, structure settlement and land use at risk locations; overuse

planting cycles. This applies to both flooding and drought as hazards.

Depending on water level and duration, floods have the greatest adverse impact on agriculture when they occur between sowing and harvesting, with the greatest damage shortly before harvesting. In the case of drought, moisture and availability of water have decisive importance primarily after sowing and during the growing period.

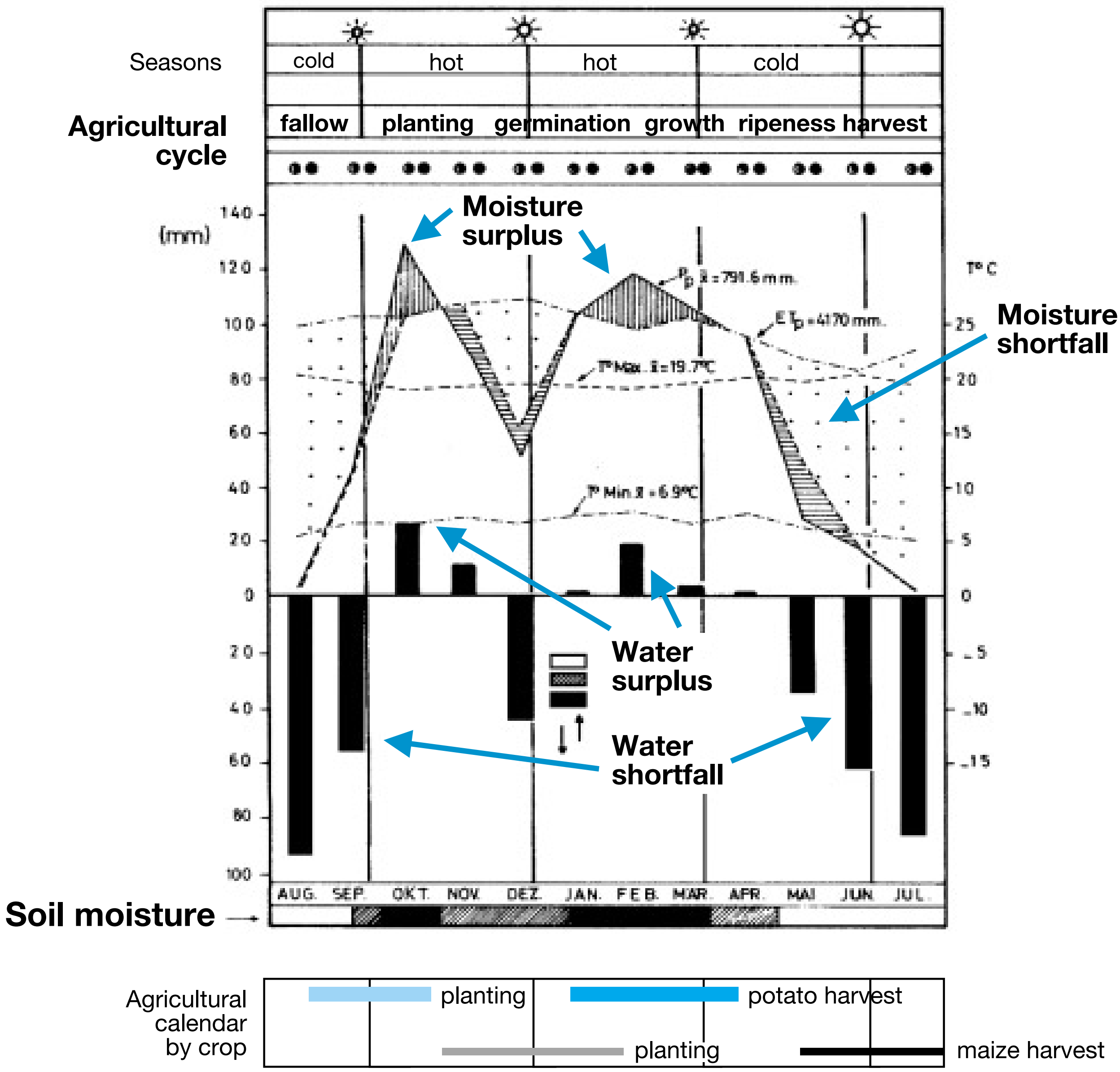
AA3 How are vulnerabilities assessed?

Besides methods for assessing physical vulnerability (i.e. quantifying the expected damage to buildings and infrastructure), there are many individual studies which have developed methods as needed, and which studied primarily the social area.

From "technical" to "social" vulnerability

It was not until very late that a start was made on recognising and accepting the role and importance of vulnerabilities in the occurrence of disasters. Initially, the emphasis was primarily on "physical vulnerability" (or "technical vulnerability"). These were understood as the level of vulnerability and exposure of a specific element. The involvement of sociological disciplines in the last few years has opened up study of other vulnerability factors, e.g. political, institutional, sociocultural,

Figure 25: **Water balance diagram with agricultural calendar** (example: Cajarmaca, Peru)



economic, etc. These are summarised under the heading of "social vulnerability". In contrast to physical vulnerability, social vulnerability can only be evaluated in qualitative and relative ways.

Many authors (O. D. Cardona, among others) regard social vulnerability in poor countries in particular as the cause of conditions under which technical vulnerabilities arise. In this process social vulnerability is closely linked to sociocultural and socioeconomic aspects (Maskrey, 1989). Other aspects which determine the degree of social vulnerability are the political factors (e.g. corruption) and institutional factors, for which there are still no standardised and generally recognised analytical instruments and rules; the same applies to sociocultural factors (e.g. risk perception).

Risk researchers assume that the number of natural events has not increased in recent decades, and that the growth in damage from natural events is due to growing vulnerability[20]. According to this theory, it is primarily the social factors such as population growth, urbanisation, logging, overuse and destruction of natural resources, climatic change due to the greenhouse effect, wars and conflicts, etc which are responsible for the growth in disasters in recent decades.

Methods for quantifying expected damage to buildings and infrastructure (physical vulnerability)

The flooding includes features which are decisive for flood damage – water level, duration, peak runoff, time of occurrence and advance warning period. The most important indicator of damage is the flood level and associated flood area. This reduces damage calculation to a single variable – water runoff – and the resulting water level. Both can change significantly as a result of changes in land use, sealing in the catchment area, and river straightening.

Flood damage can be determined on the basis of past events and allocated by damage category to damage to buildings, equipment and machinery, stocks, animals, agricultural yield and infrastructure.

Which features determine the level of damage (d) for flooding (see figure 26, page 45)?

For ethical reasons, personal injury is generally not quantified in monetary terms, but left as the number of human lives.

[20] Blaikie, P., T. Cannon, I. Davis and Ben Wisner (1994): "At Risk – natural hazards, people's vulnerability, and disasters". Routledge, pp. 57 et seq.

Example of the three elements at risk (from figure 16, p. 33): which indicators can be used to determine or estimate the level of vulnerability?

The following comments apply to the example of three physical elements and their vulnerability to flooding: buildings, roads and potato cultivation. The examples were selected as typical for DC, but do not claim to be either representative or complete. Besides other important physical elements, this presentation primarily ignores people and their knowledge and skills, organisations and institutions – i.e. the social factors. While these social factors play a role of fundamental importance in vulnerability analysis, they are not considered further at this point.

>>> with Buildings (floods): The criteria of quality, location and maintenance can be used to assess and measure the degree of vulnerability of a building.

Here, the quality of construction of the **building** is investigated and evaluated in terms of flooding. The level and duration of flooding and flow rate are taken into account. Possible indicators of construction quality include materials, wall thickness and height, foundation depth, maintenance, etc. Possible location indicators are: Is the building in a depression or elevated? What is the substructure?

The results for buildings:
construction quality excellent
>>> low vulnerability >>> rating 1;
location and maintenance excellent
average construction quality
>>> average vulnerability >>> rating 2;
average location and maintenance
poor construction quality
>>> high vulnerability >>> rating 3;
poor location and maintenance

Next, the value of the building (V) is estimated, e.g. V = € 100,000. Finally, the expected scale of the damage ((d)mi) is determined, i.e. the amount of the losses if the expected hazard (flood) impacts the element of buildings with force mi. The stated value of and degree of damage to a building and the possible damage can vary widely depending on sociocultural context, and whether the building has a solely residential function or also serves as a store for products or supplies. If poor groups in poor regions e.g. in Bolivia are affected, the

Figure 26: **Features influencing the level of damage**

Features:	**Flood heigh**	**Flood duration**	**Time of occurence – summer, winter**	**Flow speed**	**Advance warning**
Physical elements					
Buildings	•	•		•	
Machinery, equipment	•	•		•	•
Stocks	•	•			•
Livestock	•				•
Harvest	•	•	•		
Infrastructure	•	•		•	

loss of or damage to a family's home can – under certain circumstances – have much more devastating impact than in the case of a family affected in Switzerland, although in the latter case the financial damage may be much greater.

>>> with Roads (floods): The criteria of quality, location and slope of the road and maintenance can be used to assess and measure the degree of vulnerability of a road.

To determine the possible damage caused by disrupting a road, the question that has to be answered is, what is the loss of income for a family, a village or a region if the road or bridge is disrupted which makes possible marketing and purchasing of supplies and food? The amount of damage depends (among other factors) on how far the income of the affected population depends on marketing its products.

>>> with Potato cultivation and vegetable garden (floods and erosion): The vulnerability of potato cultivation to a specific flood is determined using regional coefficients (hazard factors) for slope inclination, soil type, precipitation and land use on neighbouring fields. Soil cultivation, infiltration capacity, soil moisture and diversity of cultivation and seed, the type of cultivation, resistance of potatoes to moisture buildup etc play an enormous role in evaluating vulnerability.

As already noted above, the social aspects of vulnerability are not explored further here; they are very often investigated with the help of the "Sustainable Livelihood Approach (SLA)". The SLA is an instrument tested at

Figure 27: **Example of an assessment table for the scale of flood damage to buildings for various levels of vulnerability**

Level of vulnerability	**Description of expected damage**	**Expected scale of damage (d)mi in EURO** (building value € 100,000)
Vulnerability high = 3	Buildings are seriously threatened, heavy damage to be expected inside buildings as well, up to total destruction.	€ 80,000
Vulnerability medium = 2	Building exteriors threatened but not interiors; damage to buildings possible.	€ 50,000
Vulnerability low = 1	Minimal threat to buildings, exterior and interior; slight damage to buildings possible.	€ 20,000

household level, which accordingly has only limited application for larger regions. Further information on the SLA is available in appendix 2.

Evaluation and presentation of vulnerability (physical in this case) in DC practice are illustrated using Guatemala as an example (figure 28, page 47).

RA1 How can risks be assessed and presented?

Risk, as the product of hazard and vulnerability (R = H x V), is interpreted as the probability of occurrence of damage to an element as a result of an extreme event with specific intensity. Estimating and presenting the risk as part of risk analysis can be approached from various angles.

- *Relative risk estimate:* A comparative and relative estimate of the hazard with probability of occurrence (without scaling the force), together with a relative estimate of the physical and social vulnerabilities.
- *Zoning hazards:* Presentation of critical locations makes it possible to map the risk areas for various ranges. Land use should be modified here. This leads to use categories such as no use, protected areas, ecological or cultural reserves, etc. The uses shown in this way are agreed and legalised by all those involved.
- *Assessment tables and risk assessment matrix.* The hazard with probability of occurrence and quantitative assessment of scale based on a 1-3 ranking is combined with the estimate of physical vulnerability, also ranked on a scale of 1-3 (high, medium, low) and indicators (figure 29). The analysis is supplemented by further studies on social vulnerability.
- *Risk map:* Risk is mapped on a risk map showing the risk locations (areas), hazards with their various scales, and the vulnerable elements. The level of hazard is correlated with the vulnerable elements (buildings, settlements, basic infrastructure and economic activities). This yields hazard maps with information on the level of physical vulnerability and information on relative risk (risk maps). Further studies on relevant components of social vulnerability complete the risk analysis (figure 30).

The expected scale of damage (d)mi is described in the literature as specific vulnerability.
V = value of the elements exposed to the hazard mi.
d(mi) = specific vulnerability, or the proportion of the value of the loss on occurrence of the hazard with force mi.
i = the scale or force,
In this way, risk can be defined as:
Ri = p(mi) x d(mi) in $/year

The risk map showing the results of both hazard and vulnerability analysis is regarded as the most important tool in risk analysis. Strictly speaking, however, these risk maps are actually hazard maps which are superimposed on maps of physical aspects of vulnerability. As such, they mostly show only part of the aspects responsible for risk, as certain aspects of vulnerability are difficult or impossible to show spatially. Social factors are mostly added in descriptive form.

How is risk assessed?

Risk is expressed as the average probability of occurrence of expected damage for each hazard type and scale. Annual recurrence intervals are used in the presentation.

probability of occurrence (p) x expected damage (d) = risk (R) >>> R = (p) x (d)

If the various levels of hazard and vulnerability are taken into account, the risk assessment can be summarised in the following formula:
Ri = p(mi) x d(mi) in $/year

Expected damage, i.e. the expected value of the damage from flooding, corresponds to average damage over a long period. The value of expected damage (d) in euro per km? or building or some other unit for the vulnerable element is shown as potential damage with probability of occurrence. The level of damage is weighted by the associated probability of occurrence.

The level of damage (d) and probability of occurrence (p) can be summarised and combined in a risk assessment matrix. The various colours in the matrix with their corresponding numbers (1-9) show the

Vulnerability assessment – example:
El Cerrito, Guatemala

CONRED developed a method for evaluating the vulnerability of an urban settlement to landslides. Conceptually, this is based on individual households rather than village level.

Surveys determine vulnerability, using the following indicators:

a) structural aspects of the house:

- materials for floor, foundation, walls and roofs;
- level of access to water and electricity supply;

b) economic factors

- sources of income (number);
- job;
- savings and property;

c) social factors:

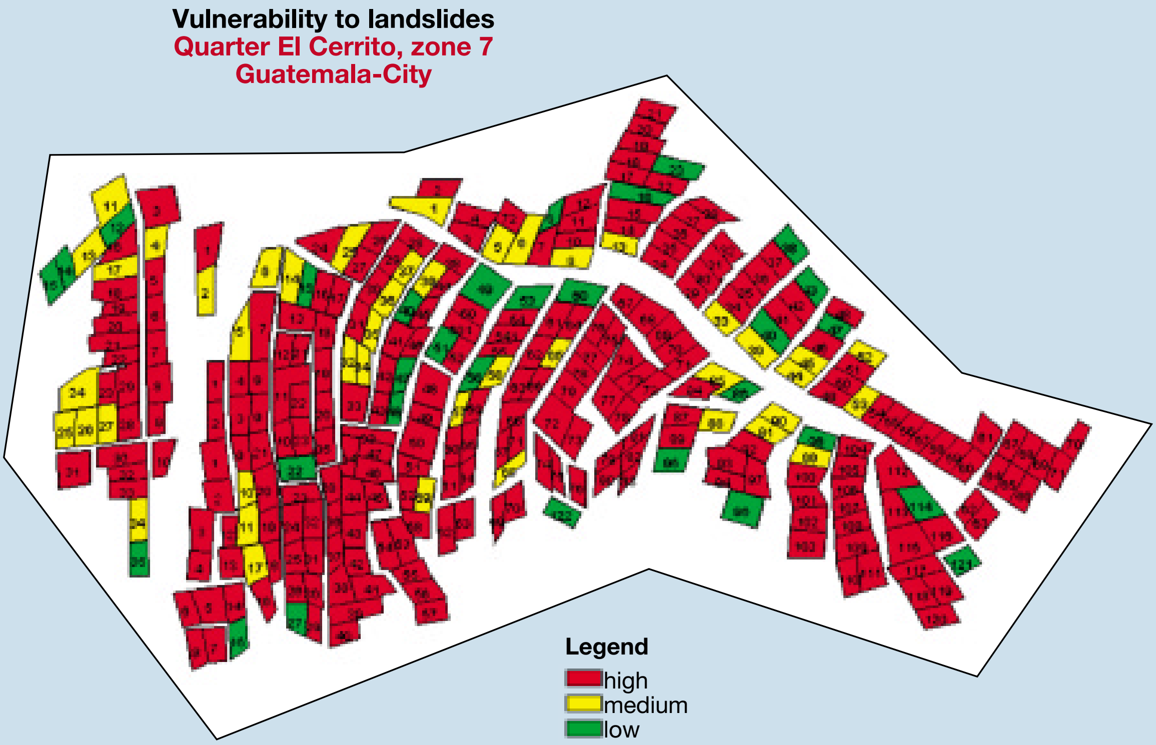
- age structure and household members;

d) at community level:

- community infrastructure: roads, water and electricity.

The map shows the results of the vulnerability analysis, with each household marked in colour according to its vulnerability to landslides (high, medium, low).

Figure 28: **Map of vulnerability to landslides at household level** (source: CONRED)



source: J.C. Villagran, 2001

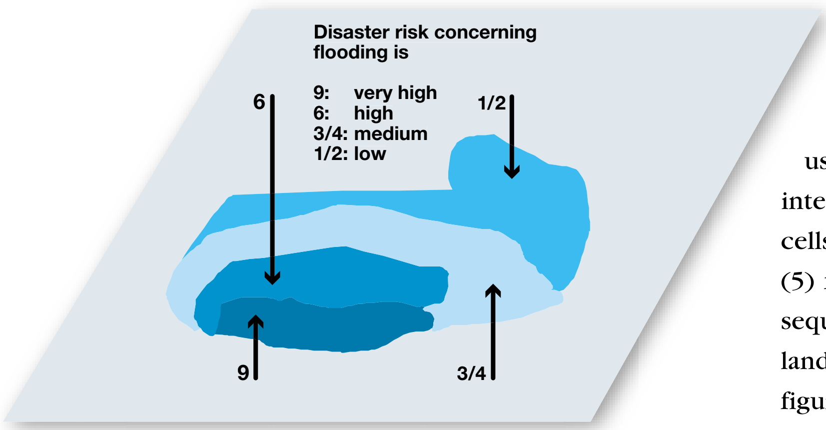
Figure 29: **Combination of scale of damage (d) and probability of occurrence (p) = risk**

SCALE OF DAMAGE (S)			
high	s3*p1 = 3	s2*p3 = 6	s3*p3 = 9
medium	s2*p1 = 2	s2*p2 = 4	s2*p3 = 6
low	s1*p1 = 1	s1*p2 = 2	s1*p3 = 3
	low	medium	high
	PROBABILITY OF OCCURRENCE (P)		

different risk values, which can be transferred to risk maps.

The combination of damage scales for flooding with the figures for the corresponding probabilities of occurrence shown in this risk assessment matrix can be shown as follows on a risk map:

Figure 30: **Risk map: combination of probability of occurrence (p) and scale of damage (d)**



Depending on the requirement, hazard maps are produced on a scale from 1:2,000 to at most 1:50,000.

In calculating or determining the overall risk, all the elements at risk (e.g. population, property, infrastructure, economic activities, etc) are taken into account with their specific vulnerability.

The literature and reports from the various projects show a large number of variants for assessing and presenting natural risks. Several of these are shown below.

Following the risk assessment concept presented above, a method for evaluating risks (using landslides as an example) was developed in 2003 as part of the project "Disaster reduction and food security in the San Pedro water catchment area" in Bolivia. This is particularly suitable for locations where the basic data is weak and finances limited. In this "method of assigning relative values", various factors are selected and partially aggregated, as shown in the following table (figure 32).

Each of these factors is given a value, incorporating in grid form the information on slope, land use and instability obtained from digitising photo interpretation. The assigned values are allocated to the cells in the grids and the various levels of information (5) for the hazard factors are aggregated in order subsequently to aggregate the result for the probability of landslides with the physical vulnerability. The resulting figure shows the risk (figure 33).

Figure 31: **Risk maps for zones in Piura, Peru, affected by the "El Niño" phenomenon in 1997–1998**

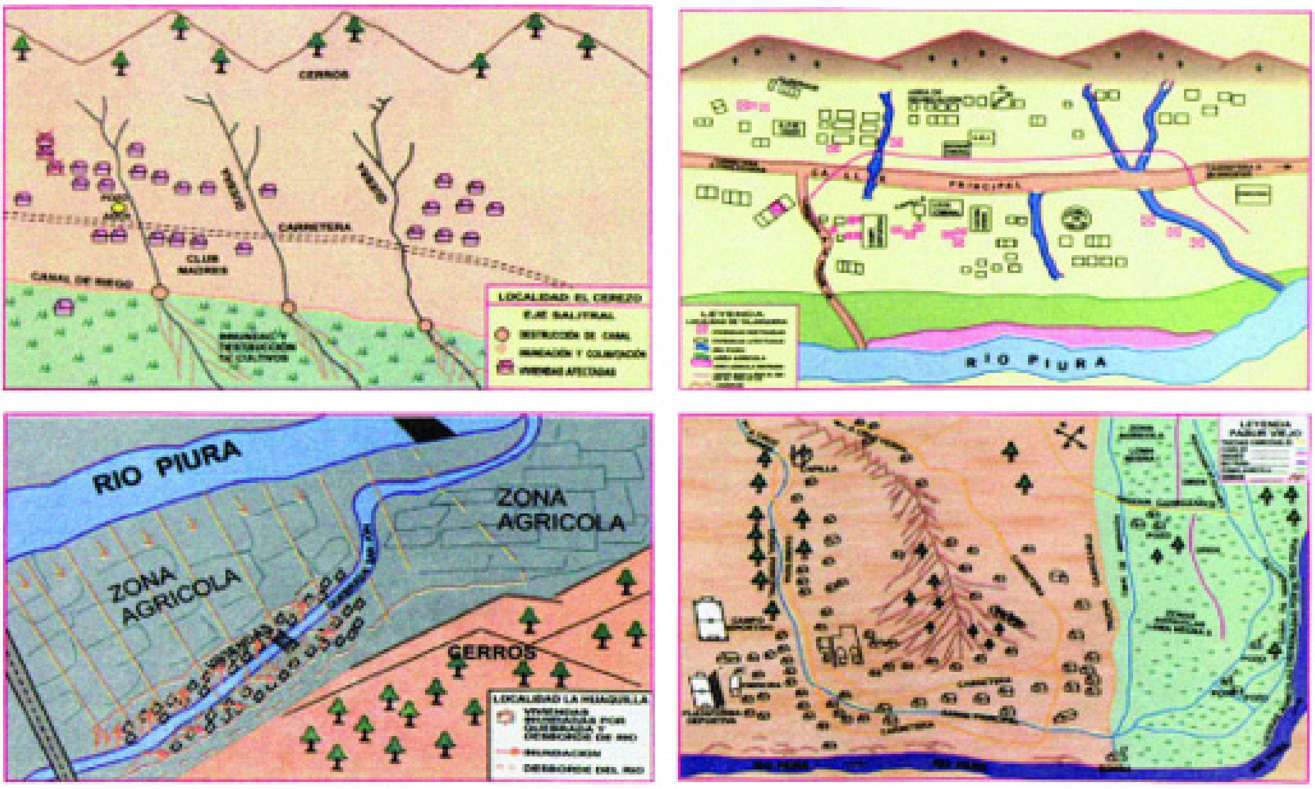


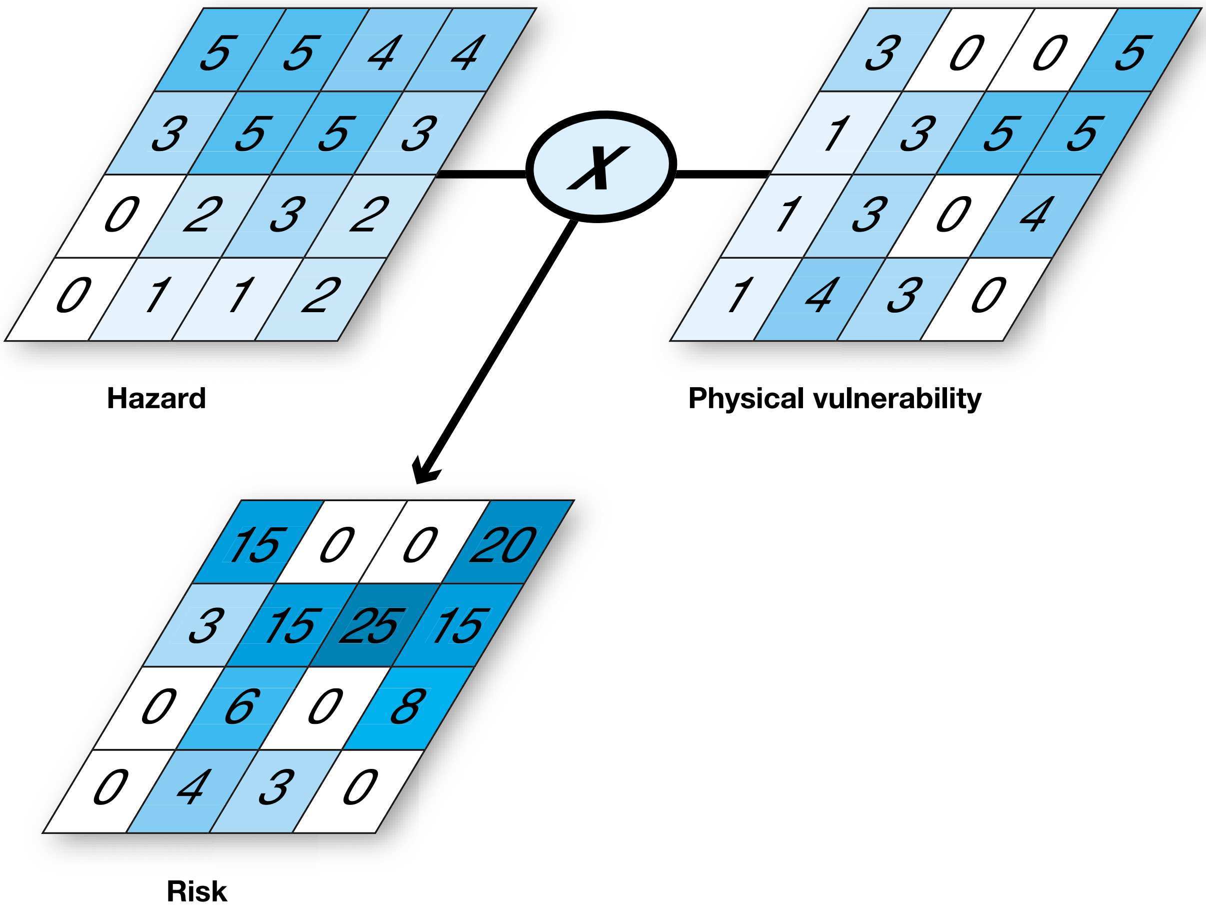
Figure 32: **Selected factors for assessing hazard and vulnerability to landslides** (San Pedro, Bolivia, 2003)

Hazard – ladslide	
Factor	**Explanation of importance of the factor for the hazard.**
Instability	The probability of landslides is very high where landslides have already happened.
Slope	The probability of landslides increases with the slope.
Land use	Land use affects the probability of landslides.
Buffer zone for unstable ares	It is assumed that the same conditions prevail in the immediate neighbourhood of unstable areas as in the unstable areas themselves (geology, soil type, microclimate etc), so that there is increased probability of landslides.
Popular perception	The popular perception of past landslides is considered (the weighting of this factor increases with climatic hazards).
Physical vulnerability to landslides	
Factor	**Explanation**
Sensitivity of infra-structure and production areas	The quality of existing buildings and vulnerability of production areas have decisive influence on risk to landslides.

Figure 33: **Combining hazard and vulnerability** (example: San Pedro, Bolivia, 2003)

Risk of landslides

Hazard		**Physical vulnerability**	
very high	**5**	very high	**5**
high	**4**	high	**4**
medium	**3**	medium	**3**
low	**2**	low	**2**
very low	**1**	very low	**1**
nonexistent	**0**	nonexistent	**0**

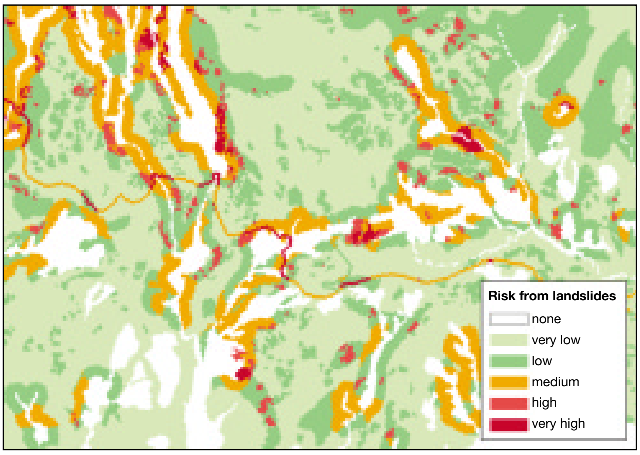


Risk classes (relative)

0 **no Risk**	1 – 4 **very low**	5 – 9 **low**	10 – 14 **medium**	15 – 20 **high**	> 20 **very high**

Transferred to the project area in San Pedro, the risk from landslides looks like this:

Figure 34: **Section of the risk map for landslides in San Pedro, Bolivia, 2003**



Further details on this instrument are given in appendix 10,"Risikoanalyse – Methode zur Vergabe von Relativwerten (MVR) am Beispiel von Hangrutschungen«.

There are many ways of assessing and presenting risk. Another possibility is the FEMA model, which is attractive by virtue of its simplicity and brevity, and which is reproduced here in summarised form.

Figure 35: **The FEMA[21] model as an example of risk assessment**

General guide to hazard and risk assessment, as a basis for planning community action in emergencies[22].

FEMA uses four criteria for its assessment

1. **History:**
   0 – 1 times in the past 100 years ➔ low (L)
   2 – 3 times ➔ medium (M)
   > 4 times ➔ high (H)

2. **Human vulnerability:**
   - consideration of vulnerable groups (old people, handicapped), population density, human dwellings with respect to hazards
   - location and value of property and vital facilities

   Rating: < 1 % (affected) (L)
   1–10 % (M)
   > 10 % (H)

3. **Maximum hazard (assuming the worst case):**
   area affected:
   < 5 % (L)
   5 – 25 % M
   > 25 % (H)

4. **Probability**
   The basis for assessment is annual occurrence
   once every 1,000 years (L)
   between 1:1,000 and 1:10 (M)
   1:10 years: (H)

rating
low: 1, medium: 5, high: 10

weighting
history (twice), vulnerability (5), maximum hazard (10), probability (7)

rating x weighting, with resulting sum and subsequent prioritisation

Hazards with a rating above 100 are classed as priorities.

Example:

Criterion	Rating	Value, weighting	Total
History	high	10 x 2	20
Vulnerability	medium	5 x 5	25
Maximum hazard	high	10 x 10	100
Probability	medium	5 x 7	35
			180

Weaknesses:
No suggestions are given for deciding (1) which hazards should be considered in the analysis, (2) how the disaster risk should be assessed, and (3) how the vulnerability should be assessed. Assessment is relatively arbitrary, depending entirely on the perception of those involved in the analysis. Further, no justification is given for the weighting used.

For example, in a risk analysis using this classification, the figure for radioactive precipitation would be the highest, which would inevitably give it priority in planning risk minimisation strategies. The reason for this is the heavy weighting (10 times) given to the maximum hazard. This weighting means that disasters which have never occurred are given excessive priority over disasters (in this case floods) which have occurred relatively frequently.

FEMA
http://www.ema.gov.au/ema/rwpattach.nsf/viewasattachmentPersonal/E5ED86F1F8A5E698CA256C8A000AC628/$file/the FEMA model.pdf

21 Federal Emergency Management Agency, USA - http://www.fema.gov
22 Natural Disaster Organisation (1991): Community Emergency Planning Guide.

RA2 Who should be involved? What can be changed?

The steps in analysis are used to develop the possible measures for reducing the risk of disaster. It may not be necessary to wait for the final result of the risk analysis to identify risk reduction measures. Recommendations for spatial planning can be identified on the basis of the hazard analysis, if e.g. threatened zones are designated as protected zones or zones not for development. The need for hazard reduction measures such as constructing polders or wetlands can be inferred from hazard analysis.

Risk reduction strategies should be based on existing knowledge and strategies, and be capable of implementation and funding.

In planning emergency and risk reduction measures, the following considerations should be taken into account:

To ensure that it can be financed and implemented, the decision on the planned preventive measures resulting from the RA must arise out of a process of political consultation, as a consensus of all the inhabitants of the affected (and causative) region. It is often more difficult and complicated to achieve this than to identify the technical measures whose costs both those affected and those not affected must share. Experience in DC has shown that it is easier to reach a consensus between technicians, politicians and the local population if highly visible protective measures are involved (which are often expensive and do not always do much for disaster reduction) than if less spectacular but possibly more effective measures are involved. To achieve optimal solutions in consensus with technicians, local populations and political decision levels, measures such as transparent information management, disclosure and discussion of the various interests and clarification of the various roles are important and useful.

7.3 Hazard and vulnerability analysis, using drought as an example

Introduction:

- Drought differs from other natural disasters in that it cannot be precisely defined spatially or temporarily. Drought is a "creeping" disaster.
- We distinguish between meteorological droughts, where precipitation in a given year is more than 25% below average, agricultural droughts where the soil moisture available is no longer sufficient for plant growth, and hydrological droughts where watercourses drain away.
- In a drought, the supply of water from precipitation, soil moisture and potential evapotranspiration from crops and other vegetation falls short of the secular average. Aridity and the more serious form of drought are situations in regional climates where the water supply available to plants and humans is inadequate to meet the demand. Demand varies very widely between regions, and generally adapts to match the secular supply. This in turn is primarily determined by average annual precipitation and the local rate of evaporation. However, variance (i.e. the extent and frequency of variations from the average) plays a decisive role. Areas where there is more or less constant humidity can under certain circumstances be seriously impacted by a brief dry spell, while other areas (e.g. arid ones) have adjusted to a shortage of water and can survive even longer dry periods without major problems.
- Besides precipitation and evaporation, affected by temperature and wind, soil types and their ability to store water, the depth and presence of ground water supplies, vegetation and a number of other factors play a role in the occurrence of drought.
- The seriousness of drought is aggravated where the actual water supply falls short of the minimum need of plants in the current stage of the growth cycle.
- In recent decades there has been a global trend towards human settlement and water-intensive cultivation even in areas where these could never exist naturally. This has been made possible by new technological options, like pumping ground water from great depths and large-scale irrigation, including huge water storage structures in some cases. How-

ever, this was at the expense of accepting a high level of vulnerability. Dry periods and droughts are recurring, mostly caused by large scale or global circulation phenomena like El Niño/La Niña. Where these persist, the result is often famine. Arid and semi-arid regions and mountainous regions are particularly at risk.

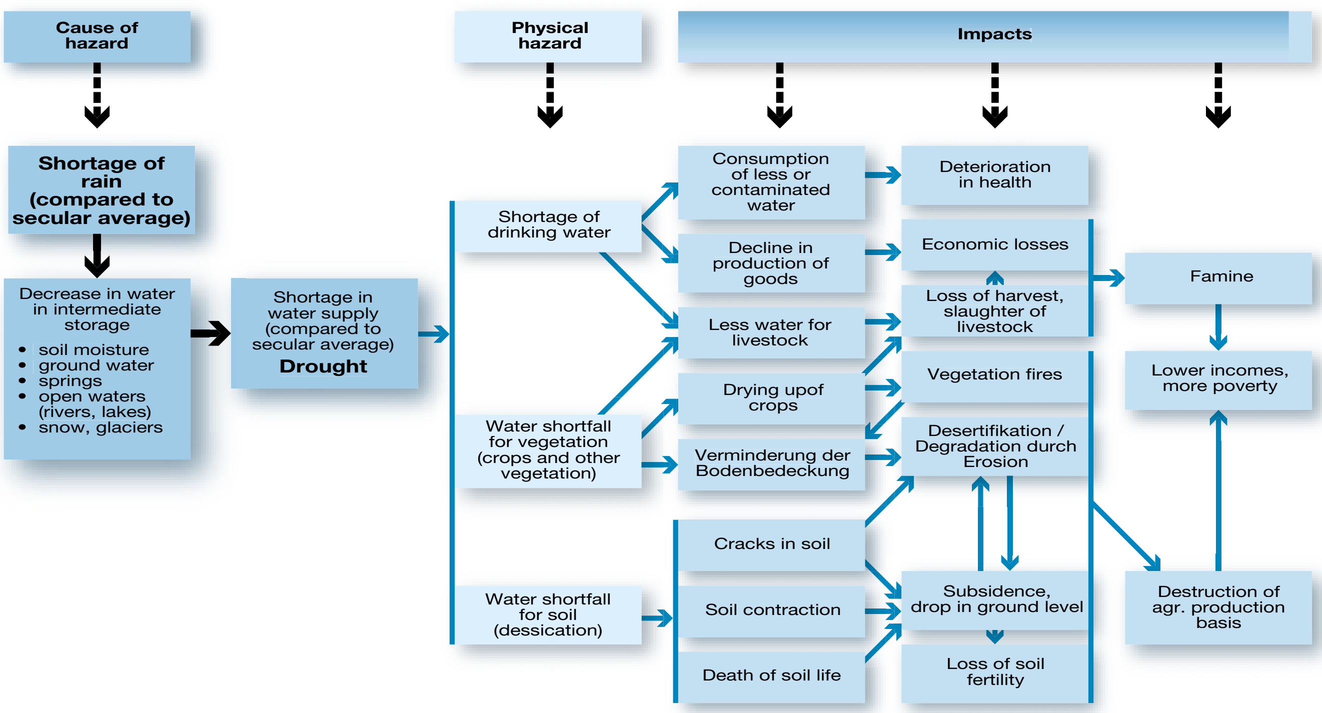
Once **drought** has been identified as the relevant type of hazard and direct physical hazard from the point of view of the local population, the following key questions are used to continue and deepen the analysis. To identify the direct physical hazard and resulting consequences, analysis using impact chains or grids has proved useful.

The **direct physical hazard** is the hazard within the impact chain which the affected population group perceive as such. In this example, this is not directly the low level of precipitation compared with the secular average, but the resulting shortage of drinking water, water deficit for vegetation and water deficit for the soil. Impact chain analysis is also helpful in identifying the causes and the impacts on the relevant basis of life of the direct physical hazard. The impact chain can be drawn up and analysed for each relevant area of the basis for life, if detailed exploration of possible hazard manifestations is required.

Detailing individual consequences of dryness and drought:

- Forest, bush, steppe and grass fires:
  dry and dried out plants are highly flammable. A lightning strike, spark or even an object functioning as a magnifying glass (e.g. glass splinters) can cause a fire.
- Subsidence:
  certain soils (particularly many clay soils) shrink tremendously when they dry, i.e. they lose volume. Particularly if there is a load (e.g. from a building), this results in subsidence.
- Desertification:
  in the case of lasting or frequently recurring periods of drought, the soil and flora are so badly damaged that their resilience (i.e. ability to recover) is damaged or even destroyed. The result is a long-term degradation of soil and vegetation, described as desertification.
- Famine:
  a lasting drought can result in the collapse of the entire food supply system in a region. This can only

Figure 36: **Impact chain to identify the direct physical hazard and its causes and impacts in the case of drought and dryness**



be restored by interregional or international aid. Drought is not the only reason for a food crisis, but rather an initiating event which plunges a non-sustainable and unstable social and economic system into a food crisis. The seriousness of this depends on the local social, economic and political environment. It is accordingly very difficult to compare causal relationships in drought-induced food crises between regions.

Key questions

(HA = questions on hazard analysis,
VA = questions on vulnerability analysis,
RA = risk analysis.)

HA1 = step 1 in hazard analysis;

VA1 = step 1 in vulnerability analysis;

RA1 = step 1 in risk analysis (HA x VA = RA)

HA1 **Which locations and areas are threatened by drought? (spatial analysis)**

To identify the areas potentially affected (i.e. the locations threatened), land use records are analysed, where available. These are supplemented by analysis of aerial and satellite images and surveys among the population affected. The collected data is entered manually or using GIS on topographical maps to a scale of 1:20,000 to 1:100,000.

Where are the areas which are potentially threatened?

A map with the potentially threatened locations is the basis for further stages in the analysis. Aerial photos are particularly suitable for participative analysis with village populations, as explained in the preceding section on flooding. The use of technical aids in spatial analysis and mapping the results of analysis depends on the context and size of the area at risk and the expected damage. Sophisticated technologies are not always necessary[23].

The food crises caused by drought can cover a vast area. Market-related dependencies, large-scale trading relations and migrations can lead to regions suffering which are not directly affected by the climatic event of drought.

VA1 **Are there vulnerable people and bases of life? Who and what is affected and threatened? Which are the important bases of life? What is produced? What does the local population make its living from?**

To identify the elements (i.e. people and their bases of life) vulnerable to drought, land use plans (where available) are analysed and/or aerial and satellite images are reviewed and analysed and supplemented through surveys or using participative workshops with the affected population.

HA2 **When and how often are future droughts to be expected? Seasons? Cycles? Frequency? With what intensity and duration (= scale, force)? Past damage?**
(Temporal and dimensional analysis)

Hydrometeorological indicators for early warning of droughts:

Recording and analysing the following parameters makes possible early identification of dry conditions or a developing drought:

- aggregate monthly precipitation
- aggregate seasonal precipitation
- soil moisture
- water levels in streams and rivers
- ground water level
- temperature
- any snow cover on mountain tops.

For the purpose of analysis, the current values can be compared with secular averages. If current values are significantly below secular averages, this is a sign of a dry period or (if this continues) a drought. These methods of recording and evaluation make possible statements for relatively small regions.

In a project context, the simplest and most effective feasible solution is to take weekly measurements of soil moisture using manual measuring instruments.

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23 A detailed description of the use of remote sensing and GIS in risk analysis is given in appendix 1 to these guidelines.

HA3 How can the assessment of hazards be visualised?

It is already possible to monitor anomalies in precipitation through geostationary or meteorological satellites and use the data for early warning of droughts.

Studies have shown that certain large-scale meteorological patterns can be associated with the absence of the summer southwest monsoon. This is the main reason for droughts on the Indian subcontinent. Factors which make possible such early warning of droughts are high-altitude winds over India, the development of hot low-pressure regions over southern Asia, and finally the El Niño phenomenon. Other factors which can also be recorded using satellites are ocean surface temperatures, the degree of snow cover, wind speed and direction, and atmospheric temperature and humidity profiles. All these factors are also closely associated with the distribution of precipitation. Satellites in geostationary or polar orbits offer excellent possibilities for obtaining information on these factors at both regional and global level. More and more accurate models are being developed which include atmospheric, marine and land-related factors.

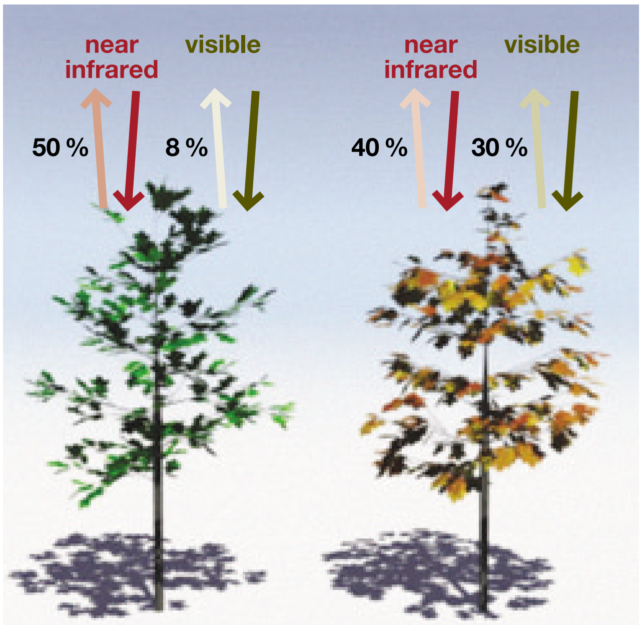
To take measures against drought at the appropriate time, analysis and monitoring of climatic developments are required. This is a prerequisite for reducing the loss of agricultural productivity in regions at risk from droughts. The analysis and monitoring of droughts also provides objective information on the occurrence, strength and persistence of drought over time. This information is important for resource management, where it is important to distribute and allocate scarce funds optimally.

Satellite data can be used to obtain a comparatively quick and low-cost overview of the presence and state of vegetation. The easy-to-calculate vegetation indices are particularly suitable for this. Particularly in developing countries, the factors of time and cost often play the decisive role in risk management. This is another reason why vegetation indices are a suitable measure in developing countries.

Vegetation indices exploit the fact that the pigments contained in the leaves of healthy plants reflect incident (solar) radiation in a very specific way. While healthy vegetation reflects relatively little visible light, reflection in the near infrared (NIR) is significantly higher. The healthier and denser the vegetation, the greater the increase. This characteristic difference between visible light and near infrared is not found in most other surface materials, including diseased or dried vegetation. Compared to green and healthy grass, for example, dry soil or dried grass reflects more visible light and significantly less NIR. This makes it possible to calculate the "Normalised Difference Vegetation Index" (NDVI) for a plot of land. The NDVI can only be used to make a relatively large-scale assessment at national or continental level.

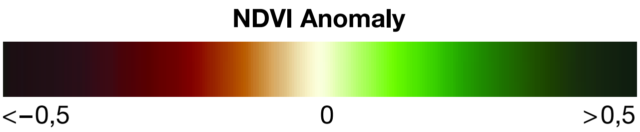
Earth monitoring satellites record the radiation reflected from the surface in separate, precisely defined ranges of the spectrum ("bands"). The US NOAA-AVHRR satellites measure radiation in five bands, including visible red (band 1: 0.58 – 0.68 nm) and near infrared (band 2: 0.725 – 1.10 nm). The reflection values for NOAA bands 2 (NIR) and 1 (red) are used in the formula NDVI = (NIR-red)/(NIR + red). This is a simple calculation for computers, performed for each pixel. The result is a relative measurement which is strongly correlated with vegetation density and vitality. For

Figure 37: **Radiation reflected by plants in satellite images**



$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72 \qquad \frac{(0.40 - 0.30)}{(0.40 + 0.30)} = 0.14$$

Source: NASA's Earth Observatory, Responsible NASA official: Yoram Kaufman



NOAA data, this dimensionless index takes values from -0.1 (no vegetation) to 0.7 (much vegetation). The figures generated in this way are presented using a special colour scale ranging from brown (-0.1–0.2) through yellow (around 0.3) to dark green (0.4-0.7).

In this way, entire states or continents can be analysed. As an illustration, here is a section of east Africa during the serious drought in 1984 (figure 38). The image shows the situation in August 1984:

the dark areas are particularly seriously affected by the drought. It is also clear that a drought does not always affect all vegetation and regions equally. Vegetation in the green areas is actually in a slightly better state than usual.

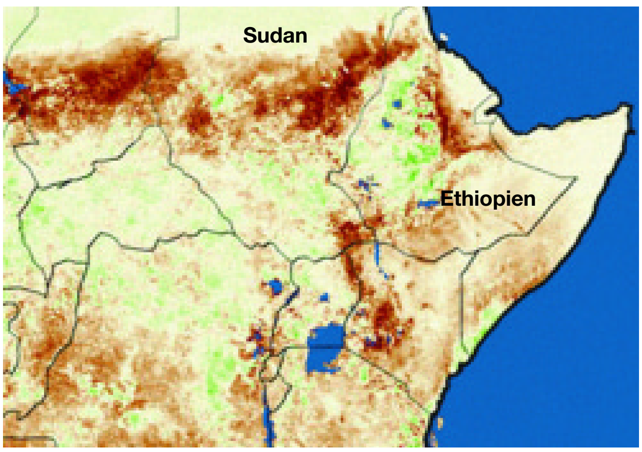
Resources and time

This method is relatively elaborate and not possible without technically trained personnel and specific hardware and software. This process of hazard analysis using remote sensing only makes sense for project areas larger than 10,000 km?. The time required for the first analysis is relatively great. However, once carried out, the time required can be substantially reduced.

VA2 What impacts does drought have on the vulnerable elements?

- A dry period or drought initially mostly manifests itself by plants starting to show symptoms of a lack of water (stress). They drop fruit and leaves, stop growth, discolour, dry out and finally die. This is often the first link in the food chain to be destroyed.

Figure 38: **Example of drought monitoring by satellite imaging**



Source: NASA's Earth Observatory, Responsible NASA official: Yoram Kaufman

Animals have no feed, humans no basic vegetable food and, because livestock starve and finally die, soon no animal food either. This is particularly critical if an area lives largely on locally-produced food, but also affects income from the sale of exports, which is finally lost. If raw materials are processed locally, the domestic economy also quickly feels the impact.

- Lasting drought can lead to total loss of agricultural crops, not only affecting the current harvest but also often requiring replanting, which is often expensive.
- Further drying of the soil leads to cracking and general contraction, which can lead to subsidence and resulting damage to buildings. Cracked soil is highly vulnerable to erosion, and the rain at the end of a dry period can under some circumstances have worse consequences for the long term than the dry period itself, if valuable topsoil – often only present in small amounts in dry regions in particular – is washed away. This results in destruction of the basis for agricultural production.
- In regions with frequent drought there is the danger of desertification. The desertification process is generally a vicious cycle: once it has started, it accelerates because e.g. the plant cover protecting against erosion diminishes with each new period of drought.
- In a continuing dry period, water consumption in private households and industry has to be limited. While this is initially a cause of inconvenience rather than damage, if it continues it can have a significant adverse impact on production (particularly with water-intensive manufacturing processes), up to the point of shutting down operations.
- There is direct loss of income due to drought in the case of hydropower stations and, in extreme cases, nuclear power stations, if water for cooling towers becomes scarce.

The following table shows typical effects for various levels of drought[24]. These can also be used in reverse as indicators of the current level of drought. The course of a drought can range from a phase of slight dryness to famine.

There may be a long interval between the appearance of the climatic event and its impact on the state of nutrition for the population. Some drought victims can die many months after the actual event. Starvation only sets in when food reserves have been consumed. In addition, the fatal consequences of malnutrition and starvation only appear with some delay. Even many years after precipitation has returned to normal, serious impacts can still occur (e.g. as a result of destruction of seed or the loss of agricultural equipment and supplies during the drought).

In the project "Disaster reduction and food security in San Pedro, Bolivia", the analysis of water availability for agriculture in connection with drought as a hazard was carried out using the following diagram (figure 40).

VA3 Variables for determining coping capacity

Indicators for determining vulnerability of food security in drought conditions depend very strongly on the regional political, social and economic environment. At micro level, the emphasis is on coping capacities and strategies at the level of individuals and groups (e.g. household communities). Four different forms of coping strategies can be distinguished:

[24] Following Hans-Georg Bohle: "Dürrekatastrophen und Hungerkrisen. Sozialwissenschaftliche Perspektiven geographischer Risikoforschung", in "Geographische Rundschau", Braunschweig, 46 (1994-7/8), pp. 400-407.

Figure 39: **Typical conditions for various levels of drought**

Level of drought	Impacts, indicators	Possible actions
mild dryness	• preserving or accumulating assets • continuing normal production strategies	development programmes
severe dryness	• sale of less important assets • reduction in food consumption • minor changes in production strategies • small changes in income strategies (e.g. borrowing money from relatives)	assistance programmes (price stabilisation, accumulating food stocks)
mild drought	• sale of important assets (not productive resources) • greater reduction in food consumption • sharp change in normal production system (partly involving ecological damage) • new income strategies (e.g. migration of labour, borrowing money from moneylenders)	aid programmes (food-for-work, cash-for-work)
severe drought	• sale of productive resources (land, agricultural equipment, seed, entire herds) • starvation • abandonment of normal production system • completely new income strategies (permanent emigration by entire families)	emergency aid programmes (food aid, distribution of seed)
famine	• coping strategies completely exhausted • flight to famine camps disaster aid programmes (accommodation, food aid, medical services)	disaster aid programmes (accomodation, food aid, medical services)

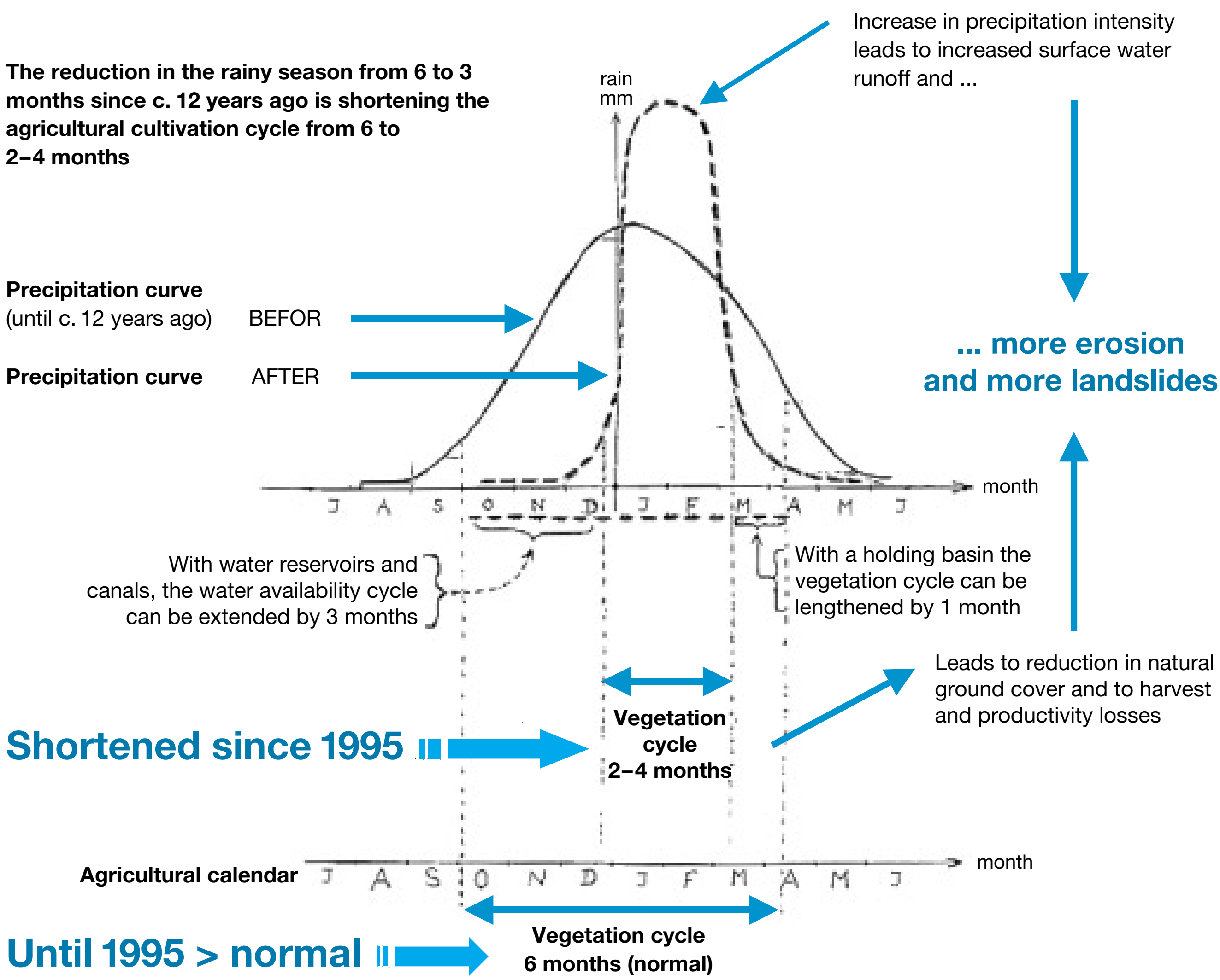
- Coping strategies in the narrow sense of the term are short- to medium-term strategies for dealing with acute crises in concrete situations. These constitute a reaction to a crisis.
- Adaptation strategies are long-term fundamental changes in behaviour resulting from basic changes in the social, economic and ecological environments.
- Risk-minimising strategies are strategies for reducing the crisis risk. They constitute a form of internal crisis prevention.
- Seasonal coping strategies are strategies for overcoming periodic seasonal food shortages.

Indicators for determining vulnerability

Figure 41 shows possible variables and their associated indicators for determining the vulnerability of groups and individuals at micro level[25]. The possible extreme

[25] From: Beate Lohnert, "Bericht zum deutschen Beitrag für den World Vulnerability Report des United Nations Development Programme"

Figure 40: **Analysis of the vulnerability of agriculture to drought** (example: San Pedro-Norte Potosí, Bolivia)



forms of the variables are shown in the right-hand column, and range from a very high coping capacity = low vulnerability (left) to very low coping capacity = high vulnerability (right).

However, it is never a single factor which determines coping capacity and vulnerability, but rather a constellation of different variables. Which indicators and which specific forms of these determine vulnerability is something which differs from one society to another and changes over the course of time. Detailed household analysis on the lines of the Sustainable Livelihood Approach must accordingly be carried out.

RA1 Assessment of risks

Hydrometeorological measurements and the vegetation index can be used to record and monitor drought conditions in real time. This can help decision makers in

Figure 41: **Indicators for determining vulnerability to drought**

Variables	Low vulnerability	High vulnerability
	key aspects for consideration	
Gender	male head of household	female head of household
	Dependent on freedom of action in cultural and economic context.	
Age	middle to old	young and very old
	Dependent on cultural situation (power status). Differences between urban and rural.	
Education and training	high level of education	little or no education
	Dependent on importance of education in society.	
State of health	healthy	ill, handicapped
	Dependent on health system and public assistance to handicapped.	
Household size	large household	small household
	Dependent on ratio of economically active to inactive.	
Reserves	reserves	no reserves
	Reserves available during a crisis depend on the nature of reserves, the importance of reserves for production and the duration of the crisis.	
Income	high income	little or no income
	Dependent on the impact of drought on income.	
Type of production	subsistence economy	production for the market
Type of agriculture	livestock farming	arable farming
Economic diversity	multiple sources of income	single source of income
Social networks	integrated into social networks	no social networks
	Dependent on position within social network. Differences between urban and rural.	

initiating strategies to modify existing preventive cultivation patterns and methods.

Precipitation measurements, soil moisture measurements and data from meteorological satellites are suitable for analysing (spatially or temporally) inadequate precipitation at times when crops are in a critical stage. Analysis of plant status and condition based on this is a suitable approach for monitoring droughts.

If these results are linked to data on the potential coping capacity of households, villages or regions, a risk assessment can be derived.

RA2 What should be changed? What can be changed?

To combat the results of droughts, both short-term and long-term strategies are needed. Short-term strategies include early warning and monitoring and evaluation of droughts. Long- term strategies aim at drought reduction through:

- correct irrigation planning
- soil and water conservation
- resource conservation
- choice of seed
- optimisation of cultivation patterns and customs
- livestock migration
- storage and stocks
- land use planning

The best form of prevention of dryness and drought is economical use of water even in times when the supply is plentiful. This means that water storage facilities should always be kept as full as possible, the groundwater level should not be lowered unnecessarily, and evaporation should be kept to a minimum. This includes planting crops which are appropriate to the local climate as a whole, and not just certain climatic aspects such as longer sunshine periods, temperature, etc. These will also survive occasional water stress, and at least will not die immediately.

Monocultures are generally more vulnerable to damage than mixed cultivation, as different plant species do not start to suffer at the same time. Total loss of monocultures can be avoided if – in irrigated farming – increasing duration of dryness is met by successively abandoning parts of the cultivated area, in order to ensure adequate water to the remaining area.

Construction of large water storage facilities to ensure irrigation and drinking water supplies has led to improved drought prevention in many countries. However,

Figure 42: **Example of a matrix of measures for risk reduction**

(Modified from F. Pischke's thesis in the project San Pedro, Bolivia, "Traditional risk prediction and prevention strategies in the San Pedro catchment area, Potosi, Bolivia")

	Hail	Frost	Torrential rain	Drought	Erosion, landslides
Spatial diversification of agricultural production	•	•	•	•	•
Diversification of income sources	•	•	•	•	•
Housing for livestock			••	••	•
Greenhouse cultivation	•••	•••	•••		
Horticulture	•	•	•	•	•
Irrigation systems				•••	
Mechanical techniques (terracing, etc)			•••	••	••
Agroforestry		•••	•••	•••	•••
Other agronomic practices			••	••	••

Key:
• = reduces the impact of the hazard indirectly
•• = reduces the impact of the hazard directly
••• = reduces vulnerability

poor and inefficient land and water management is still a primary cause of soil degradation. The use of remote sensing to identify land degradation, changes in soil use and changes in groundwater fluctuation in combination with locally appropriate agriculture can provide a basis for more efficient use of land and water. For example, satellite data was used to mark soils which are water-logged and have high salt content, and subsequently to design ecological impact studies. This led to solutions to these problems.

In drought prevention it is important to respect both the numerous links between natural resources and the environmental system and interdependence between natural resources themselves.

7.4 Hazard and vulnerability analysis, using erosion as an example

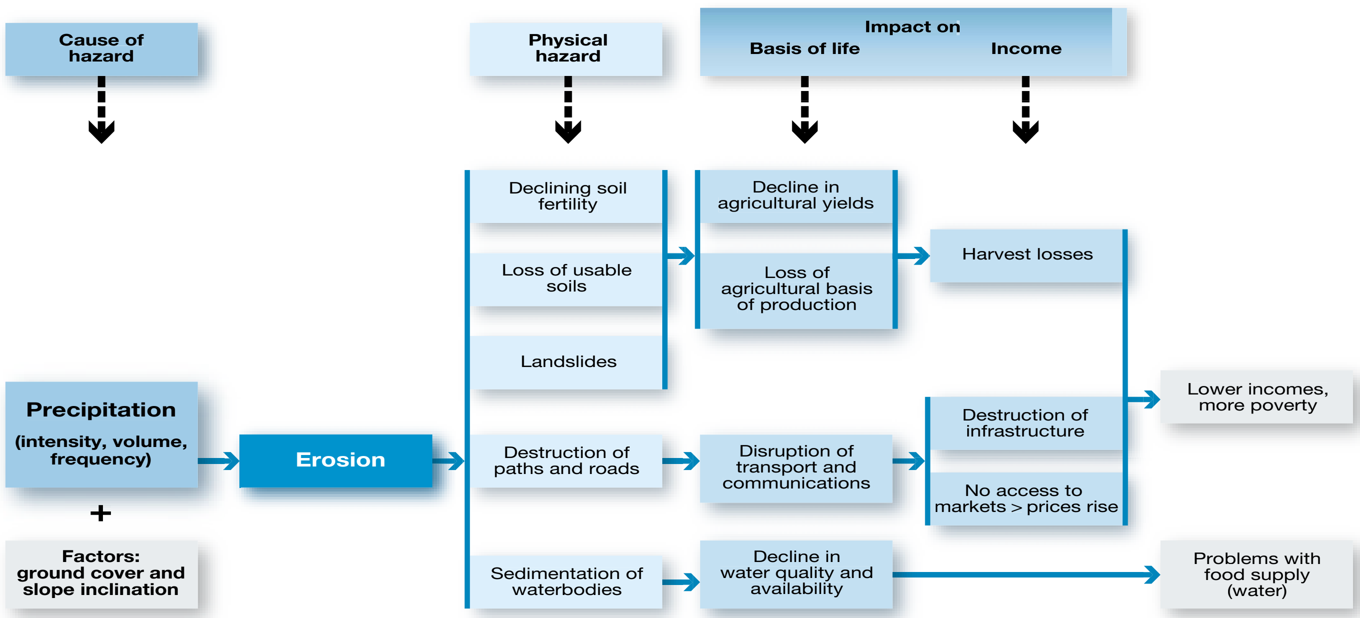
After identifying erosion as a relevant hazard, the analytical process is pursued in the same way as for flooding (as a result, this section will frequently refer to diagrams and figures in the preceding section).

First, an impact chain is established for the direct physical hazard's showing the impacts of erosion (cf. figure 43).

Overview of risk analysis, using erosion as an example

In contrast to flooding, erosion is a creeping disaster, which is not even regarded as a classic disaster. Erosion occurs primarily during torrential rains, but after several erosion events it has a particularly lasting influence on soil fertility. Sudden catastrophic events in the form of landslides e.g. as the result of erosive undermining of river courses are also possible, but these will not be covered here.

Figur 43: **Impact chain to identify the direct physical hazard and its causes and impacts**



Key questions

(HA = questions on hazard analysis, VA = questions on vulnerability analysis)

HA1 **Which locations and areas are threatened by erosion? *(spatial analysis)***

A prerequisite for planning and implementing suitable measures for reducing erosion by water and reducing the burden on waters from silt resulting from erosion is the most accurate identification possible of the areas at risk from erosion and the main routes for surface runoff.

Evidence of erosion can be recorded and estimated for a wide area by mapping and also quantified by suitable measuring instruments. A map showing the locations threatened by erosion is the basis for further stages in the analysis (cf. figure 14, p. 32). Areas at possible risk from erosion can be estimated using specific indications such as steeply sloping regions without vegetation cover and visible signs of erosion, or by surveying farmers, or can be identified for large areas with the help of calculations of factors required for erosion.

After identification of areas threatened by erosion, the elements affected by this (i.e. people and their basis of life) are considered.

VA1 **Are there vulnerable people and bases of life? Who and what is affected and threatened? Which are the important bases of life? What is produced? What does the local population make its living from?**

Here again, there are no fundamental differences from the analytical procedure for flooding. As erosion is a creeping disaster, however, it should be noted that the problem is not perceived so explicitly by the population, so that it is less easy to correct through participative methods.

Elements potentially affected by erosion (see also the impact chain) are: agriculture, infrastructure and water quality as a result of sediment deposits.

After identification, the threatened elements and locations are marked on the map (see figure 16, p. 33).

HA2 **When and how often are erosion events to be expected? Seasons? Cycles? Frequency? With what intensity and duration (= scale, force)? Past damage? *(Temporal and dimensional analysis)***

Figure 44: **Identification of vulnerable elements in San Pedro, Bolivia** (marked by the village population)

The scale of soil erosion is primarily determined by individual extreme precipitation. As a result of these isolated precipitation events with widely varying initial conditions, it is only possible to determine the soil erosion events dependent on local conditions, despite considerable expenditure of resources on monitoring (surveying, mapping etc). Detailed knowledge and analysis of the hazard factors affecting erosion (precipitation, current land use, soil infiltration capacity, slope, shape of the water catchment area) is needed to estimate the varying force and probability of occurrence, along with trends and tendencies. Figure 15 (p. 32) shows how this can be presented on a map, and describes the procedure in more detail.

The decisive factor in erosion is the intensity, mostly shown as metric tons per hectare per year. Historical records and aerial images permit a rough estimate of the scale of erosion, but are not enough for quantification. The best option is to use existing formulae (USLE/MUSLE) for estimations, or use models, modelling and simulations for calculation (see appendix 6).

Factors for calculating erosion

In the following section the factors influencing erosion are presented. As is clear from figure 45, the factors are divided into climatic factors not amenable to influence, stable factors virtually impossible to influence, and factors which can be easily influenced. The diagram goes well beyond a potential hazard analysis. This is logical to the extent that actual erosion can only be determined by including the environmental factors subject to human influence. The diagram is followed by detailed consideration of the importance of the individual factors, to develop a sense of the role these play.

The potential danger of erosion is extremely great in the tropics and subtropics, primarily due to climatic conditions (the change between wet and dry seasons, torrential rain, storms). As long as the soil is protected by vegetation, there is no danger, but with increasing cultivation where soil is left bare, erosion reaches much higher rates on average than in moderate climatic zones.

Hazard factors

Climate:

Precipitation, primarily intensity, seasonal distribution (critical rainfall) – for more detailed comments on precipitation and variability of precipitation, see the example of flooding.

Rocks and soil:

The vulnerability of soil to erosive forces is described as erodibility. The following factors play a role in erodibility: soil type, soil structure, water absorption capacity, pore volume, storage stability, stratification and their angle of slope and surface roughness; soil resistance to erosion depends primarily on its composition, cementation and colloid formation. It is difficult to identify specific factors as particularly decisive. The most important are texture and structure. In terms of soil texture, soils with a balanced particle size distribution are least vulnerable, as they are generally permeable to water and form aggregates stable under erosion.

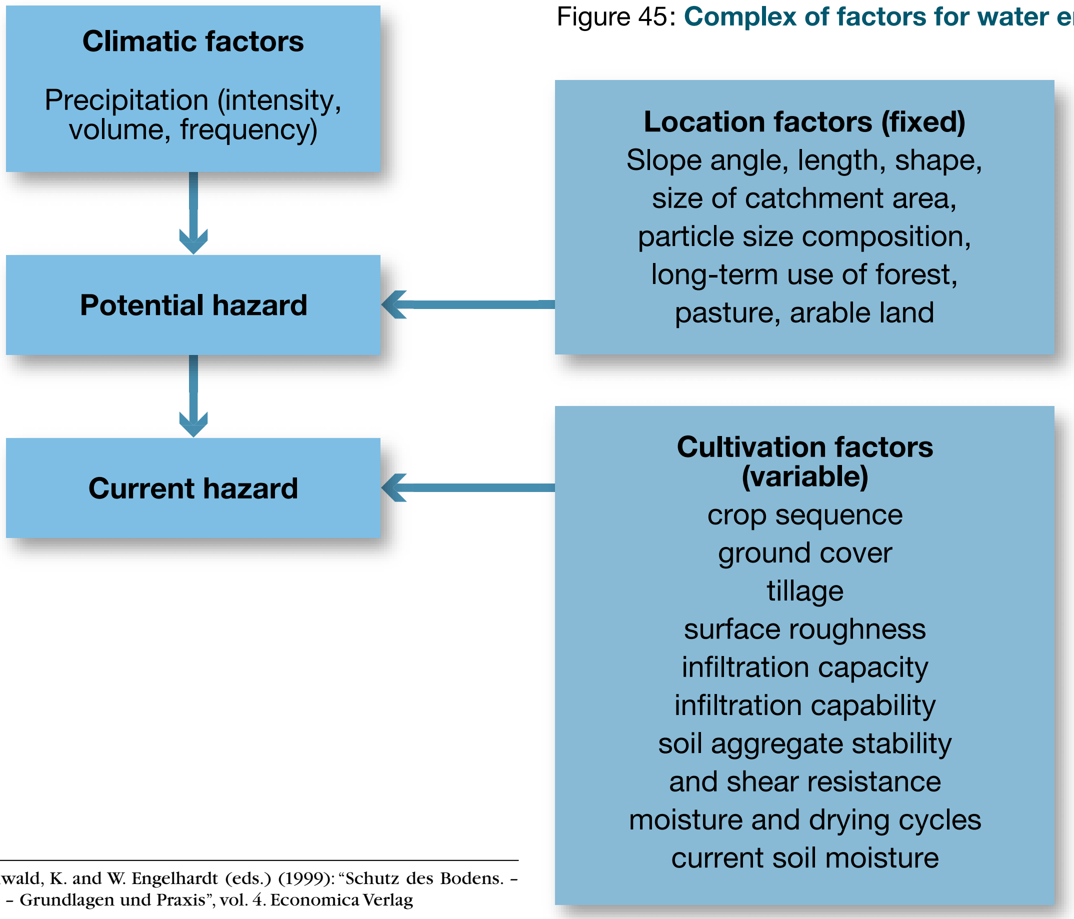
In general the vulnerability of soil to water erosion is influenced by

- high silt and fine sand content
- low clay content
- low humus content
- coarseness of aggregates
- low permeability.

Relief

Water erosion occurs primarily on slopes, where the mathematical relationship between slope and water erosion is exponential rather than linear. The length of the incline is also decisive, as the runoff volume

Figure 45: **Complex of factors for water erosion**[26]



[26] From Buchwald, K. and W. Engelhardt (eds.) (1999): "Schutz des Bodens. – Umweltschutz – Grundlagen und Praxis", vol. 4. Economica Verlag

changes with length. Once again, there is an exponential relationship between slope length and erosion.

Vegetation
Plant cover protects the soil from wind and rain and also reduces surface runoff and fixes the soil mechanically through the roots. Addition of organic mass also makes possible humus formation, which favours the formation of stable soil structure. With these characteristics, vegetation is an important individual factor influencing erosion.

Calculation
As the scale of soil erosion can vary very widely over the course of a year, models were developed which record the relationships in soil erosion, for the purpose of improving our understanding and forecasting ability. In practice, easy-to-use empirical procedures like USLE (Universal Soil Loss Equation) and ABAG (General Soil Erosion Equation) are mostly used for estimation. To take advantage of physically based process modelling for land management in "problem areas", it is necessary to select priority areas for collecting the necessary data and improving the cost-benefit ratio in reviewing simulation results through mapping and surveying. The various procedures and a critical review of these are given in the appendix.

Studying the future trend in erosion is equivalent to forecasting. The experience of farmers can be used (with the restriction described above) to provide information on changes in recent years.

Visualising erosion

Annual averages are a possible way of visualising erosion. While erosion increases when torrential rains occur, it is mostly the long-term average which has the greatest influence on the decrease in soil quality or silting of water courses (see figure 18, p. 35).

For this reason, the combination of scale and probability of occurrence of erosion events provides little information for determining the risk.

VA2 What impacts does erosion have on the vulnerable elements?

Erosion has both onsite and offsite impacts. Onsite impacts are the impacts of erosion on areas where erosion occurs, such as arable land with impacts on soil fertility, or river courses with possible destabilisation of roads through undercutting by rivers. Offsite impacts occur where material transported by erosion is deposited again (sedimentation in rivers) or where erosion leads to contamination of drinking water with pesticides (which can reach rivers in the soil).

In the long term, the scale of erosion must remain below the rate of new soil formation (where new soil formation can be supported by applying soil material or fertiliser). Again, different population groups have different perceptions of the impacts of erosion, for example depending on what opportunities they have to offset the loss of fertile soil through other means of production, or – in the case of agriculture – what alternative sources of income they have.

Vulnerability factors and indicators for determining vulnerability

The following section considers the vulnerability factors to be considered in the case of erosion. As already explained in the subsection on flooding, vulnerability is divided e.g. into economic, physical, social and environmental dimensions. In this, consideration focuses on either the elements at risk from erosion (e.g. arable land) or the factors influencing vulnerability, e.g. by affecting the ability of people to cope with the hazard, such as education or access to information.

1) Economic dimension of vulnerability

Here, we look at how far the economic situation of those affected is influenced by erosion. Erosion here impacts the basis for agricultural production, and – in exceptional cases – also the impacts of the destruction of basic infrastructure. How important are the elements at risk here for the economic situation of those affected?

Roads as an example of basic infrastructure
How important are the roads at risk, e.g. for transport? Are there possibilities of switching to other roads? Or to rail or rivers?

Agricultural basis of production
What is the importance of agricultural production for total income (diversity of income)? Are there other sources of income?

2) Physical vulnerability factors

The aim here is to investigate how vulnerable the elements (buildings, roads, infrastructure) are to erosion.

Vulnerability is affected by the location of the elements, i.e. their proximity to the hazard, and their resistance. Possible indicators: inadequate road construction (no drainage, surfacing) or inadequate surfacing of terraces.

3) Social dimension

Here, we are concerned with the way that society and social organisation affects vulnerability. Possible issues for consideration are e.g. social stability, the state of public health and the state of education.

This part of vulnerability analysis is the most difficult to grasp. Possible indicators for estimating the social dimension are e.g.:

- power relationships, rights of use
- civil participation in land use plans
- length of schooling and graduation rate, literacy
- access to information
- child mortality, access to basic services
- structure of ownership

Examples: High child mortality and poor access to the basic infrastructure indicate an inadequate health service. A population with a poor state of health has in turn less energy for tackling erosion protection and will also be less capable in other areas as well.

The structure of ownership: if farmers are only working leased fields or even fields where ownership is unclear, they will be less willing to invest in erosion protection than if the fields belong to them.

4) Environmental dimension

Here, we are considering vegetation, land and water and their use.

In the case of agricultural areas, it is a question of the nature of cultivation (monocultures) and cultivation practices (e.g. terracing) and their impact on vulnerability to erosion. Monocultures (particularly maize) are highly vulnerable to erosion. Terracing reduces the danger of erosion. Other possible points for consideration are the degree of ground cover, the presence of precautionary and protective infrastructure (tree plantations, etc) and spatial planning measures such as subdivision into a large number of small areas separated by protective hedges which reduce erosion.

Self-protection capability

The study of self-protection capability is included in the analysis here as constant "protection" or adequate land use is required to prevent or reduce erosion. Ways of preventing erosion in agriculture include building terraces or protective walls or planting hedges. Early warning (as in the case of flooding) is less important, as long term planning is the only effective way of preventing erosion.

With regard to agriculture as an element at risk in vulnerability analysis, the following questions (among others) arise:

a) *Type of cultivation:* Do the types of cultivation (rotation, mixed cultivation, monocultures, soil treatment practices, technology) promote vulnerability of agriculture to erosion?
b) *Do farmers have an opportunity to make up for the loss of fertile soil through fertiliser etc?*
c) *Diversity of sources of income:* Is the producer or affected local population dependent solely on agriculture, or do they have other sources of income? Which?

As in the case of flooding, it is helpful to look at the impact of torrential rains in connection with the time of occurrence (see figure 28, p. 47). If precipitation always coincides with the months of thickest vegetation, this reduces the risk of erosion. Particularly in areas with marked dry seasons, the onset of precipitation with thin vegetation cover quickly leads to heavy erosion.

VA3 Assessment of vulnerabilities

Besides methods for assessing physical vulnerability (i.e. quantifying the expected damage to buildings and infrastructure), there are many individual studies which have developed methods as needed, and which studied primarily the social area.

Elements particularly affected by erosion are agricultural production areas and infrastructure.

In the case of agricultural production areas it is also important to analyse how fast soil fertility decreases with depth. With the help of the methods described above, we can estimate the scale of erosion; now we have to use the decrease in soil fertility with depth to estimate the effect of erosion on soil fertility. In the tropics, where heavy rain means that soil fertility may sometimes actually increase with depth, slight erosion can sometimes be an entirely favourable event.

By contrast, soil erosion can have particularly negative impacts if it occurs on soil heavily contaminated with pesticides, as this can result in contamination of waters.

Social aspects of vulnerability are not considered in more detail here. They are very often studied using the “Sustainable Livelihood Approach (SLA)”. The SLA is an instrument tested at household level, which accordingly has only limited application for larger regions. It is presented in detail in appendix 2.

RA1 Assessment and presentation of risks

Various types of risk assessment and visualisation have been presented in the section on flooding. In the case of erosion, risk can be best assessed by expected loss of production.

The risk map showing the results of both hazard and vulnerability analysis is regarded as the most important tool in risk analysis. It is also possible to draw up problem trees showing the relationships between various factors (cause and effect) and the process character.

RA2 What should be changed? What can be changed? Legislation, norms, institutions? Strategies? Plans?

After analysing the situation through the above steps, the final step is assessing and identifying what intervention is possible and appropriate.

If the aim is to prevent erosion on a slope, this is only usefully possible if all the interest groups on the slope are prepared to help. It is important to start by studying this willingness before starting work on planning erosion protection measures. The lower lying communities on a slope rely on the farmers above them collecting or distributing the flow of water, as otherwise the water will impact the lower part of the slope with excessive force.

To develop a useful strategy, pairwise ranking can for example be used to show the importance of various factors, and develop approaches to finding solutions.

Figure 46: **The method of pairwise ranking (establishing ranking orders)**

Pairwise ranking is a technique for ranking a number of items. These can e.g. be problems or options. If risk analysis for erosion shows that there are five possible ways of restricting this, the matrix can be used to decide which is regarded as the best.
The following matrix is used to present the results of the comparison of the various possibilities. The blue box shows the comparison between option 1 and option 2. In our example, option 2 is regarded as better, and is accordingly entered in the box.

	1	2	3	4
2	2			
3				
4				
5				

Example:
Option 1: agroforestry
Option 2: strip cultivation (rice with soy in strips)
Option 3: conventional cultivation
Option 4: infiltration ditches
Option 5: row cultivation (double rows with grass, mangoes, rice)

The entire matrix is filled in this way. The decisions here are taken by those affected. The opportunity should be taken to discuss which option is seen as best. This makes it possible to update the advantages and disadvantages of the individual methods.

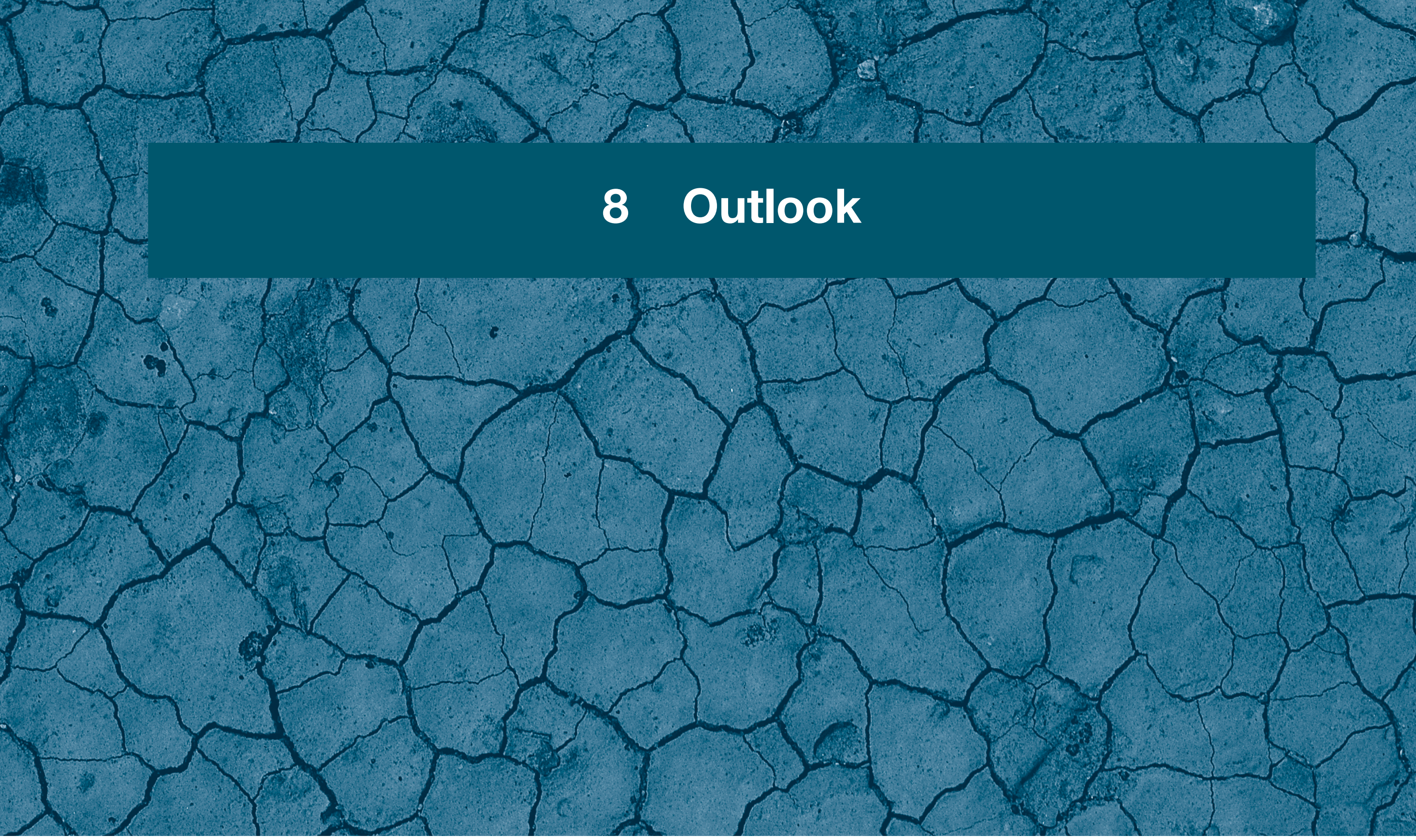
	1	2	3	4
2	2			
3	1	2		
4	1	2	3	
5	5	5	5	5

An almost completed matrix: the completed cell in blue shows the comparison just made between options 4 and 5. It is assumed that option 5 is regarded as better, and a 5 is accordingly entered in the box. When the matrix is filled in, we count the number of times each option is mentioned, and then draw up the ranking.

Ranking 1: "5" was mentioned four times	**row cultivation (double rows with grass, mangoes, rice)**
Ranking 2: "2" was mentioned three times	**strip cultivation (rice with soy in strips)**
Ranking 3: "1" was mentioned twice	**agroforestry**
Ranking 4: "3" was mentioned once	**conventional cultivation**
Ranking 5: "4" was not mentioned at all	**infiltration ditches**

The discussion should not only lead to the ranking, but also make clearer the reasons for this ranking.
This method does not take into account possible complementary effects (positive or negative) between the various measures. It is assumed that each measure is independent of the others.

8 Outlook



The present guidelines are based on cooperation with staff at GTZ Eschborn, particularly the section "International cooperation in the context of conflicts and disasters", the sector project "Disaster Risk Management", and with various projects of bilateral German development cooperation in partner countries in Latin America, Africa and Asia. They are part of a process of discussion which began several years ago, and is still in progress.

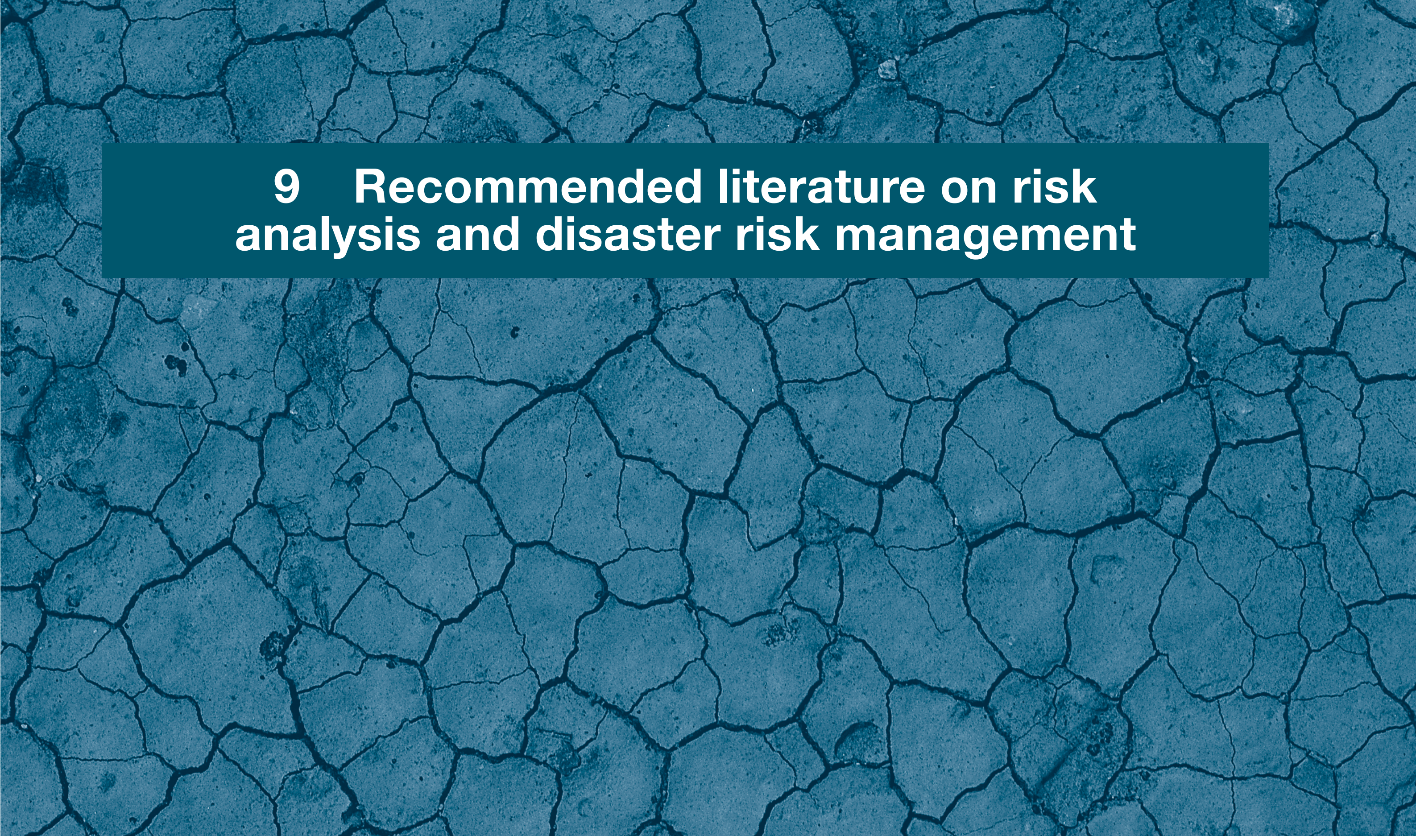
The guidelines also offer a platform for continuing this process of discussion on methods and techniques of risk analysis as part of disaster risk management in DC. In addition, they are intended to stimulate discussion, criticism and questions to drive the further development of risk analysis as an instrument.

A particularly important part of this is for projects and programmes to contribute their concrete local experience to the discussion and share the experience of others. The first practical experience from TC projects was presented and discussed at the workshops in Piura (Peru, 3–5.6.2003) and Cochabamba (Bolivia, 22–23.9.03)[27]. In the course of these, a number of core topics emerged which will be explored and developed as priorities in future work. These include e.g. developing vulnerability indicators for evaluating the effect of DR measures in the projects (among other purposes). Another priority topic is horizontal and vertical integration of DRM with other planning and development strategies.

Given the growing importance of disaster risk management (DRM) as a cross-cutting task in DC, the BMZ commissioned the GTZ with the sector project "Disaster Risk Management", which started work in October 2003, among other things on developing the instruments and methods needed for efficient disaster reduction and assisting discussion with the projects.

There are still many questions from the projects and much need for discussion about risk analysis, specifically on the concrete working and implementation level. The sector project sees itself as a contact for unresolved questions, and is happy to support future initiatives, workshops and project ideas, coordinates documentation of planned and future products on the topic, and is interested in an intensive structured dialogue with the projects and programmes.

27 For the relevant workshops reports, see appendix 9 available from disaster-reduction @gtz.de



9 Recommended literature on risk analysis and disaster risk management

The following 10 appendices (70 pages) and a CD (appendix 11) are available from the GTZ, Eschborn (disaster-reduction@gtz.de).

Appendices to the Guidelines available at the GTZ

1) Fernerkundung und Geographische Informationssysteme im Katastrophenmanagement (14 pp.)
2) Der „Sustainable Livelihood Approach“ SLA (Analyse-Ansatz auf Haushaltsebene) (10 pp.)
3) ENSO – El Niño Southern Oscillation (4 pp.)
4) Soil and Water Assessment Tool (SWAT) (3 pp.)
5) Das Frühwarnsystem NAXOS-Praedict für Hochwasserschutz (4 pp.)
6) Methoden zur Erfassung der Erosion (USLE, etc.) (6 pp.)
7) Vorgehen nach NOAA (National Oceanic and Atmospheric Administration) (4 pp.)
8) Aufgaben und Aktivitäten bei der Durchführung der Risikoanalyse (4 pp.)
9) Ausgewählte Organisationen und Kontaktpersonen zur Risikoanalyse (13 pp.)
10) Risikoanalyse – Methode zur Vergabe von Relativwerten (MVR) am Beispiel von Hangrutschungen, PGRSAP-GTZ-Wachholtz Survey Ltda, 2003 (7 pp.)
11) Interaktive CD-ROM „Digitaler Informationspool zu Naturkatastrophen und Katastrophenvorsorge“.

The following are suggested for **further reading**:

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