WP1 deliverables: AIDA project conceptual framework & Information resources review

Task 1.0.1: Conceptual framework

Task 1.0.3: Information resources review

Author: Norman Kerle, ITC

Part I: Disaster risk conceptualised, and the situation in Africa
Part II: Global and international DRM initiatives, and ICT for DRM in Africa

Table of contents

1. Objectives and scope of this document ... 4
2. Natural disasters in Africa ... 4
  2.1 Scale and numbers ... 8
  2.2 Understanding disaster statistics ... 10
3. Disaster management conceptualised ... 10
  3.1 Hazard ... 11
  3.2 Elements at risk ... 13
  3.3 Vulnerability ... 14
  3.4 From risk to Disaster Risk Reduction (DRR) ... 18
    3.4.1 Defining risk ... 18
    3.4.2 The effect of capacity ... 20
    3.4.3 Practical risk assessment ... 21
    3.4.4 Managing risk & acceptable risk ... 24
4. The scalability of risk ... 25
5. The hazard situation in Africa ... 27
  5.1 Hazard-assessment at a continental and regional scale ... 27
    5.1.1 Seismic hazard ... 28
    5.1.2 Volcanic hazard ... 30
    5.1.3 Droughts ... 32
    5.1.4 Flood hazard ... 35
    5.1.5 Windstorms ... 38
    5.1.6 Tsunamis ... 41
    5.1.7 Wildfires ... 42
    5.1.8 Epidemics ... 44
    5.1.9 Hazard from sea level rise ... 47
    5.1.10 Hazards from grasshoppers and locusts ... 50
  5.2 Summary ... 51
6. From hazard to risk ... 52
  6.1 Vulnerability in Africa ... 53
  6.2 Summary ... 54
7. Disaster Risk Reduction policies and strategies ... 55
  7.1 International Decade for Natural Disaster Reduction (IDNDR) ... 55
  7.2 The Geneva Mandate ... 56
  7.3 International Strategy for Disaster Reduction (ISDR) ... 57
  7.4 The Hyogo Framework for Action (HFA) ... 58
  7.5 Global Facility for Disaster Reduction and Recovery (GFDRR) ... 60
  7.6 The International Charter “Space and Major Disasters” and GEOSS ... 60
  7.7 Initiatives within Africa ... 62
  7.8 Summary ... 63
8. The role of ICT for DRM in Africa ... 64

8.1 Information and Communication Technology (ICT) 64
8.2 Communication technology in Africa 65
9. International ICT-based DRM efforts directed towards or including Africa 68
9.1 Seismic hazard 68
9.2 Volcanic hazard 70
9.3 Drought hazard 72
9.4 Flooding Hazard 75
9.5 Windstorm hazard 76
9.6 Tsunami hazard 77
9.7 Wildfire hazard 78
9.8 Epidemics 79
9.9 Sea level rise 80
9.10 Locusts/grasshoppers 81
10. Tools for information transfer and use – beyond the internet 82
10.1 GEONETCast 83
11. African ICT initiatives 85
11.1 Earth observation and space communication technology 85
11.2 Capacity building in ICT 88
11.3 Regional ICT efforts for DRM 89
11.3.1 ODINAFRICA 89
11.3.2 AfricaArray for seismic monitoring 90
11.3.3 Regional Subsahara Wildland Fire Network (Afrifirenet) 90
12. Summary 91
13. Acronym list 94
14. References 96

PART I - Disaster risk conceptualised, and the situation in Africa

1. Objectives and scope of this document

The purpose of this conceptual framework (CF) is to set the scene for AIDA, to provide a common basis for the various work packages, as well as for other stakeholders attached to or involved in AIDA. It reviews (i) the hazard, vulnerability, risk (HVR) and disaster situation in Africa as a whole, (ii) their scale, distribution and consequences, (iii) the various players in disaster risk management (DRM), (iv) existing policies and approaches with respect to international initiatives such as the Hyogo Framework for Action (HFA), and (v) provides a set of definitions for terms and concepts used. It further addresses the role of Information and Communication Technology (ICT) in Africa, and provides an inventory of international hazard monitoring systems that are aimed at or include Africa, tools for data and information generation, management and dissemination, as well as significant DRM initiatives originating on the continent and with regional or continental scale. In addition to WP1 deliverable 1.0.1., the Conceptual Framework, the document includes a thorough Information resources review as deliverable 1.0.3.

Disaster management, in itself a controversial idiom, is strongly characterised by terms being used interchangeably and incorrectly. This has to be avoided for a project that will provide valuable information on the status of HVR in Africa, and the utility of ICT to reduce and mitigate them, and may thus form a decision-making basis for future resource allocation. Thus the following sections also conceptualise the issue and provide a comprehensive term overview. After that a more detailed assessment of the HVR and disaster situation will follow, integrated in the discussion on scale that is begun in the disaster management conceptualisation.

The CF limits itself to a review at a continental to regional scale. Many noteworthy ICT-based efforts for DRM exist at national levels, but those fall outside the scope of the document. It is rather meant to allow all contributors to AIDA to use the same terminology and concepts, and to be aware of efforts that are either being set up or already operational. Lastly, the CF is a dynamic document that will be revised and expanded as needed as AIDA progresses.

2. Natural disasters in Africa

Natural disasters are continuously increasing in number globally, and there is agreement that (i) vulnerability is rising worldwide, (ii) economic damage and the number of affected people is continuing to increase, and (iii) that disasters constitute a severe impediment to economic growth. This is especially true for developing countries, which have suffered more than 90% of all fatalities, and have been disproportionally burdened by the economic losses as well, due to, amongst other reasons, their lower GDP, limited reserves, and an under-developed insurance industry. While Asia has been confronted with the largest absolute number of annual natural disasters, Africa has seen the most rapid increase in recent years. Figure 1 shows the number of reported natural disaster worldwide since 1900, illustrating the strong upward trend. A similar development can be observed for the number of affected people (Figure 2), with the data strongly marked by large numbers associated with individual events and specific disaster types. While, for example, the 2002 Asian tsunami affected approximately 2.5 million people, and up to 3.2 million were reported affected during Hurricane Nargis in Myanmar in 2008, in particular flooding results in the largest numbers of affected people. In 2007 in China a reported 108 million people were affected by flood events (CRED, 2008), while other sources reported up to 200 million (e.g. Reuter's Alertnet; www.alertnet.org) The largest event recorded in Africa was a drought in 1999 that affected some 23 million people in greater Kenya (CRED, 2008).

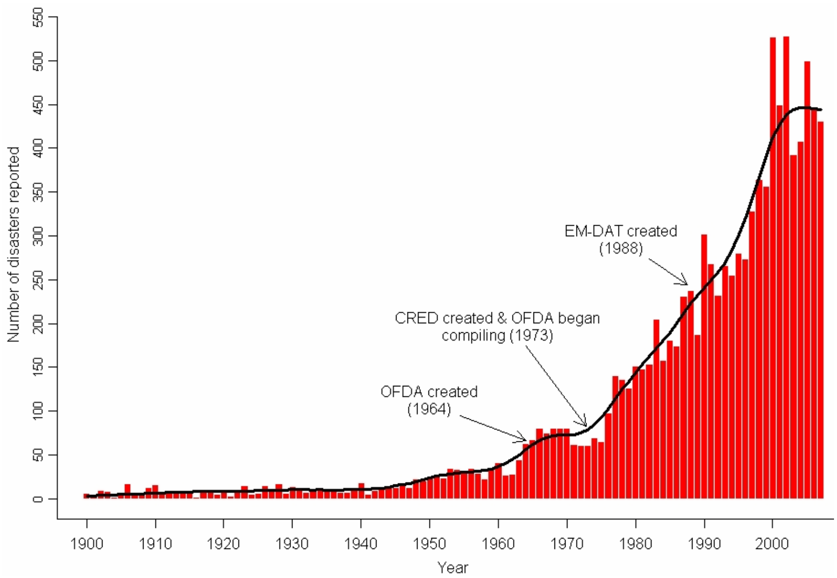


Figure 1: Number of natural disaster reported between 1900-2007. (Source: EM-DAT. OFTA/CRED International Disaster Database, Université Catholique de Louvain)

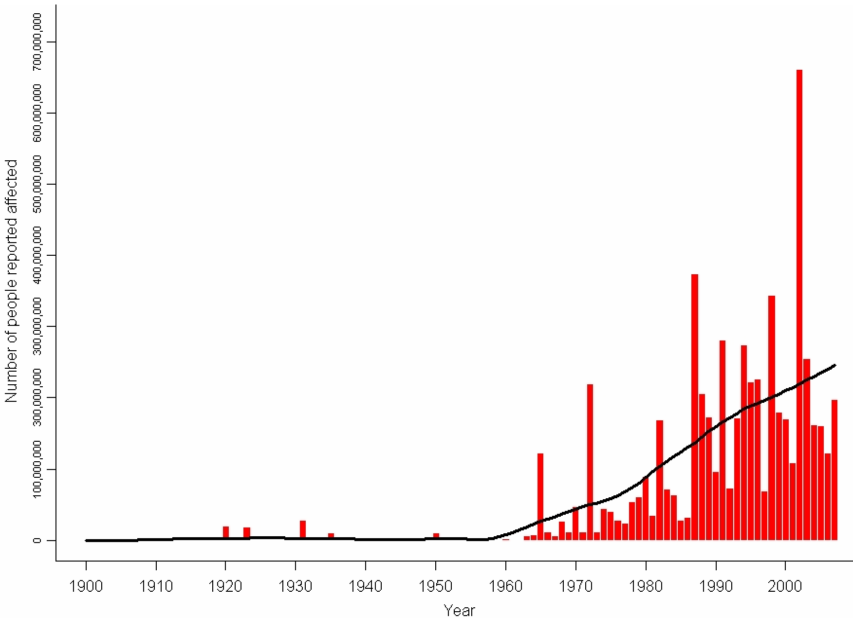


Figure 2: Number of people reported affected by natural disasters between 1900-2007 (Source: EM-DAT. OFTA/CRED International Disaster Database, Université Catholique de Louvain).

Of the 5,210 natural disasters reported between 1991 and 2005, a total of 1,031 events took place in Africa (Figure 3). Of those the majority (58%) was hydrometeorological in origin (drought, flooding, windstorms, extreme heat), followed by biological events (38%) that include for example epidemics and insect infestations. Geological events (e.g. earthquakes, volcanic eruptions, and tsunamis) occur comparatively rarely (3% of all events), reflecting the comparative geological stability of the continent. Over the last 25 years Africa has thus experienced about 20% of all reported natural disaster events. However, it is also the continent that has seen the strongest increase in the number of events (Figure 4).

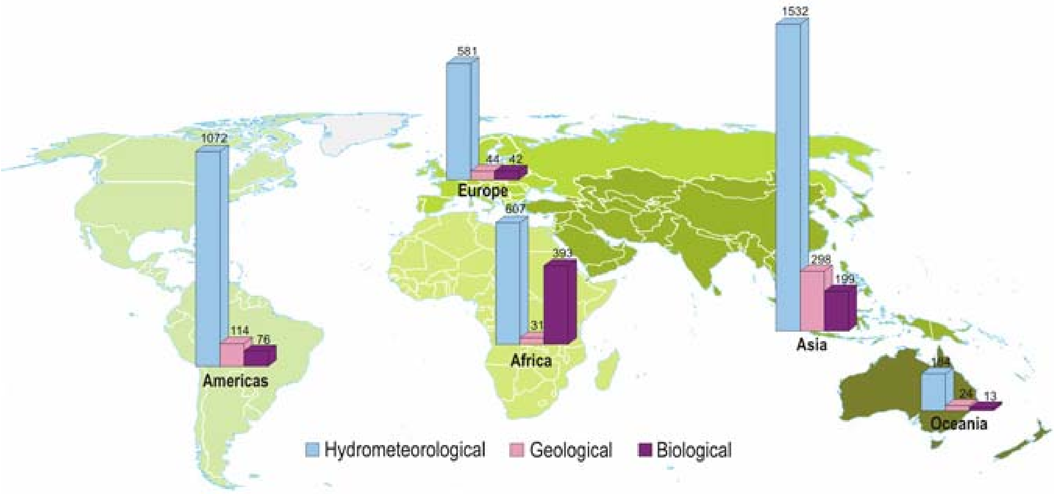


Figure 3: Regional distribution of natural disaster by origin between 1991-2005 (Source: ISDR/ EM-DAT. OFTA/CRED International Disaster Database, Université Catholique de Louvain).

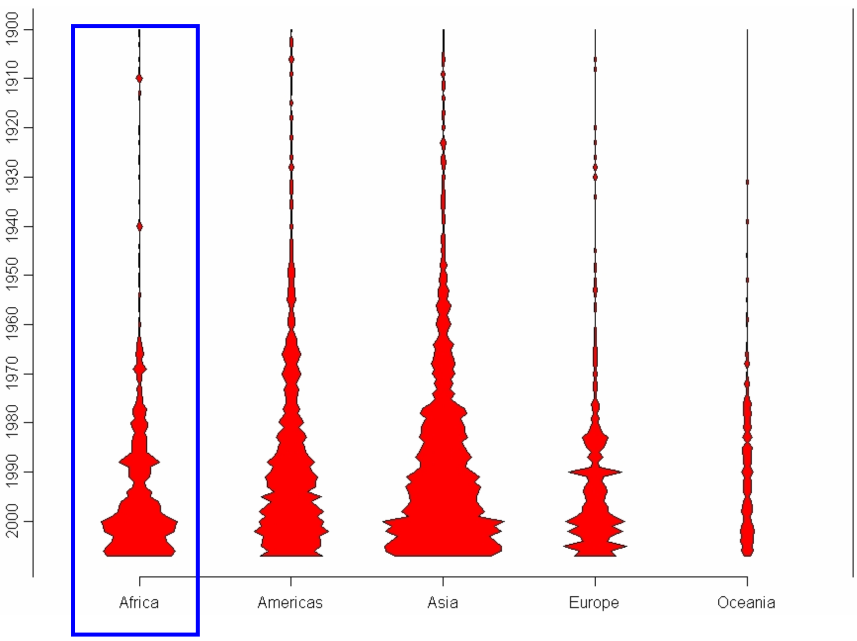


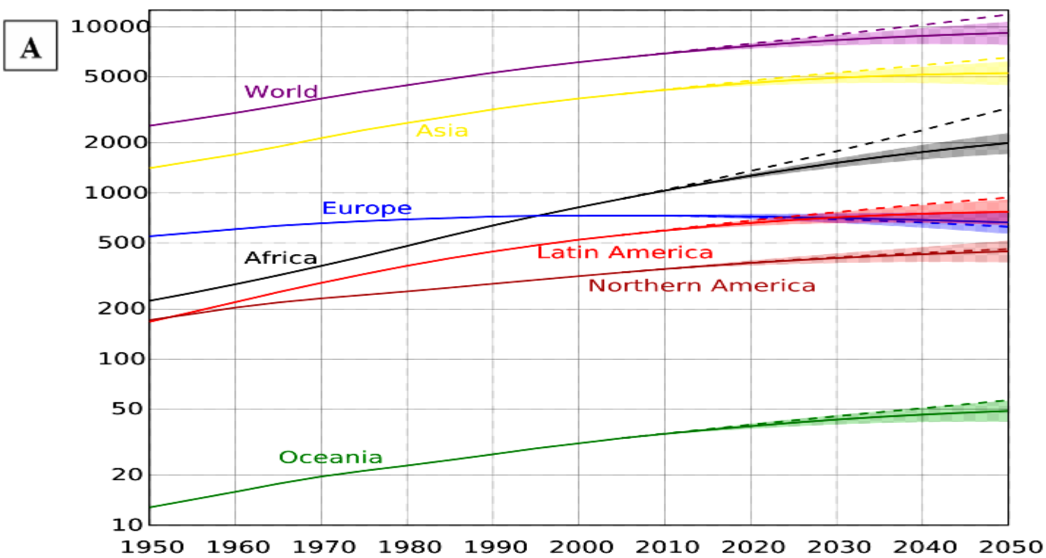
Figure 4: Number of reported natural disasters between 1900-2007 per continent. Africa has seen the strongest increase. (Source: EM-DAT. OFTA/CRED International Disaster Database, Université Catholique de Louvain).

There are several reasons for the increase in the number of events, of which some are generally agreed upon, while others remain controversial.

- With the number of people growing from approximately 790 million in 1750 to 6.6 billion in 2008 (Figure 5), a natural event is now more likely to occur in populated areas than in the past, as population growth leads to higher element at risk numbers, and, consequently, higher risk and disaster rates (see section 3 for a review of relevant terms and concepts).
- One consequence of the strong population growth is that the poorer population fractions are frequently marginalised and forced to settle in hazardous areas such

as unstable slopes or floodplains, where even events at a modest magnitude can lead to a disaster. Such spatial marginalisation is usually also coupled with socio-political marginalisation, meaning that lack of access to education, adequate healthcare and sanitation, but also savings or access to other financial resources, and lack of political lobbying power, lead to increased vulnerability, as further laid out in section 3 (UN-HABITAT, 2003).

- With global economic development the amount of wealth and thus potentially destroyable assets has also increased rapidly. With more assets that may suffer damage or destruction during an event, the number of disasters also rises. For example, where previously a modest flood or seismic event would have gone barely recorded, it now readily results in damage in the million or even billion US$ range.
- The very low number of historic disasters in Africa, particularly until the 1960 and 70s, is also a result of patchy reporting and comparative lack of interest. Only with more interest in the affairs of the continent, the advent of seamless media coverage in all parts of the globe, with increasingly ubiquitous real-time reporting and better internet penetration, has reporting become more comprehensive. It may thus be that the increase in the number of actual disastrous events in Africa before the 1970s was less strong than is suggested by Figure 4. Section 2.1 discusses further why some reported numbers may be incorrect.
- More contentious has been the debate about hazards becoming more frequent and severe as a result of global warming. Environmental changes associated with global warning have been well documented, for example in the recent 4 reports by the Intergovernmental Panel on Climate Change (e.g. IPCC, 2007). The changes documented to have been occurring, as well as those projected, strongly affect various aspects of the environmental system, with consequences for environmental hazards. The changes relate in particular to hydrometerological hazards (stronger windstorms, flooding [from more severe precipitation as well as coastal flooding with rising sea levels]), general precipitation regime changes that can either lead to stronger flooding to more severe droughts (Gregory et al., 2005). Another significant change related to rising temperatures that has already been observed is disease spreading. For example, in Kenya, Malaria has been found to be occurring at ever higher elevations since the 1960s, whereby deforestation has also been found to contribute (Afrane et al., 2007). Geological hazards are not normally influenced by global warming, the exception being mountain hazards that increase with glacier melting, resulting in slope instability and runout flows. The so-called Jökulhlaups occur when ice-dammed lakes break free, resulting in devastating floods.



B

Region	1750	1800	1850	1900	1950	1999	2050	2150
World	100	100	100	100	100	100	100	100
Asia	63.5	64.9	64.1	57.4	55.6	60.8	59.1	57.1
Europe	20.6	20.8	21.9	24.7	21.7	12.2	7.0	5.3
Africa	13.4	10.9	8.8	8.1	8.8	12.8	19.8	23.7
Latin America and the Caribbean *	2.0	2.5	3.0	4.5	6.6	8.5	9.1	9.4
Northern America *	0.3	0.7	2.1	5.0	6.8	5.1	4.4	4.1
Oceania	0.3	0.2	0.2	0.4	0.5	0.5	0.5	0.5

Figure 5: A - Population growth per continent between 1950 and 2050; B – per-continent historical and predicted populations by percentage distribution (Source: Wikipedia)

2.1 Scale and numbers

Neither the distribution of the disasters tabulated above, nor that of the number of affected people is in any way uniform across the African continent. Being geographically and geologically diverse, it displays a range in natural and man-induced/-amplified hazards comparable to other parts of the world. Figure 6 shows the most common hazards to have affected Africa in recent decades. Apart from epidemics, in particular HIV/AIDS, it is the globally most common natural hazards that also dominate the situation here. With an inhomogeneous continental situation there are regional trends in hazard distribution (see chapter 5), and the way hazard events kill or otherwise affect the people. The main graph in Figure 6 shows the number of fatalities from 1975-2001, sorted by hazard type. Drought, especially in the Horn of Africa, as well as south-eastern Africa, has killed most people. In western and central Africa it is epidemics that have caused most fatalities, while flooding has claimed most lives at the northern and southern continental edges. The limited utility of such broad statistics is illustrated by the windstorm category that accounts for most fatalities in the island states around Madagascar. However, windstorms typically cause death through tidal waves and flash flooding, less so by wind force itself. Thus boundaries between hazard types can be fluid. After all, much of the flooding indicated in the graph will also have been caused by excessive precipitation resulting from storm systems. Of equal importance is the underlying database, and the reporting quality that has led to it. The main disaster reference database, EM-DAT, or Emergency Events Database, maintained by the Center for Research on the Epidemiology of Disasters (CRED; http://www.cred.be/) at the Catholic University of Louvaine in Belgium, is the source of the disaster overviews shown in Figure 1 to Figure 4. Disaster events are registered in the database if they satisfy **at least one** of the following criteria:

- Ten (10) or more people are reported killed;
- Hundred (100) people are reported affected;
- A state of emergency is declared, or
- A call for international assistance is issued.

With support by the US Agency for International Development's Office of Foreign Disaster Assistance (OFDA), EM-DAT has been maintained since 1988. It contains core data on the occurrence and effects of more than 15,000 disasters in the world that have occurred from 1900 to the present. The database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies.

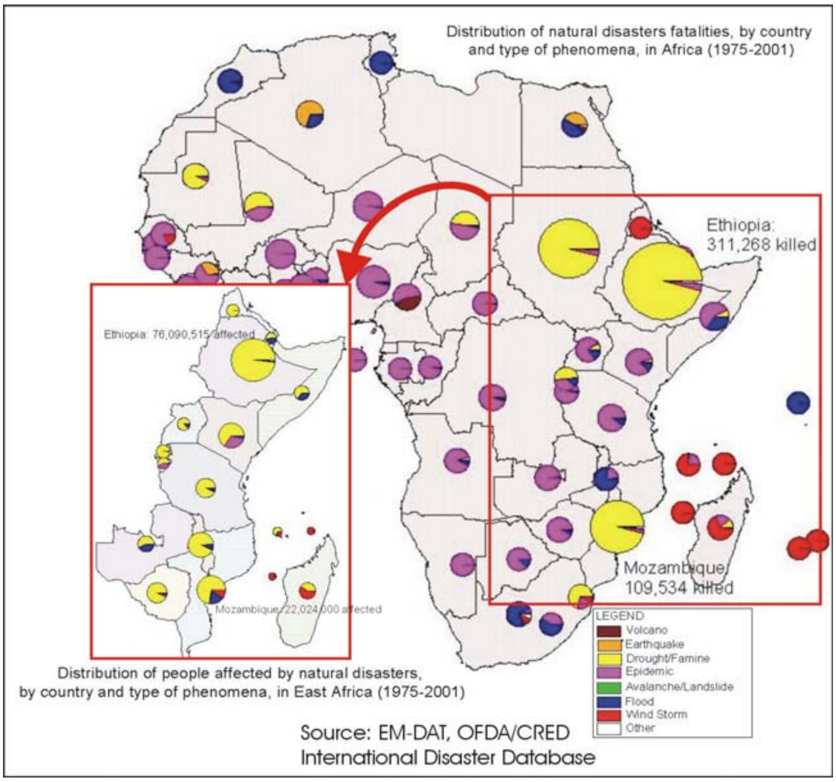


Figure 6: Number of affected people per hazard type in Africa, with inset showing the number of fatalities for the Eastern part of the continent (1975-2001).

The **number of people killed** includes persons confirmed as dead as well as persons missing and presumed dead. **People affected** are those who require immediate assistance during a period of emergency (i.e. including basic survival aid such as food, water, sanitation, shelter, or immediate medical aid). **People reported injured** or **homeless** are aggregated with those reported affected to produce a **total number of people affected** (CRED, 2008).

The relatively low thresholds in principle do work towards a comprehensive reporting on disaster events. However, for the statistics to be reliable it requires a seamless reporting in all countries and for all disaster types. This may still be challenging for (i) isolated or small scale disaster events that are not reported to higher administrative levels, (ii) in countries or at times where comparatively small events fade in significance compared to the general socio-economic or political situation, (iii) in countries where no adequate reporting infrastructure exists, (iv) in countries with no interest to report the actual occurrence of a disaster or its consequences, (v) conversely, where an interest exists to exaggerate the scale of an event for political or financial assistance reasons, and (vi) where secondary disasters are not reported separately from the main event, e.g. landslides following an earthquake or a tropical storm. Examples for those difficulties in Africa could be countries such as the Democratic Republic of Congo (DRC) and Somalia (i, ii, iii), or Sudan (iv). Point (vi) is a particularly difficult one as secondary events may go largely unnoticed (e.g. a fire outbreak following an earthquake), where the lethal agent is difficult to assess (e.g. flooding or high winds during a storm, or disease instead of malnutrition during a famine). Also numbers of flood victims have to be considered with care. For example, in recent floods in Mozambique more people died of disease (mostly cholera) than the actual flooding (Naidoo and Patric, 2002).

2.2 Understanding disaster statistics

It is important (i) to understand the sources and the nature of statistical data and that they may be incomplete, or at times over- or understate the actual disaster number and consequences, (ii) to realise that data are usually tabularised following administrative units that may poorly reflect the actual area affected by hazardous events or its consequences, and (iii) that many hazard types often occur jointly, or that certain events lead to typical secondary hazards, such as earthquakes resulting in landslides or disease outbreaks.

Disaster event and damage statistics are clearly a critical part of the risk assessment procedure, as well as to focus the deployment of limited resources. However, the information, and how it relates to different hazard/disaster aspects, needs to be well understood. If the information in Figure 6 was to be used to determine especially hazardous parts of Africa it would have to be decided what the determining criterion is: the inset does not show the number of fatalities per hazard type, but rather the estimated number of affected people, leading to a rather different situation. While, for example, in Ethiopia most people are both killed and affected by drought, in Kenya or Tanzania epidemics kill most people, while a far larger share is affected by drought. Thus decisions have to be made on whether fatalities or the number of affected persons constitute the graver problem, as resulting risk and thus priority maps will differ accordingly.

What, then, is meant by **affected**? As with any statistic the definition of terms is critical. The UN's International Strategy for Disaster Reduction (ISDR) has discussed this problem (http://www.unisdr.org/), as summarised and amended here. It is clear that the term is open to definition, and may be variable in spatial and temporal scales. For example, experiencing a drought for a few weeks will clearly have a different effect from prolonged droughts that may span years (similar to the 6 years of drought Australia has been suffering). Additionally, numbers of affected people are usually derived from statistical data. For that the population in part of an affected area can be counted, and results extrapolated for the entire area affected by the event. It can also be done based on census data, with results, naturally, only being as good as the underlying data and the assumptions made. With recent and accurate census counts missing in many African countries, such estimations of affected people will contain inaccuracies. Data can further be skewed by variable rationales behind data collection. Reinsurance companies, for example, may prioritise their data collection in areas of particular interest to their business, which may leave out poorer areas. For natural disasters during the last decade, data on fatalities were reported to be missing in about 10% of all events, while some 20% lack information on the total number of people affected, and about 70% do not cover economic damages (ISDR, 2006). A further source of ambiguity can be the dates given for disaster events, which can result in incorrect statics. In particular for long-lasting disasters, such as drought, a single date may be meaningless. In such case it is customary to use the date an official state of emergency was declared by an appropriate organisation, though this should be made clear and done consistently. Long-term trends can be rendered inaccurate or potentially useless where administrative boundaries change, as it invalidates subsequent statistical tabulation or analysis.

3. Disaster management conceptualised

Disaster management is a summary-term for the assessment of hazard, vulnerability and risk, which then forms the foundation for a comprehensive evaluation of risk reduction and disaster mitigation measures. The term itself, even though it has become the prominent idiom in this field, is ill-chosen, as the objective should not be to manage a disaster, but rather to work towards understanding what may lead to a disaster of different magnitudes, and how to avoid or mitigate disasters. It is thus at best a historically applicable term, where dealing with disasters was reactionary for lack of mitigation and early warning means, but also lack of conceptual understanding of what causes disasters, and how they can be avoided or their impact reduced. A key tenet of the environmental determinism school, it reflects the now largely outdated belief that disasters are caused by a violent nature on helpless society and cannot be avoided (Alexander, 1991; Smith, 2001). It is now widely understood that a disaster is a result of a **hazard/hazardous agent**, i.e. an event that can cause harmful consequences, but only if that event spatially intersects with **elements at risk**, such as people or infrastructure, that are **vulnerable** to be affected (Blaikie et al., 1994; Wisner et al., 2003). ‘Affected’ here can cover the entire range from injured/interrupted to killed/destroyed (see 2.2). A hazard can thus be a natural phenomenon such as an earthquake or volcanic eruption, a man-made event such as a chemical spill, or man-aggravated such as a landslide on a deforested slope, or flooding in an area where a river course has been artificially constrained by dikes or levees. All three terms are discussed in detail below.

3.1 Hazard

A hazard is a potentially damaging physical event, phenomenon and/or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can also include latent conditions that may represent future threats and can have different origins: natural (geological, hydrometeorological and biological), or induced by human processes (environmental degradation and technological hazards). Different hazards can occur concurrently or sequentially, with potential interference and amplification. For example an earthquake can introduce instability in a previously stable slope, or weaken a dam, resulting in a secondary technological hazard. A hazard is characterised by its type, location, intensity, frequency and probability. For example, an annual flooding event with a certain water height and duration may constitute a readily quantifiable hazard to people or infrastructure, with the hazard declining with increasing distance from the source of the threat (e.g. the river or coast). A 100-year-flood, on the other hand, while much lower in annual probability ($p=0.01$ instead of $p=1$ for a given year), represents a more severe hazard, as water height and overall energy of the flood system by definition are higher. Additionally, because of the higher water levels the affected area will be larger, leading to a more spatially extensive threat, i.e. a hazard also being present where there is none with respect to an annual flood. The above mentioned hazard degradation away from the source, as is typical for flooding, is not universally applicable. The actual location within, for example, a lava flow, landslide to toxic gas cloud is likely to make little difference to people and, with the exception of gas clouds, infrastructure. A detailed consideration of the hazard characteristics, however, is needed, as for example the landslide or gas type may have variable consequences.

A comprehensive overview of the history of hazard theory is given by Bryant (2004). The book reviews how hazards, initially more natural than man-made, have accompanied human existence, and impacted on it, both temporarily and with limited spatial extent, but also more lastingly and at regional to global scales. It further recounts the effect of hazards and hazardous events on myths and legends, and the beginning transition from catastrophism, i.e. the belief of disasters as divine punishment, to scientific understanding at the time of the Enlightenment in the mid-18th century. From this emerged the concept of uniformitarianism, which stipulates that (i) what we observe or what happens in nature follows natural laws (thus countering the beliefs of the catastrophists), and (ii) a constancy of rates of change or material condition through time. The latter implies that processes measured or observed today, such as erosion or wave action, have occurred in a comparable manner also in the past, and will continue to do so in the future. It does not, however, imply a linear continuity or constancy – after all, entire landscapes have resulted from individual, often cataclysmic events. This in fact poses one of the most substantial challenges in hazard research: we can observe from past records (e.g. geological) was has happened only when it has been preserved, which is clearly not always the case. Furthermore, while the past, also for hazards, is the key to the future, nature does show tremendous variability and extremes, meaning that hazardous events at magnitudes never before witnessed or observed in the record may occur. While for some hazards, in particular those of geological origin, comprehensive and often nearly complete records exist for many parts of the world, which can be used to determine likely intensity/frequency relationships, this is not true for other hazard types. We have limited or no information on disease outbreaks in historic or pre-historic times, and likely only a fraction of all asteroids hitting Earth has been identified, leading to uncertainty in hazard assessment. The situation is also difficult when hazards interact or compound each other. For example the hazard to a person posed by a flue virus may under normal conditions be low; however, when affecting persons weakened by malnutrition following a drought, or by a HIV infection, the threat will be substantially higher.

From a hazard assessment and quantification perspective it is important to note that two rather different concepts of hazard exist. Hazards are seen either as (i) any **event or situation that may pose a danger or threat**, be it natural or man-induced/-amplified, with the potential to affect adversely human health, property, the environment or economic activity, or (ii) the **probability of occurrence of a potentially damaging phenomenon** caused by a natural or man-induced/-amplified process or situation within a specified period of time and given area (e.g. van Westen et al., 2006). (i) describes a situation with the potential for destruction that has an implicit, though not necessarily known, probability of occurrence. For example, a boulder perched on the edge of a cliff likely poses a hazard for persons or assets being present near the bottom of the cliff as the boulder may fall. However, how long that boulder has already been in its current location, which processes may lead to its dislocation, their rate, and thus the probability of that happening may well not be known. Definition (ii), however, explicitly refers to a probability, and ideally separately assessed as spatial and temporal probability. For a 10-year flood event, for example, the area potentially covered by water will thus be assigned a hazard with p=0.1/year. Strictly speaking, however, a calculation would have to reflect the variability of hazard magnitude within the flooded area as a function of water depth, meaning that the hazard value would in principle have to be assessed for every point in the flooded are. This means that a given hazard value should not only location and time-period specific, but also magnitude-specific. The advantage of (ii) though is that it leads to a defined value (a probability between 0 and 1) that can be used to calculate risk (see 3.4). Definition (i) does not lead to such a value and is thus more of a qualitative statement. Several comprehensive glossaries exist that cover all hazard and risk related terms, for example at http://pdm.medicine.wisc.edu/vocab.htm, or the extensive Multi Language Risk Management Glossary (www.europhras.org/anderedokumente/GMLGR5L_6_12_07.pdf), prepared under a FP6 project.

Apart from difficulties in definition, the aforementioned tenet of continuity or constancy is increasingly challenged (see for example Smith, 2001, for a detailed discussion). If a natural process in the past occurred with a certain intensity-frequency relationship, subsequent anthropogenic impact on the natural system containing or impinging on that process may have changed that relationship. This implies that observed hazard parameters, e.g. the frequency of tropical storms of a certain scale, or the maximum wave height during a storm surge, may not be valid as a prediction tool for future hazards anymore. This is not only a problem for natural hazards, but even more so for biological threats. For example, the change in malaria hazard as a function of rising temperatures (see section 2) means that computer models used to assess the threat of malaria spreading have to be adapted to the changing situation. Similarly, hazards reliant on other vectors, for examples humans participating on global travel, change their reach and coverage with increasing global air travel and freight shipping numbers. Hence, what may have been a local hazard in times when travel was more restricted now easily becomes a global hazard. The issue of scale is addressed in more detail in section 4.

3.2 Elements at risk

As laid out in section 3.1, a hazard may lead to the loss of life, injury or damage, implying that a hazard can not exist in isolation, but rather is defined by its interaction with elements on which the damage, injury or degradation can be inflicted. Those elements are termed **elements at risk** (EaR), and comprise people, household and community facilities and services, property, economic activities, and the natural environment. As an example, a landslide, sandstorm or similar natural event on another planet does not normally pose a hazard; however, it may constitute a threat to temporarily present spacecraft or permanent installations. The hazard levels may vary for these two scenarios, as the time period of exposure would be different. However, such proximity is not needed if the hazard has a long reach. For example, solar wind generated by our sun poses an occasionally substantial hazard to telecommunication infrastructure, in particular satellites, despite the distance of some 149 million km on average. In the same manner potential interstellar hazards can be considered, with Earth as a whole being a potential EaR..

We can thus note that in addition to a record of the presence of a potential EaR, we also require additional information on their characteristics. For example, a dwelling made of temporary material such as cardboard and scrap metal will interact differently with a hazard such as a flood or a windstorm compared to a reinforced concrete building. This implies that a given EaR behaves differently to different hazards. An adobe building may provide better resistance to a wind storm than a flimsy temporary shelter; however, the latter may better withstand the motion during an earthquake. This means that we need to consider what is termed the **vulnerability** of the EaR (e.g. Papathoma-Kohle et al., 2007). This aspect is further discussed in section 3.3. Table 1 gives an overview of typical EaRs that may have to be included in a risk assessment study. Note that such a study not only includes a mapping of the element, e.g. building, but also its relevance to risk has to be included, meaning that we have to understand its characteristics in terms of hazard-specific vulnerability, its value to estimate potential losses, but also the potential wider significance of a given EaR during a disaster. This can be negative, e.g. the disproportionate effect of losing electricity or a major transportation hub, or the headquarter of emergency management (such as the loss of the Disaster Command Center located in the World Trade Center in Yew York during the 2001 attack). However, EaRs can also play a disproportionally positive role. For example, a storm or flood shelter can be considered as a building with a certain vulnerability to a given hazard type and magnitude. However, it can also dramatically increase the **capacity** of the affected community, thus having a positive influence on the overall risk (for a detailed discussion on capacity see 3.4.2).

Elements at risk

Population

- Overall population (per administrative and area unit)
- Special needs fractions (children, elderly, disabled, migrants, homeless, etc.)
- Concentrations of populations
- Activity-based location (e.g. temporal distribution as function of occupancy)

Building stock
- Residential buildings (sorted by single- or multi-family, temporary/ mobile)
- Industrial (e.g. light, heavy, food, drugs, chemical, nuclear)
- Commercial (e.g. retail, professional, banks, hotels)
- Institutional (e.g. religious, education, recreational, entertainment)

Critical facilities
- Public safety (police, fire station, hospitals/medical care, public shelters)
- Transportation hubs (airports, train and bus terminals, ports)
- High loss facilities (e.g. nuclear power stations, dams, military installations)
- Hazardous facilities (e.g. nuclear power stations, chemical facilities, refineries)

Transportation infrastructure
- Airports
- Roads
- Bridges
- Tunnels
- Rail lines
- Bus or other public transit infrastructure
- Ports and ferries

Lifelines (excl. transport)
- Water system
- Electricity grid (including transformer stations and other critical knots)
- Communication
- Sewage
- Gas grid
- Oil pipeline system
- Emergency power systems

Environment
- Water resources
- Forest resources
- Agricultural resources
- Biodiversity
- Protected areas (type, location, extent, known vulnerability)
- Other natural resources of value or significance

Table 1: Elements at risk that may have to be considered in comprehensive risk assessment.

3.3 Vulnerability

Environmental determinism went hand in hand with the idea of bounded rationality that assumed that humans will essentially not learn from their mistakes and always return to rebuilt on the debris left by a disaster. This theory has also long been superseded by better understanding on the concept of **vulnerability** and what causes and motivates people to live in harms way and have limited capacity to withstand a hazardous event. However, the notion of people not being able to learn from their mistakes, and to move (back) into hazardous areas, still has some merit, and will become relevant again in the more specific discussion on national and local vulnerability, as well as the notion of **acceptable risk** (section 3.4.4).

The idea of society being helpless against nature was challenged by the idea that industrialisation would lead to technical and scientific progress that would also provide a safeguard against hazardous events, and that thus in a post-industrial society nature would be tamed and disaster cease to occur. Central to the theory was thus that man had the ability to conquer nature. Yet this thinking largely divorced natural events from society, as if they were unrelated. A disaster could occur as a result of a natural process, and somehow safeguards, increasingly of an engineering nature, could prevent harm from being done. Rivers were being dammed or straightened, floodplains cut off, but also the first fire codes (e.g. in the 1850s in California) and building codes (1920s) implemented. This thinking was questioned by White (1945), a geographer who led the influential **Chicago-school** for decades. The geography-based approach centered on considering the social system as well, thus potentially allowing also for solutions other than physical or structural. Increasingly sociologists jointed research in this field and focused on the role people and society play (Smith, 2001).

The 1960s and 1970s were marked by disasters with exceptional losses. The 1965-67 drought in India caused some 1.5 million fatalities, followed shortly afterwards (1968-72) by a drought that killed 1 million in the Sahel. Also the 1970 cyclone in Bangladesh killed an estimated 500,000 people, and the 1976 Tangshan (China) earthquake some 242,000, with other events, as diverse the failed anchovy harvest in Peru or severe cold in the US, happening as well during these years. While the fatality rates caused by these events were not the highest ever seen – the 1928-30 drought in China killed an estimated 3 million, which was followed by the 1931 flood that caused somewhere between 2 and 4 million fatalities – they caused a change in perspective. They exposed a vulnerability to extreme natural events, also in developed countries. Consequently environmental determinism was fundamentally called into question by the **political ecology** school that tried to consider political, economic and social factors, giving rise to the understanding that not only a hazardous nature is required for calamitous events to occur, but that, given that results are not uniform, the specific socio-political and economic environment also determine the consequences of an event. This gave rise to the concept of vulnerability, i.e. a person, society or infrastructural element being prone to injury or damage.

It is now understood that a combination of factors determines the degree to which a person's live and livelihood are at risk during a hazardous event. It can also be defined as a measure of the degree to which a system may be harmed in response to a stimulus. This is true for both events that occur in nature or in society. What we need to know is not only how the stimulus changes, but also which parts of the system will be more susceptible. While this definition is straightforward, vulnerability has been defined from both a purely physical perspective, or exclusively in terms of social construction – thus different concepts can be applicable in different situations. For example, the hazard-based approach to flood hazard may consider flood magnitude, frequency, flow velocity, warning time, and speed of onset. The social perspective would begin with what makes EaR vulnerable. Recent research has thus moved away from the environmental determinism that saw vulnerability only as a risk of exposure to a hazard, to a view as a socially constructed phenomenon, and also synthetic approaches that consider both ends exist (see for example Clark et al., 1998; Cutter et al., 2003). With the acceptance that vulnerability is socially differentiated, two different views developed. The Chicago-school geography developed a **hazard-based view** that sought to understand how human adjustments, e.g. better landuse planning and hazard perception, could be added to the structural mitigation approaches. A competing approach was the **disaster-based view** of sociologists who focused on the collective human behaviour as a critical determinant during a disaster, and on how preparedness could be improved to face such events better (Smith, 2001). Extensive reviews and monographs exist that discuss in more detail the evolution of hazard and vulnerability theory, highlighting in particular the role of political economy and social constructivism, i.e. how social, economic and political structures influence vulnerability, and how social phenomena evolve in a particular social contexts, respectively. Also the role of the individual vs that of community and society has been studied, distinguishing individualism and structuralism, focusing either more on individual psychology or on sociology, prospectively. See for example Cardona et al. (2003).

A more influencing and lasting advance was made by Blaikie et al. (1994), based on the ideas of **political economy**. Their **pressure-and-release model**, also called the **disaster crunch model,** sees disaster as socio-economic processes interacting with physical exposure, They thus focus on the root causes underlying vulnerability, unsafe conditions and dynamic pressure. They see economic, political and demographic processes as the root causes for vulnerability, as they primarily lead to an uneven distribution of resources. To this is added the dynamic pressure that results from socio-political processes and circumstances, such as migration, and that essentially translate the root causes into unsafe conditions. In other words, the root causes can answer *why* people are vulnerable, while dynamic pressures explain *how* those root causes progress into unsafe conditions. The latter are then what express vulnerability in time and space, i.e. the vulnerable context where people are exposed to a hazard. The theory explains vulnerability as the limited capacity to anticipate, cope with, respond to, and recover from external stimuli.

With these developments came renewed attention to the role of under-development, economic dependency and colonial legacy, with research inevitably focusing on the vulnerability of the poor and disadvantaged. This perspective also explained the disproportionate fatality rate due to disasters in less developed countries (see section 2). By the late 1990s work on disaster and risk had become complex, with various disciplines contributing, and concepts and theories being defined. Vulnerability became increasingly defined not only aalues a function of exposure, but also capacity and potentiality (Watts and Bohle, 1993). Building on the notion of dynamic pressure, Kelly and Adger (Kelly and Adger, 2000). Brooks et al. (2005) emphasised the dynamic nature of vulnerability. Leichenko and O'Brian (2002) also talked about dynamic vulnerability that incorporates environmental and social changes as they influence the capacity of regions or social groups. Collective (infrastructure) and individual determinants (knowledge, resources) of vulnerability were identified. Another useful definition was given by Jeggle and Stephenson: "Vulnerability is a set of prevailing or consequential conditions, which adversely affect the community's ability to prevent, mitigate, prepare for or respond to hazard events. These long-term factors, weaknesses or constraints affect a household's, community's or society's ability (or inability) to absorb losses after disasters and to recover from the damage".

In recent research typically **4 types of vulnerability** have been considered: **physical**, **social**, **environmental** and **economic**. This describes how different elements at risk (see 3.2 and Table 1) may suffer during a hazardous event. Buildings or other physical infrastructure may be damaged or destroyed, while, for example, people evacuated in time may be in a safe environment and thus not vulnerable. Conversely, for certain hazard events, such as drought, heat waves or chemical spills, the physical infrastructure may remain unaffected, while parts of or society as a whole may be vulnerable. Some hazardous events can turn into disasters if large swaths of the natural environment are destroyed, e.g. during a fire, tsunami, flooding or drought. Depending on the economic basis an economic vulnerability may exist. This will be a function of economic diversity and dependencies within the economic system. For example, a society focused on fishing and fish processing may be highly vulnerable to a hazardous event that may damage the fishing fleet, such as a storm or tsunami. In such a case the main tools for fishing may be destroyed by an event, resulting also in economic consequences for the fish-processing industry due to high interdependence. Clearly, an isolated approach appears unsuitable, as a society is likely to display multiple vulnerabilities.

It is thus clear that vulnerability assumes an even more important role than the hazard itself, already observed in the early 1980s by Hewitt (1983), while at the same time eluding an easy and universally applicable conceptual grasp. Consequently it has been measured in different ways. Anderson and Woodrow (1998) distinguished (i) physical/material, (ii) social/organisational and (iii) motivational/attitudinal vulnerability. Typical characteristics would be for (i) disaster-prone location and poor infrastructure, for (ii) weak social network structure, ineffective decision making and ethnic conflicts, and for (iii) negative attitudes towards change, lack of unity and cooperation, and fatalism. While these parameters are intuitive, a certain inconsistency can also be observed when lack of adequate education is included under (i), or unawareness about hazards is listed as a motivational problem (iii). Developments in hazard theory are visible when the above classification is compared with the one by Maskrey (1998), who considered a total of 9 vulnerability types: physical, technical, economic, environmental, social, political, cultural, educational and institutional. This correctly reflects that essentially every aspect of a community or society is susceptible to disruption and loss. Assessing these various vulnerabilities, however, must be seen as a substantial challenge, due to the need for detailed understanding of what constitutes these different vulnerabilities, the substantial data needs, but also their hazard type and magnitude dependence.

There are further problems, in particular with social vulnerability (SV) indicators. While it is clear that individual characteristics, such as gender or education, influence SV, poor does not necessarily equal vulnerable, a frequent conceptual mistake in the early days. Neither does being female or part of a minority group. It is also not a linear combination of factors: rather there are variable thresholds, joint effects, feedbacks, and linkages between scales. Some researchers have attempted to quantify SV (e.g. Cutter et al., 2003).

This, however, presents a conceptual challenge for quantitative risk assessment. Physical or economic vulnerability characterize a clearly quantifiable degree of loss (Douglas, 2007), which can range between 0 (no loss) and 1 (total loss). SV, on the other hand, links to a person's ability to anticipate, cope with, resist to and recover from the impact of a hazardous event, faces challenges such as scaling. After all, how can we quantify the vulnerability towards an annual flood event, for example for a small child vs a young male adult? The situation is easily assessed qualitatively using logic and reasoning – a child has lower body height, thus will already be challenged to survive in water heights that pose no serious threat to a healthy and strong man, and has less strength. We would thus assign a much higher personal vulnerability to flooding to the child than the young man. This alone, however, is difficult or even impossible to quantify, in particular in a sense of fractional losses. To this we have to add that SV is a combination of personal vulnerability but also that of the immediate family or community, which may reduce or increase the vulnerability. If the child from the above example lives in a family that is well informed about hazards, coping and evacuation means, the vulnerability may ultimately be lower than that of the man if he was, for example, a migrant worker living in a place with a limited social network, and insufficient knowledge on how to behave during a hazard event. In case of a disaster he may thus be caught unaware, thus having in fact a higher SV. This is also true at a larger scale. If, for example during a drought, a community relies on a medicine man or similar spiritual figure to 'bring' rain instead of moving to areas that are less affected by the shortage of water, this community may have a high SV, especially if the miracle hoped for does not happen. Conversely, a single person with relevant knowledge, scientific or otherwise, who is being listened to, can drastically reduce the SV of an entire community if his advise is acted upon.

Realising these challenges in quantifying SV, Kelly and Adger (2000), as well as Smit and Pilifosova (2003), focus on understanding functional relationships rather than calculating absolute SV values. For Rashed and Weeks (2003) an assessment of SV in absolute terms is not possible, as it is continuously modified and varies over space and time. Hence, the principal aim is to identify variables that help explain how SV is generated, as also stated by Clark et al. (1998), for whom the main purpose of vulnerability maps is the ability to identify threatened populations and areas on which to focus limited resources.

3.4 From risk to Disaster Risk Reduction (DRR)

As stated earlier, disaster management is a term of limited accuracy and utility. It has, consequently, been questioned and superseded by **Disaster Risk Management (DRM)** and **Disaster Risk Reduction (DRR)**. DRR is a more accurate term than DM in that is implies a management not of the disaster event itself, but rather of the risk. Risk has become an accepted aspect of life, a condition we are implicitly or explicitly aware of. It is accepted in a sense that we realise a certain vulnerability and potential external shocks that are outside our control, such as when we choose to participate in road travel or more adventurous recreational activities. Thus while the risk is rarely quantified explicitly, it is assumed and accepted that some activities carry a higher risk than others, and we make a decision to accept it or not. We can manage that risk by (i) understanding it and (ii) possibly reducing it, for example by choosing safer transport means (trains or more robust cars), or by avoiding traffic or unsafe recreational activities during certain times or weather. Hence, at a basic psychological level there is generally awareness of the three risk components – hazard, elements at risk, and vulnerability – and how they interact in principle.

3.4.1 Defining risk

In DRM we realise that the risk of a natural or man-made disaster has similar components, and thus we commonly define risk as the product of hazard (H) and vulnerability (V):

$$\textbf{Risk} = \mathbf{H \times V} \qquad \text{(Equation 1)}$$

This reflects the aforementioned spatial intersection of a hazardous event with vulnerable elements at risk. So far, however, this is only a concept, and a broad one at that. It does not state which hazard(s) is(are) being considered, nor which aspect of vulnerability. The equation thus has to be refined to include information on the hazard type, its magnitude, as well as the specific or combined vulnerability (see 3.3). The risk equation can thus be rewritten for a specific risk:

$$\textbf{Risk (specific)} = \mathbf{H_{(i)} \times V_{(PSEE)}}, \qquad \text{(Equation 2)}$$

where $H_{(i)}$ is the specific hazard, and $V_{(PSEE)}$ = physical, social, economic, environmental

The equation makes clear that risk is not a static variable and does not exist as a single condition or value, but rather that it has to be specified which hazard(s) at which scale is(are) is considered. Thus it can also be distinguished between the risk to a single hazard, or total risk. However, equation 2 does not yet include the elements at risk component (E), resulting in

$$\textbf{Risk (specific)} = \mathbf{H_{(i)} \times V_{(PSEE)} \times E_{(i)}} \qquad \text{(Equation 3)}$$

where $E_{(i)}$ are the relevant elements at risk.

Typically the objective is to arrive at a quantitative value for risk. This, however, is difficult when concepts and units are not easily matched. In its simplest form risk can also be calculated as

$$\textbf{Risk (specific)} = \mathbf{H(i) \times V(PSEE) \times A} \qquad \text{(Equation 4)}$$

where A is the amount, i.e. value of an EaR (see also section 4).

We can consider the example from 3.1, where the flood hazard was p=0.1/year. If we had a building with a value of $50,000 that would get entirely submerged and lost during the flood, the vulnerability to such an event would be $V_{(P)}$ = 1, and the annual risk:

Risk (flooding) = 0.1 x 1 x 50,000 = $5,000 (Equation 5)

This is illustrated in Figure 7. Note that only physical vulnerability, here = 1, i.e. complete submersion and thus loss, is considered.

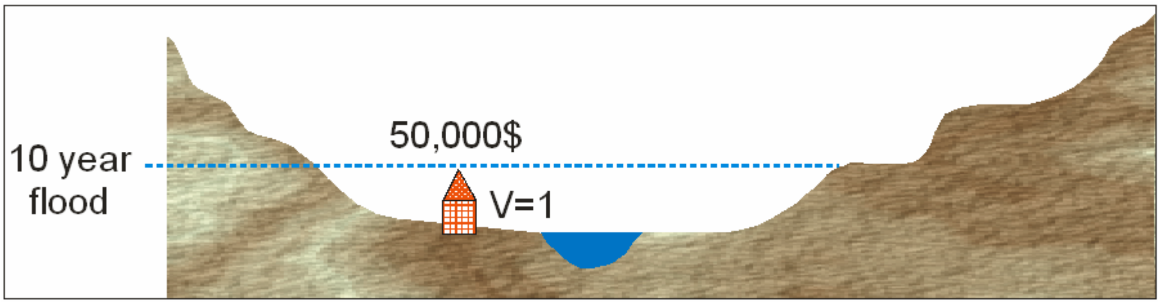


Figure 7: Flood risk for a single building (adapted from ITC lecture material, C. van Westen).

The situation is still comparatively simple for a single building. In Figure 8 the concept is expanded to reflect reality better. Here we have several buildings that relate differently to the extent of the 10 year flood. With losses thus also varying, the vulnerability, and thus risk, has to be adapted, resulting in:

Risk = 0.1 x (0.5 x 200,000) + (1 x 50,000) + (0.1 x 100,000)
= $16,000 (Equation 6)

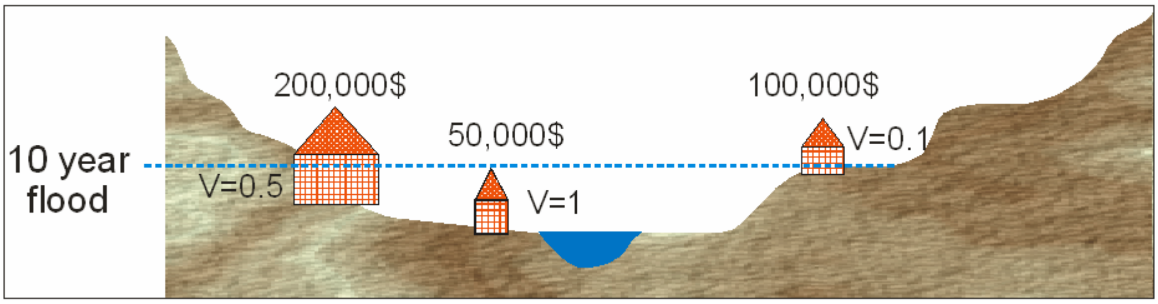


Figure 8: Flood risk for several buildings with variable exposure and vulnerability (adapted from ITC lecture material, C. van Westen).

This, however, only includes the risk for the 10-year flood, which represents but one scenario. Hence a more comprehensive analysis would include different flood scenarios, as shown in Figure 9.

Thus in the final scenario we can calculate the total annual risk for all flood scenarios:

Risk = (0.5 * 0.01 * 50,000) + (0.1 * 0.1 * 50,000) +(0.02 * 1 * 50,000))
= 1,750 US $ (Equation 7)

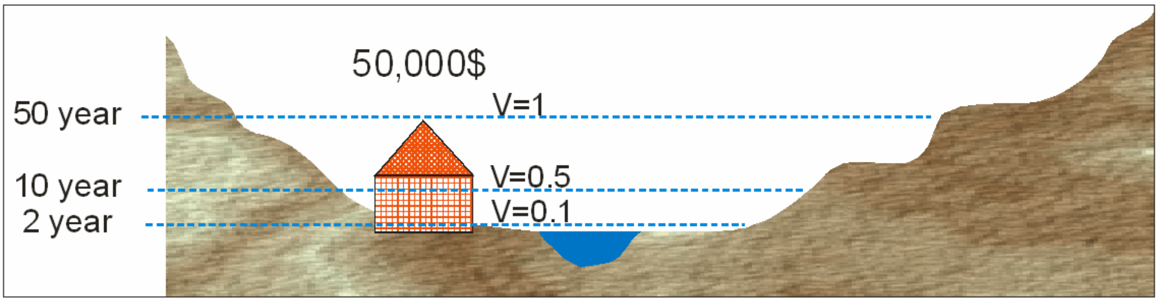


Figure 9: Flood risk for several return periods (adapted from ITC lecture material, C. van Westen).

The risk for different scenarios can also be illustrated in a risk curve, which relates the risk to the likely overall expected loss (see Figure 10).

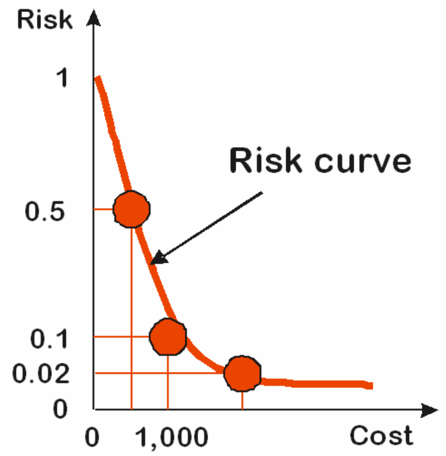


Figure 10: Example of a risk curve.

3.4.2 The effect of capacity

As explained in section 3.3, vulnerability can be considered a condition or set of conditions that reduces people's ability to prepare for, withstand or respond to hazard, and to suffer damage or injury. As per the idea of DRM and DRR, risk can be reduced, on one hand by reducing the hazard, but also by reducing the vulnerability of a system or its elements. That this can be done in 2 ways is clear from Equation 4: we can reduce the hazard, the vulnerability or the value. For example, a landslide hazard can be reduced by reforesting the slope; a flood hazard can be mitigated by creating designated upstream areas that can be flooded when needed. Vulnerability can be reduced, for example by providing a population with knowledge on existing hazards or early warnings, by strengthening social networks, or by providing better access to critical lifelines. The latter can also be considered separately, in addition to the fundamental three parameters of risk: **capacity**. The capacity to cope with an event is the sum of those positive conditions or abilities which increase a person's or a community's ability to deal with hazards. These can thus be policies and institutional systems to reduce the damaging potential of hazards and reduce vulnerability of societal systems, or practical efforts such as ensuring minimal travel distance to evacuation centres and shelters for all citizens (Flint and Luloff, 2005; Allen, 2006). We can thus rewrite the risk equation as follows:

Risk (specific) = H(i) x V(PSEE) x A / Capacity (Equation 8)

Thus, simply put, an increase in capacity offsets the negative contributors and leads to an overall reduction of risk.

3.4.3 Practical risk assessment

The theoretical rules for risk assessment are thus available. In practice, however, this means that we need comprehensive knowledge on (i) all present hazards, (ii) the probability of an event at different magnitudes occurring, (iii) detailed information on the values of all possible affected infrastructure, economic activities, and the environment, and (iv) data on the four types of vulnerability detailed in section 3.3, again differentiated per hazard type, and reflecting both personal as well as group components. The challenges of compiling such data – and using them in a robust manner – are obvious.

The challenge lies in risk being a spatial, and spatially extremely variable, problem. To assess how much flood water will be where, for how long, which building plot may experience liquefaction during an earthquake, or whether a mudflow from a distant volcano will reach a community far away, require solid scientific understanding of the relevant hazards, alone and possibly in combination. This also makes it a multi-disciplinary problem, with (i) hazard assessment being done, for example, by earth scientists or biologists, (ii) EaR mapping by geographer, planners or civil engineers, (iii) cost estimation done by economists, (iv) vulnerability assessment being carried out by structural or civil engineers, and (v) risk assessment being done by geoinformation system (GIS) experts. In its simplest form the footprint of a given hazard is intersected with mapped EaR, taking into consideration that hazard aspects such as type, magnitude or onset speed, as well as the types of EaR and their vulnerability and value, resulting in a risk footprint (Figure 11).

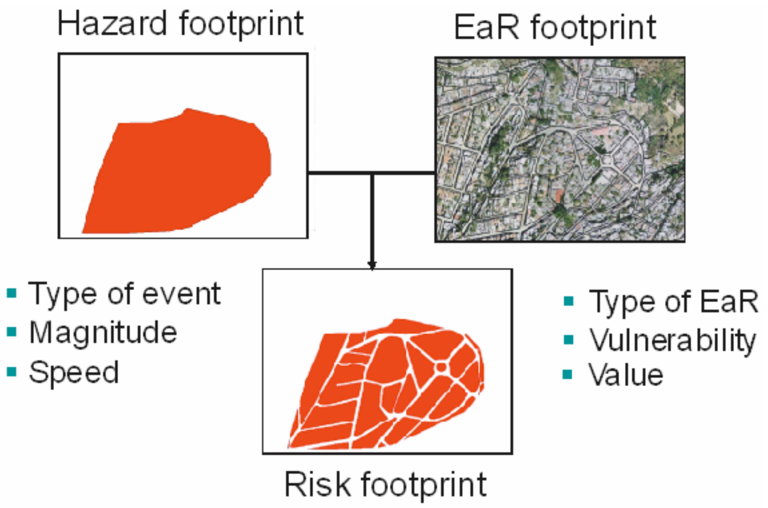


Figure 11: Risk assessment based on intersection of hazard and EaR information.

In addition to the approach shown in Figure 11 there are other methods that can be used to assess risk. The following list provides an overview:

- **Qualitative approaches**
  - Basic map overlaying methods
  - Community-based assessments
- **Semi-quantitative methods**
  - Multi class overlay of hazard and elements at risk
- **Quantitative risk assessment (QRA)**
  - Estimation of direct effects only
  - Complete QRA

With lack of a detailed theoretical basis for risk assessment, but also lacking spatial data, qualitative methods have been employed traditionally. Even the simple footprint overlay method shown in Figure 11 can be considered qualitative unless actual risk numbers are calculated, in which case it can be considered semi-quantitative. The second method – community-based risk assessment – in fact retains substantial value, and research continues in this field, particular in the area of Participatory GIS (PGIS), which is concerned with extracting valuable knowledge from communities, village elders or councils etc., and integrating it with other sources of spatial data, such as satellite images or hazard maps (e.g. Tabara et al., 2003; Raaijmakers et al., 2008). Such mapping and consultation efforts can involve transects or profiles, livelihood or coping analyses, scenario development etc. Often such activities lead to sketch maps of the hazard, vulnerability or risk situation (e.g. Figure 12). This will be considered in more detailed in section 3.4.3, which focuses on multi-scale risk assessment in Africa.

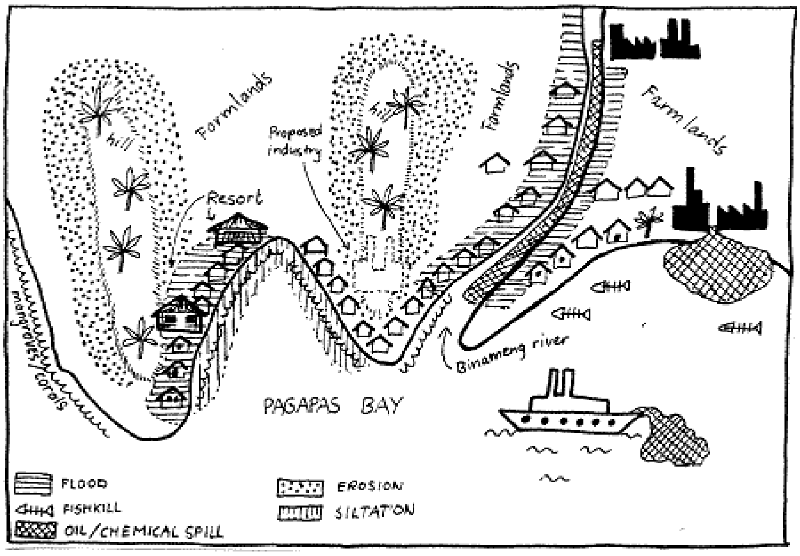


Figure 12: Sketch map of different hazards facing a community.

Such mapping can result in a more quantitative yet still useful risk matrix that is seen in the light of potential consequences. Even though it is simple and subjective, it has the advantage that it can be done involving community opinion, but without the need for sophisticated technology, and is applicable for large areas (Figure 13).

Consequence Class	Hazard Class		
	Low	Medium	High
Less severe	1	2	3
Severe	2	3	4
Highly severe	3	4	5

Figure 13: Example of a simple, qualitative risk matrix.

A commonly used form of a risk matrix is shown in Figure 14. It is based on a loss estimation in terms of expected fatalities and injuries, impact on building stock and infrastructure, environment and economic activity, as well as defined probabilities of an event occurring. The matrix thus remains a function of hazard type and magnitude, but results in a scoring that, depending on the quality of the input data and applicability of the assumptions, can be quite accurate and a useful planning and mitigation tool.

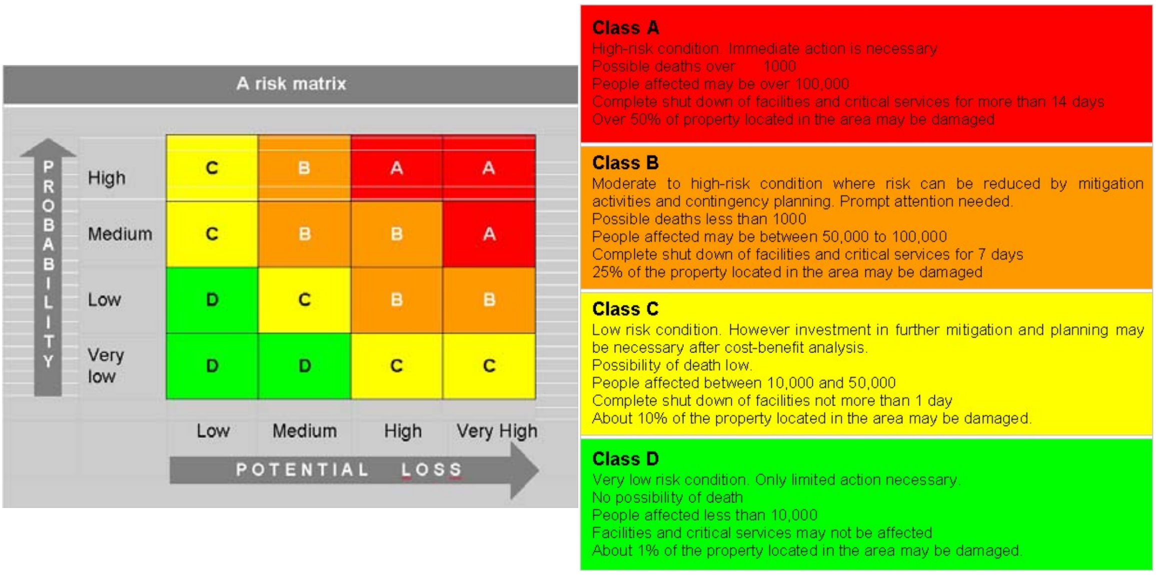


Figure 14: Risk matrix based on probability of an event and the potential loss. The meaning of the risk classes is transparently defined.

While risk assessment can be challenged by lack of data, a profusion of data can be equally troublesome. If, for example, detailed data on the socio-economic situation of an area are available, a comprehensive assessment of vulnerability is possible. This, however, leads to the question how the various positive and negative contributors to vulnerability should be integrated. One solution is **Spatial Multi-Criteria Evaluation** (SMCE). As it is based on GIS technology, i.e. ICT, it is considered in more detail in part II, and only a brief explanation is given here. In SMCE all parameters relating to social vulnerability (e.g. percentage of children or elderly, hazard-specific indicators (e.g. number of people living in flood hazard zones), hazard-specific physical vulnerability (e.g. number of buildings located in a flood hazard zone), as well as capacity indicators (e.g. distance to hospitals, see section 3.4.2) are included. Working with the data, however, requires knowledge and careful judgement on the contribution and relative importance of a given parameter. Instead of assigning an absolute weighting value, the relative importance of one parameter over another is specified. For example, it could be determined if SV of a family or community is more negatively affected by the percentage of unemployment than by the ethnic composition, or whether the strength of a social structure is more or less important than income. It is clearly a subjective approach that can be based on field assessments as well as previous sociological research. It requires that the problem and contact are well defined and understood, and the factors used are standardised and weighted. However, it has the advantage that a large number of factors can be considered in one model (see for example Munda et al., 1994). Figure 15 illustrates such a SMCE decision tree that can be used to estimate and map social vulnerability.

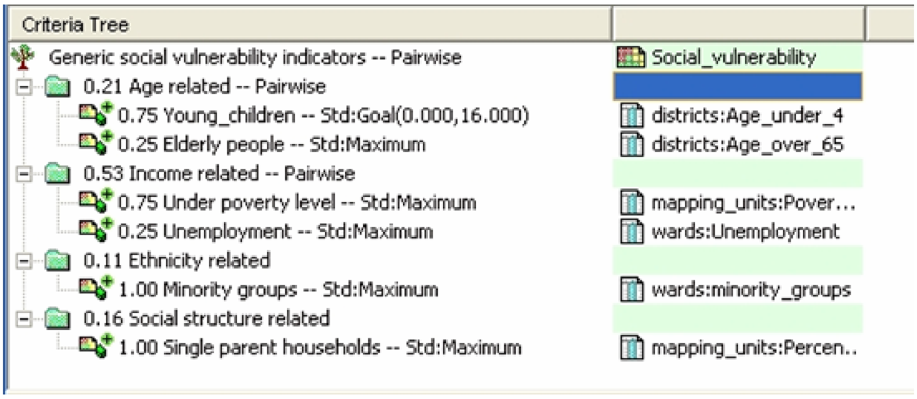


Figure 15: Example of a SMCE criteria tree for the assessment of social vulnerability. Weights signify the relative importance of a parameter, either alone in the model or compared to a related variable (Source: RiskCity training material, ITC).

Given the frequently incomplete or fragmented nature of available or potentially useful data sources, risk assessment methods that work on different spatial scales can be applied. For example, Hall and Jewson (2008) compared storm risk based on historic data of landfall (local scale) with landfall estimates based on storm track models (regional). Such potential data interchangeability is important as many theoretical or case studies can not be readily transferred to other areas for lack of parts of the data. Understanding if and how those missing data may be replaced is crucial. Typical examples are studies based on a certain type of satellite data. There are very few unique sensors that can not be replaced, thus with sufficient technical knowledge on the sensors and image characteristics suitable replacements can be found. This will be reviewed in more detail in the chapter that assesses the utility of ICT for DRR in part II.

In this section the theory of risk assessment and quantification was reviewed. The text and examples should make clear that risk is a complex concept that results from a joint assessment of present hazards, various vulnerabilities, and assets that may be damaged or destroyed. Assessing the risk is possible in different ways, making use of more qualitative or more quantitative means, and thus resulting in more relative or more absolute risk figures. All components of risk are fundamentally dynamic and highly variable, meaning that a risk assessment strategy must be adapted accordingly.

3.4.4 Managing risk & acceptable risk

Risk assessment is a tool that serves the higher goal of disaster risk reduction. We are thus faced with a situation with 3 components: risk analysis, evaluation and management (Figure 16). While a comprehensive risk assessment can tell use that hazards, vulnerabilities and values are present, and what may occur under different scenarios and probabilities, risk evaluation must then be done to determine which scenarios may be allowed to happen or not. Only after this assessment has been done can be decided whether the existing risk exceeds a threshold of acceptability, and what can be done to reduce the risk.

Wilde (1994) talked about risk homeostasis, suggesting that individuals, communities and societies maintain and thus accept a certain level of risk. This not only implies that we willingly and consciously settle on flood plains or in seismically active areas, but also that while reducing the hazard, e.g. by building dikes to keep out floods, we increase the elements at risk and potentially destroyable assets by building up even more property in the original flood hazard zone, thus maintaining the risk.

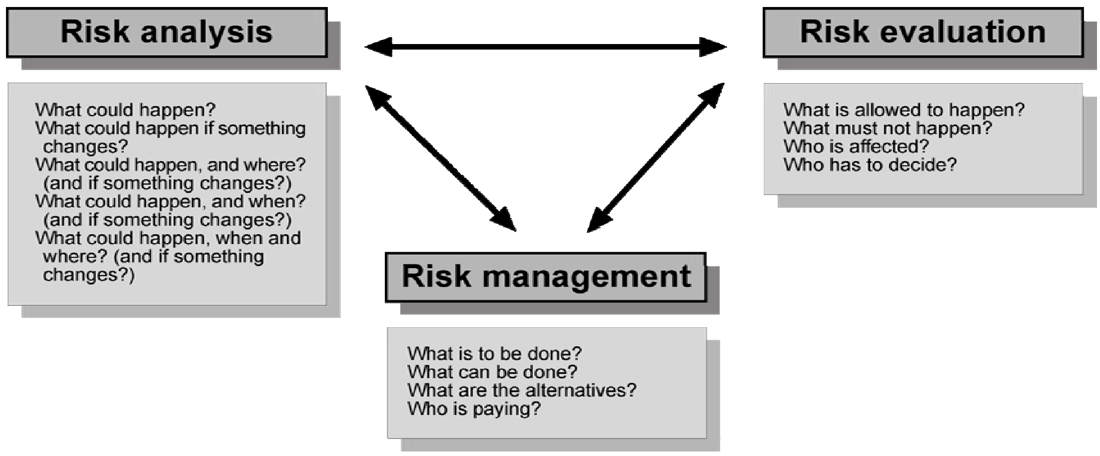


Figure 16: Overview of the risk management components (after Hollenstein, 1997).

There is clearly also a **cost-benefit dimension**. While settling in a seismically threatened city may have both economic and cultural benefits, it comes at a risk that we may voluntarily accept. However, it may also be involuntary, when a lack of specifically economic, alternatives dictates a move to higher-risk areas. It needs to be clear, however, that there is a difference in total risk between the above *voluntary* and *involuntary risk* scenarios: people who expose themselves voluntarily tend to do it because the benefit outweighs the (potential) cost, typically because vulnerability is actually lower (better houses, information, knowledge, etc.), and capacity is higher (savings, insurance, etc.). People who have no choice typically suffer higher risks, due to higher vulnerability and lower capacity, and frequently higher direct hazard exposure as well.

4. The scalability of risk

There are two additional problems with risk assessment that need to be discussed here. Risk is typically shown in a qualitative manner, whereby tables or maps designate areas to be a low, medium or high risk, with those maps and tables rarely stating which hazards, magnitude scenarios, and vulnerabilities were considered.

Figure 17 shows a typical example of a questionable risk map for the US. Shown are the areas potentially affected by various hazards, irrespective of any EaR (cities, etc.) or their vulnerabilities. It is thus only a hazard map, and a very coarse one at that. Similarly, Figure 17 shows a global map of malaria risk. The map can be seen to show where the hazard, i.e. malaria-transmitting Anopheles mosquitoes, exist, and thus where one “may run the risk of catching malaria”. It is (i) too coarse to reflect incidence variability as a function of terrain elevation (areas approximately >1,500 m being safe), and (ii) does not show any variability in vulnerability, nor (iii) a risk variation due to variable population densities.

To create useful, objective and comparable maps not only the underlying assumptions and included aspects have to be made clear, also a more quantitative approach is desirable. For that to be done, however, both the multi-hazard and the various types of vulnerability have to be quantified. In most of the past risk assessment work risk has been described as the possible loss due to a specific hazardous event, which only included a single hazard type, and typically only physical vulnerability. An example for that would be the expected loss in a city or part thereof during an earthquake of a given size and location. Such risk could be quantified in terms of the value of the fractional damage of the existing building stock and infrastructure (see Figure 8). Hazard, in this case, is unitless, while any monetary term is suitable in the quantification of physical loss or damage. While this approach clearly leads to an incomplete risk assessment, making it more comprehensive is difficult. Social vulnerability can not be quantified in monetary terms as injury or death can not be assigned a value, and also environmental damage is difficult to estimate. Similarly, economic damage with all its secondary and tertiary effects defies an easy calculation. Thus quantitative risk assessment remains an area of active research, with some authors stating that no quantification beyond an index – objective but not quantitative in monetary terms – is possible (Smit and Pilifosova, 2003).

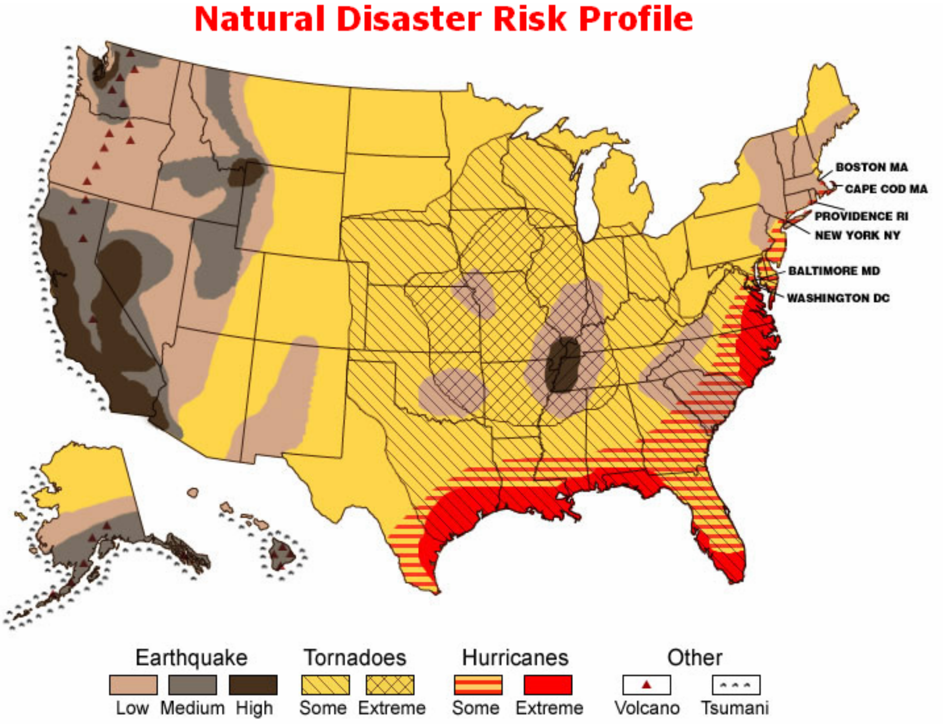


Figure 17. Multi-hazard risk map of the US (Source: http://www.floodsquad.com/).

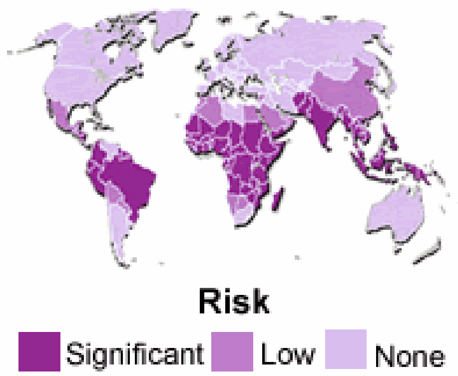


Figure 17. Global Malaria risk map (Source: http://www.separationsnow.com).

The second complication is **scale**. All aspects of DRR are fundamentally scalable and scale-dependent. For example, risk, such as of flooding, can be evaluated on a micro-scale, e.g. in terms of frequency, magnitude and duration. Coupled with the specific vulnerability of a single building or group of structures for a flood of a given height and duration, the consequences can be quite accurately determined. Similarly, a structural assessment of a building with respect to its ability to withstand ground motion during an earthquake not of a given magnitude but rather local intensity can be performed. However, assessing flood potential and its consequences for an entire city or watershed, or possibly at a national level, will inevitably require a more abstract model and coarser data, which will allow a general or perhaps average risk (as depending on the specified scale and assumptions) to be calculated. This can highlight general risk distribution and serve as a decision making tool to identify priority areas for more detailed assessments. In that sense the map in Figure 17 can serve as an overview of potential malaria incidence. However, it cannot serve as a guide to potential consequences that go beyond the scale and data resolution of the initial risk model.

In general, commonly used flood models or seismic ground motion models tend to work on coarser geographic scales. This has reasons of practicality and feasibility, but also in data availability. To model the structural setup of every building, and the way it may behave in a whole range of possible seismic events, including potential aftershocks, is often not feasible. Frequently also the precise modeling is not easily possible. For example, calculating the possible effects of a landslide is challenging, as the precise impact on a structure will depend on material properties, flow speed, water content, impact angle, etc., i.e. parameters many of which can only be estimated.

Scale also applies to vulnerability and thus, eventually, risk. A single family with a limited resource base, e.g. a single piece of livestock, is highly vulnerable. If the livestock perishes it may cause a disaster for the family. In DRR a disaster is defined as an event that causes injury and death or economic loss that exceeds the coping capacity of the affected people or region, creating a need for outside assistance. This is thus also applicable at a family scale, where the family with the deceased livestock will be dependent on assistance by family or neighbours. The latter, in turn, would in part define the family's capacity to cope with the event – if a strong social network, or a setup by the (perhaps local) government exists to aid in situations of hardship, the risk can be reduced as the overall outcome of the hazardous event (e.g. the livestock's death) will be reduced. Vulnerability and risk can be considered along these lines for villages, neighbourhoods, towns, regions, countries or even continents or the Earth as a whole. This creates a multi-faceted situation whereby all aspects of the risk equation are entirely scalable, but also need to be assessed with respect to a present hazard or combination thereof, and for all possible magnitudes and combinations. In its practical implementation this is clearly challenging and often indeed not possible, as either the data are missing or the causalities between multi-hazards and secondary/tertiary are not sufficiently understood.

5. The hazard situation in Africa

5.1 Hazard-assessment at a continental and regional scale

For most hazard types Africa to too large and diverse a continent to permit a straightforward mapping. Thus when one looks for hazard maps for Africa it becomes clear that not always much exists. This chapter describes the various hazards affecting Africa, what is known about their distribution and consequence, and to what extent relevant hazard or risk maps already exist. First the most relevant natural hazards are evaluated, followed by the biological ones.

5.1.1 Seismic hazard

Figure 18A shows a continental seismicity map of Africa, depicting earthquakes by depth, while Figure 18B illustrates the magnitude of historic earthquakes. It thus gives a general impression of the hazard, linked largely to continental plate tectonics, e.g. in the North of the continent where Africa pushes into Europe, and along the Great Rift Valley in the East. It is also clear, however, that it is based on a coarse net of instruments, as many countries on the continent are not well studied and monitored (Skobelev et al., 2004; Vannucci et al., 2004). Furthermore, it says something about previous events and their magnitude, i.e. the energy released during an event, and thus something about what size earthquake may be expected in a given area. However, it says nothing about the earthquake frequency, nor about local intensities, which are of greater significance for structural damage, nor can it be used well to work out hazard scenarios for different magnitude seismic events in a given location. This is because site response, i.e. how the ground in a given place will react to a particular seismic signal depends on rock type, soil type and thickness, local slope angle and location of a building in question along this slope, and other parameters.

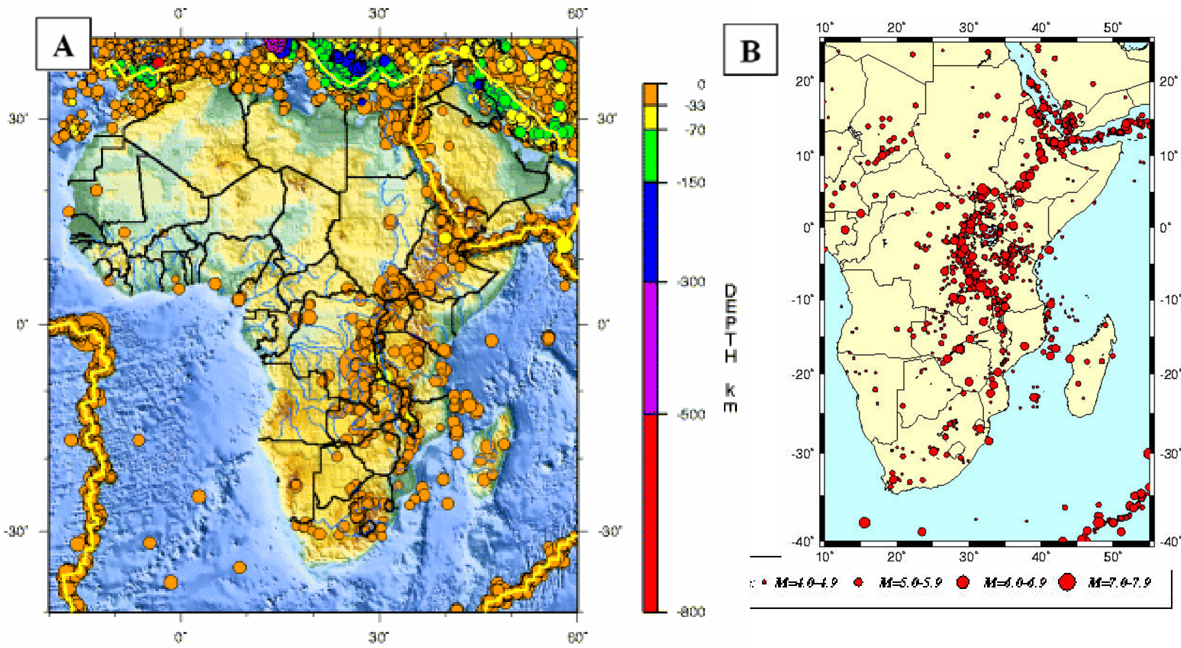


Figure 18: A - Seismicity in Africa between 1900 and 2000, shown by depth (Source: USGS); B – earthquakes with magnitude > 4.0 between 627-1994 (Source: Midzi et al., 1999).

Instead of magnitude and maps of previous events an overview of intensities, such as reflected in peak ground acceleration (PGA), is more useful (Figure 19). PGA quantifies the maximum acceleration experienced by the ground during an earthquake. It is useful as building codes, where they exist, prescribe the maximum acceleration force a building must be able to withstand during a seismic event. A comprehensive assessment is best done through seismic microzonation, where variable potential for seismic hazards (shaking, liquefaction, etc.) is quantified. However, due to the detailed data needed this is typically done at more local to regional scales (see for example Fat-Helbary and Tealb, 2002).

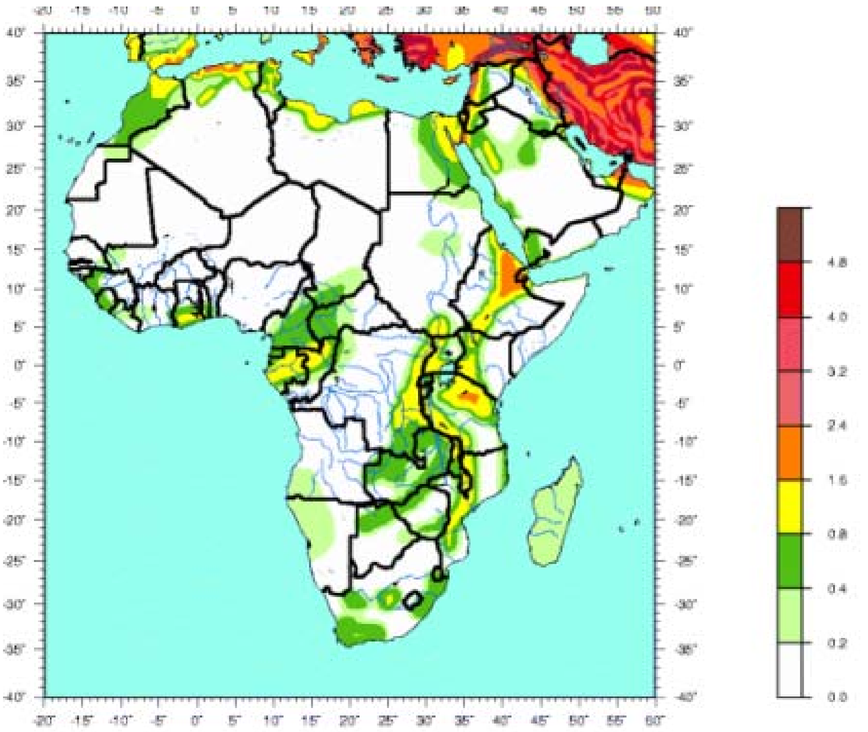


Figure 19: Peak Ground Acceleration (m/s²) with 10% probability of exceedance in 50 years (Source: USGS).

Table 2 shows the number of recorded seismic events and associated fatalities per country in Africa, for the period from 1900-2008. The table reflects the relative geologic stability of the continent, when comparing the number of people killed with those in other parts of the work, particularly in Asia.

Country	**Number of seismic events**	**Number of earthquake fatalities**
Algeria	6,757	546,003
Burundi	3	0
Congo	6	0
Egypt	594	57,950
Ethiopia	24	0
Ghana	17	0
Guinea	275	20,000
Kenya	1	0
Libyan Arab Jamah	320	0
Malawi	9	0
Morocco	12,728	0
Mozambique	4	0
Rwanda	81	1,535
Somalia	298	104,800
South Africa	70	1,285
Sudan	3	8,000
Tanzania Uni Rep	19	6,250
Tunisia	13	0
Uganda	111	57,000
Zaire/Congo Dem Rep	40	15,590
Total	**21,373**	**818,413**

Table 2: Number of recorded seismic events and associated fatalities by country between 1900-2008 (Source: EM-DAT. OFTA/CRED International Disaster Database, Université Catholique de Louvain).

5.1.2 Volcanic hazard

The situation is similar for **volcanic hazard**. Figure 20 shows the location of active volcanoes in Africa. Out of fifty-two countries in mainland Africa, twelve harbour active volcanoes: DRC, Uganda, Tanzania, Sudan, Rwanda, Niger, Libya, Kenya, Ethiopia, Eritrea, Chad, and Cameroun, in addition to island states such as the Sao Tomé & Principe and the Cape Verde Islands. While this can be a guide to find out in which countries a volcanic hazard may be present, it has little practical value beyond that. This is not only because a volcanic eruption can, similar to an earthquake, have vastly different magnitudes. It is also because the hazard most associated with a volcano – a lava flow – is but one of about 16 hazards that a volcano may pose, with several of them potentially working in conjunction. Of the hazards that are shown in Figure 21 only one – atmospheric gas injection – is of potential global or continental consequence. The ability of any of the volcanoes shown in Figure 20 to produce such eruptions, however, is not shown. Thus it is typically assessed on the ground during detailed geological and sedimentological fieldwork that can reveal the potential explosivity, primarily based on past eruptions (see for example Wiart et al., 2000). Of the remaining hazards very few can have effects beyond the greater edifice itself. Ash and gases injected into the troposphere or potentially stratosphere pose a substantial threat to aircraft, thus creating a regional aviation hazard, which again depends highly on the activity level of a volcano and its explosivity (Simpson et al., 2002; Guffanti et al., 2005; Marti and Ernst, 2005). Another hazard of significant spatial extent is a lahar, or volcanic mudflow, which can still be devastating over 100 km from the source (Scott et al., 2001), and travel furthest when channelled. However, African volcanoes tend to pose less of a lahar hazard than other continents as most lack snow cover or other substantial water sources. Finally, a geographically far-reaching hazard posed in particular by volcanic islands is a tsunami triggered when volcanic flanks fail. A typical phenomenon for Alaskan volcanoes, and also well documented for the Hawaiian Islands, in Africa they currently pose a threat only on the Canary Island of La Palma (Day, 1996).

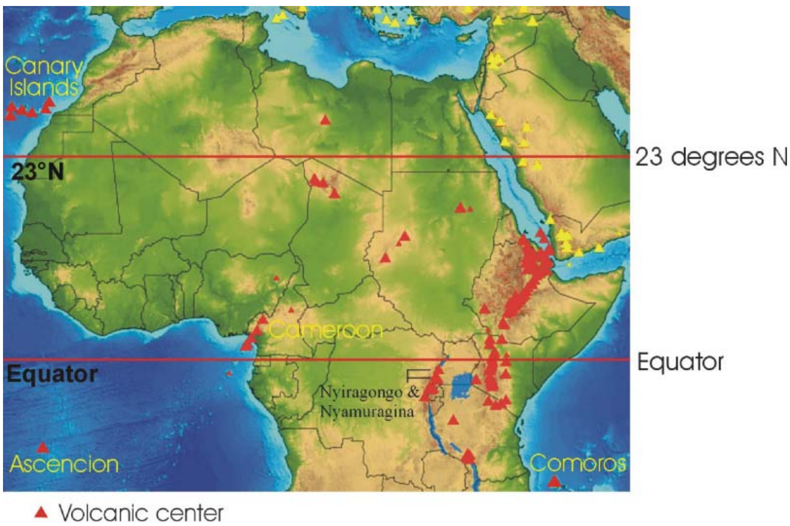


Figure 20: Active volcanoes in Africa.

Table 3 makes it clear that also volcanic activity has only led to a relatively low number of fatalities in Africa since 1900. What is noteworthy is that African volcanism has produced an unusual range of activity. In 1977, Nyiragongo’s lava lake (DRC) drained, releasing low viscosity lava that travelled 20 km towards the city of Goma at speeds approaching 60 kmh^{-1}, killing approximately 150 people. A renewed eruption in 2002 destroyed ca. 80% of Goma’s economic assets, as well as the habitation of some 120,000 of its citizens. Another unusual volcanic disaster involved volcanogenic gas, occurring in 1986 in Cameroon, when vast amounts of CO_2 were released from the Nyos crater lake, travelling some 25 km, and asphyxiating nearly 1,800 people, making it the worst volcanic disaster on the continent. Unique activity is also found at volcanoes in Tanzania, famously at Oldonyo Lengai, where not silica-based but carbonatite (= washing soda) lavas are erupted.

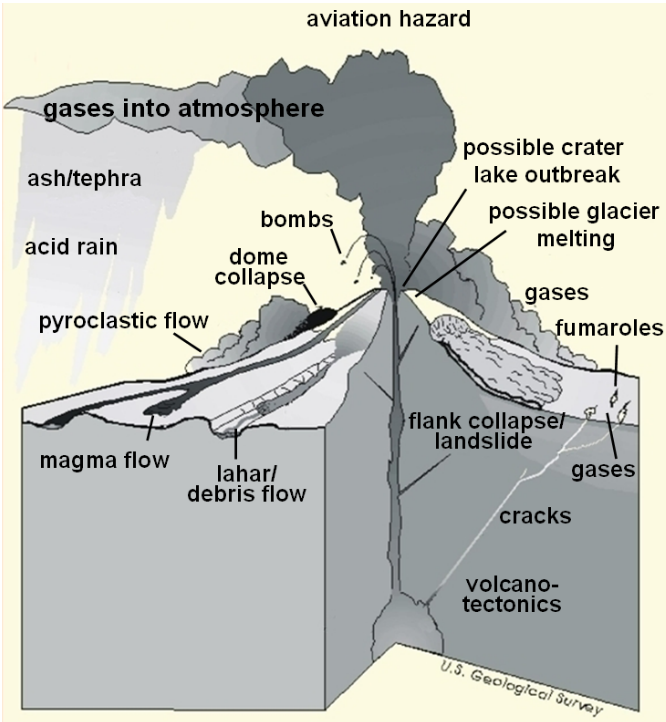


Figure 21: Overview of volcanic hazards. Adapted from USGS.

	Number of fatalities	Number of affected people
Cameroon	1,783	12,500
Cape Verde Is	0	1,300
Comoros	19	304,000
Ethiopia	69	11,000
Reunion	0	1,000
Zaire/DRC	347	0
Total	**2,218**	**329,800**

Table 3: Number of fatalities due to volcanic activity in Africa between 1900-2008 (Source: EM-DAT. OFTA/CRED International Disaster Database, Université Catholique de Louvain).

In sum, more than with any other hazard, a comprehensive local understanding of a given volcano, with its eruptive history and potential of those many individual hazards is the prerequisite for risk mapping. Additionally, good knowledge is needed of the ways the various volcanic hazards with their highly variable magnitudes can affect different EaR. A comprehensive regional volcanic risk map other than for atmospheric gas injection or the aviation hazard is thus rather meaningless.

5.1.3 Droughts

Drought must be considered the most important weather-related natural hazard in Africa. Though inherently a result of natural processes, drought is often aggravated by human action, affecting very large areas for months or even years, and consequently having a serious impact on regional food production. Due to the lasting effect and detrimental consequences on mortality rates, it often results in a reduction of life expectancy for entire populations and economic performance of large regions or several countries. During 1967-1991, droughts affected 50% of the 2.8 billion people who suffered from all natural disasters, and killed 35% of the 3.5 million people who lost their lives to natural disasters (www.ceos.org).

Drought differs from seismic and volcanic hazards in several important points. They don't occur unannounced, typically last months to years, they affect with potentially high fatality and casualty rates much larger areas than the former, and they lead to a disaster in a manner that is much more strongly a function of vulnerability and inequality. While earthquakes and volcanic activity generate a primary or secondary traumatic impact, drought only kills by leading to famine when high, in particular social, vulnerability exists. After epidemics, in particular HIV/AID and malaria, it is the hazard that has caused the largest number of fatalities and, even more so, affected people. In Africa it is the hazard that has touched nearly every country (Table 4), which, again next to epidemics, makes it exceptional.

Country	Number of drought events	Number of fatalities	Number of affected people
Algeria	2	12	0
Angola	6	58	2,610,000
Benin	2	0	2,215,000
Botswana	6	0	1,344,900
Burkina Faso	11	0	5,563,290
Burundi	3	126	2,800,000
Cameroon	4	0	586,900
Cape Verde Is	10	85,000	40,000
Central African Rep	1	0	0
Chad	8	0	2,356,000
Comoros	1	0	0
Congo	1	0	0
Cote d'Ivoire	1	0	0
Djibouti	7	0	647,750
Eritrea	2	0	3,900,000
Ethiopia	11	402,367	48,136,200
Gambia The	7	0	830,000
Ghana	3	0	12,512,000
Guinea	2	12	0
Guinea Bissau	6	0	132,000
Kenya	11	221	35,352,000
Lesotho	5	0	2,010,500
Liberia	1	0	0
Madagascar	5	200	2,795,290
Malawi	6	500	19,678,702
Mali	9	0	2,827,000
Mauritania	10	0	5,860,907
Mauritius	1	0	0
Morocco	5	0	412,000
Mozambique	10	100,068	16,797,500
Namibia	6	0	783,200
Niger	11	85,000	12,755,058
Nigeria	1	0	3,000,000
Rwanda	6	237	4,156,545
Sao Tome et Principe	1	0	93,000

Senegal	8	0	7,549,000
Somalia	10	19,673	2,883,500
South Africa	8	0	17,475,000
Sudan	7	150,000	23,210,000
Swaziland	5	500	1,630,000
Tanzania Uni Rep	8	0	8,037,483
Togo	3	0	550,000
Tunisia	2	0	31,400
Uganda	7	194	3,206,000
Zaire/Congo Dem Rep	2	0	800,000
Zambia	5	0	4,173,204
Zimbabwe	5	0	13,855,000
Total	**252**	**844,168**	**273,596,329**

Table 4: Number of drought events with associated number of fatalities and affected people per country in Africa between 1900-2008 (Source: EM-DAT. OFTA/CRED International Disaster Database, Université Catholique de Louvain).

As shown in Figure 6, the countries with most drought/famine fatalities are Ethiopia, Sudan, Niger and Mozambique. It is worth recalling here that such assessments can only be as reliable as the underlying data. For example, with almost 14 million people listed as drought affected in Zimbabwe, fatality rates of zero may be questioned. Additionally, the EM-DAT database also records **complex disasters**. Three of those are listed for Africa for the given time period, in the subtype description also all labelled as famine. Although only for one event, a 2007 famine in Burundi, 134 fatalities are listed, substantial numbers for affected people are given: Burundi – 2 million, Togo (1992) – 50,000, and Sudan (1998) – 2.6 million, numbers that would have to be added to Table 4.

Mapping drought hazard must be considered a substantial challenge. For one, it is far more dynamic than volcanic and seismic hazards. Additionally, a definition based purely on the natural aspects (as for the above geological hazards) does not suffice. Drought can be defined as “the threat of a temporary negative deviation of an environment's moisture status” (Myburgh, 1994), which considers only the precipitation aspects. However, there are more aspects to drought. The moisture status of an area results from a complex interplay of parameters such as precipitation, the prevalent temperature pattern that affects evapotranspiration, topography, vegetation type and coverage, soil type and thickness, and land use. In fact, the UN Food and Agricultural Organisation (FAO) defines drought less in terms of natural cause than its effect as “a condition of soil moisture deficit which results in yield reduction”. Here we clearly move away from a natural hazardous agent and implicitly incorporate EaR and their vulnerability. More than with any other physical hazard considered in this CF do the boundaries between the physical hazards side and social receptiveness to disruption blur. Consequently there are different ways of assessing and mapping drought hazard. Figure 22 shows a Drought Hazard Index map for Southern Africa based on physical parameters (annual runoff). It differs substantially from the map in Figure 23, which shows a drought hazard map from an area in Asia based on yield loss, conceptually a very different approach. The social component is also strongly reflected in the global water scarcity map of the FAO, shown in Figure 24. It shows on one hand the physical supply side – **physical water scarcity** – defined as limited physical water availability with more than 75% of all river water having been withdrawn for industrial or agricultural purposes. Conversely, **economic water scarcity** describes a situation where sufficient water is available, but where the human, institutional or financial capacity is lacking to access it (FAO, www.fao.org).

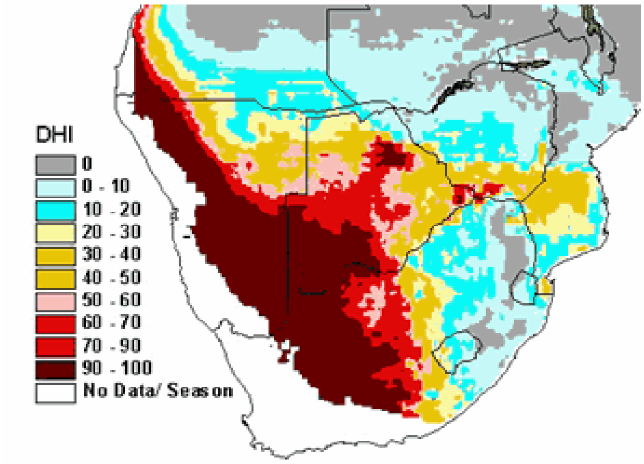


Figure 22: Drought Hazard Index map for Southern Africa (Source: Climate Hazards Group, University of California, Santa Barbara).

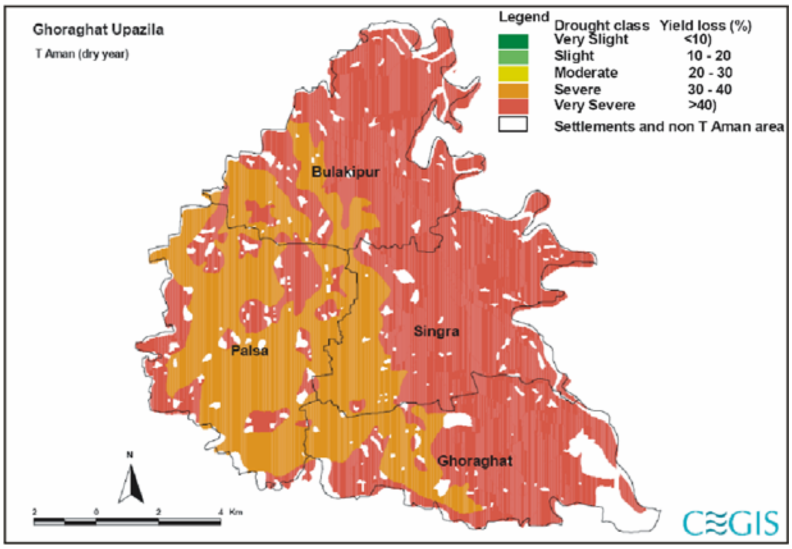


Figure 23: Example of a drought hazard map based on yield loss estimation (Source: Center for Environmental and Geographic Information Services, Bangladesh).

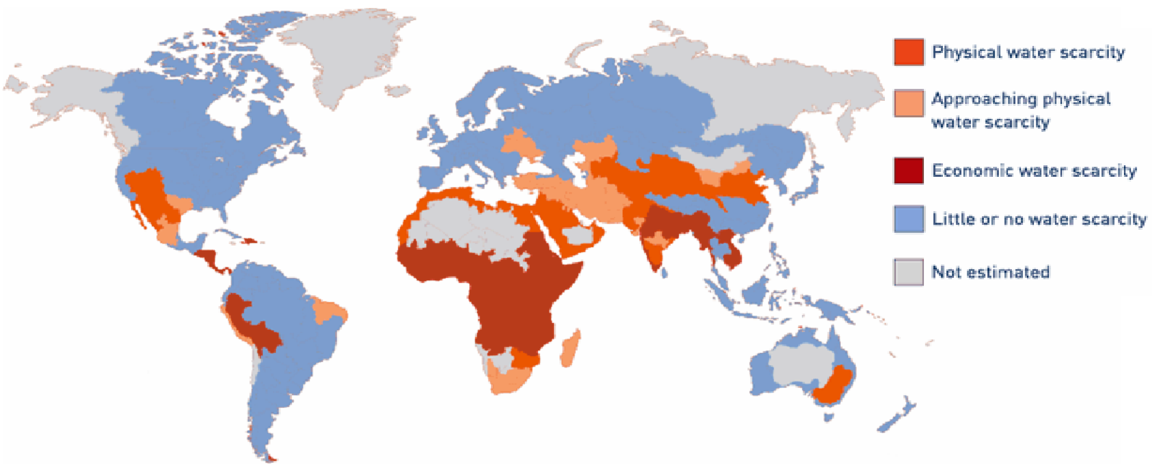


Figure 24: Global water scarcity map (Source: FAO, ww.fao.org).

In part II this topic is discussed in further detail, in the context of monitoring and mapping of the various drought-related parameters with ICT. It will become clear that despite the conceptual and definitional variability ICT in fact has a very large contribution to make, allowing drought hazard to be well mapped, and drought related famines and disasters to be mitigated.

5.1.4 Flood hazard

Figure 6 showed flooding in Africa as a lesser hazard, and one that is concentrated largely in the countries bordering the Mediterranean and those in the southern part of the continent. However, this would be an incorrect assessment, and also one that shows how statistics are easily outdated and may give a wrong overall impression. First, the graphic shows the scaled number of affected people per hazard. This results in the countries with exceptional numbers of affected people (Ethiopia, Sudan, Mozambique) to appear prominently due to large absolute numbers, while the symbology for all other countries is correspondingly small. In most of those countries the effects of epidemics also vastly outweigh the consequences of other hazard types, suggesting that those do not play a major role. Table 5 does show that overall flooding is less of a concern in Africa, with some 622 recorded events since 1900, and less than 22,000 fatalities. While substantially more than Europe (437 events with just over 8,000 people killed), it compares favourably with the Americas and particularly Asia. The number of floods in the Americas was about 25% percent higher (though again the potentially larger incompleteness of the data for Africa has to be kept in mind), but resulting in nearly fivefold fatality numbers. Both numbers, however, are vastly exceeded by the data for Asia, where about twice as many floods (1,412) killed over 3 million people. This clearly reflects in particular coastal hazards, and incorporates exceptionally high fatalities figures for flood events in countries such as Bangladesh already mentioned before, or those of the 2004 Tsunami. By comparison, thus, Africa has a far lower flood hazard.

		Number of flow events	**Number of fatalities**	**Number of affected people**
Africa	Unspecified	222	6,901	13,679,467
	Flash flood	73	2,580	1,899,289
	General flood	320	12,114	30,371,759
	Storm surge/coastal flood	7	169	1,202,829
	Total	**622**	**21,764**	**47,153,344**
Americas	**Total**	**808**	**100,614**	**58,017,732**
Asia	**Total**	**1,412**	**3,228,317**	**2,990,093,565**
Europe	**Total**	**437**	**8,299**	**13,269,597**
Oceania	**Total**	**102**	**416**	**599,408**

Table 5: Total number of flooding events with associated fatalities and affected people in Africa, versus figures for other continents between 1900-2008 (Source: EM-DAT. OFTA/CRED International Disaster Database, Université Catholique de Louvain).

However, when we consider flooding in Africa it becomes clear that it is also individual events on an exceptional scale that are responsible for the large share of fatality and casualty numbers. For example, the 2000 Mozambique flood killed some 800 people, nearly half of all reported flood fatalities in the country since 1900. Similarly unusual were the 921 fatalities during the 2001 Algeria flooding, or the 3,000 in 1927.

However, the table also shows that flooding is far more effective in affecteing people rather that killing them. As is a general characteristic of floods, the hazard is of relatively low direct impact, it typically does not arrive unannounced, but is very effective in destroying crops and property. This is also clear from Table 6: floods are the most effective hazard to affect people in Africa compared to the number of fatalities. Conversely, epidemics, which in the EM-DAT database include parasitic, bacterial and viral infections, are the most lethal. However, again we have to exercise caution with these data. The low numbers for epidemics fatalities and affected people already suggest an incomplete database. And indeed the record does not include chronic diseases such as HIV/AIDS and tuberculosis. However, AIDS alone killed an estimated 19 million people in Africa to date (www.uneca.org*)*, and can surely be considered a disaster.

Returning to the flood hazard situation, Figure 25 provides a better overview of its distribution than Figure 6. It shows clearly that in addition to the earlier discussed areas also central Africa has been strongly affected by flooding, a recent example being the 2007 flood that affected much of Uganda for several weeks, affecting more than 700,000 and killing 100.

Hazard type	**Number of fatalities**	**Number of affected people**	**Ratio (K/A)**
Flooding	21,764	47,153,344	216,658
Drought	844,168	273,596,329	32,410
Volcanic activity	2,218	511,353	23,055
Wildfire	73	12,378	16,956
Storm	581	95,480	16,434
Earthquake	21,373	1,669,040	7,924
Epidemic	447,079	11,965,297	2,676

Table 6. Total number of fatalities vs affected people per hazard type, and ratio between both parameters. It is clear that flooding is most effective at affecting people and property, while epidemics are more lethal. Calculated from data by EM-DAT. OFTA/CRED International Disaster Database, Université Catholique de Louvain.

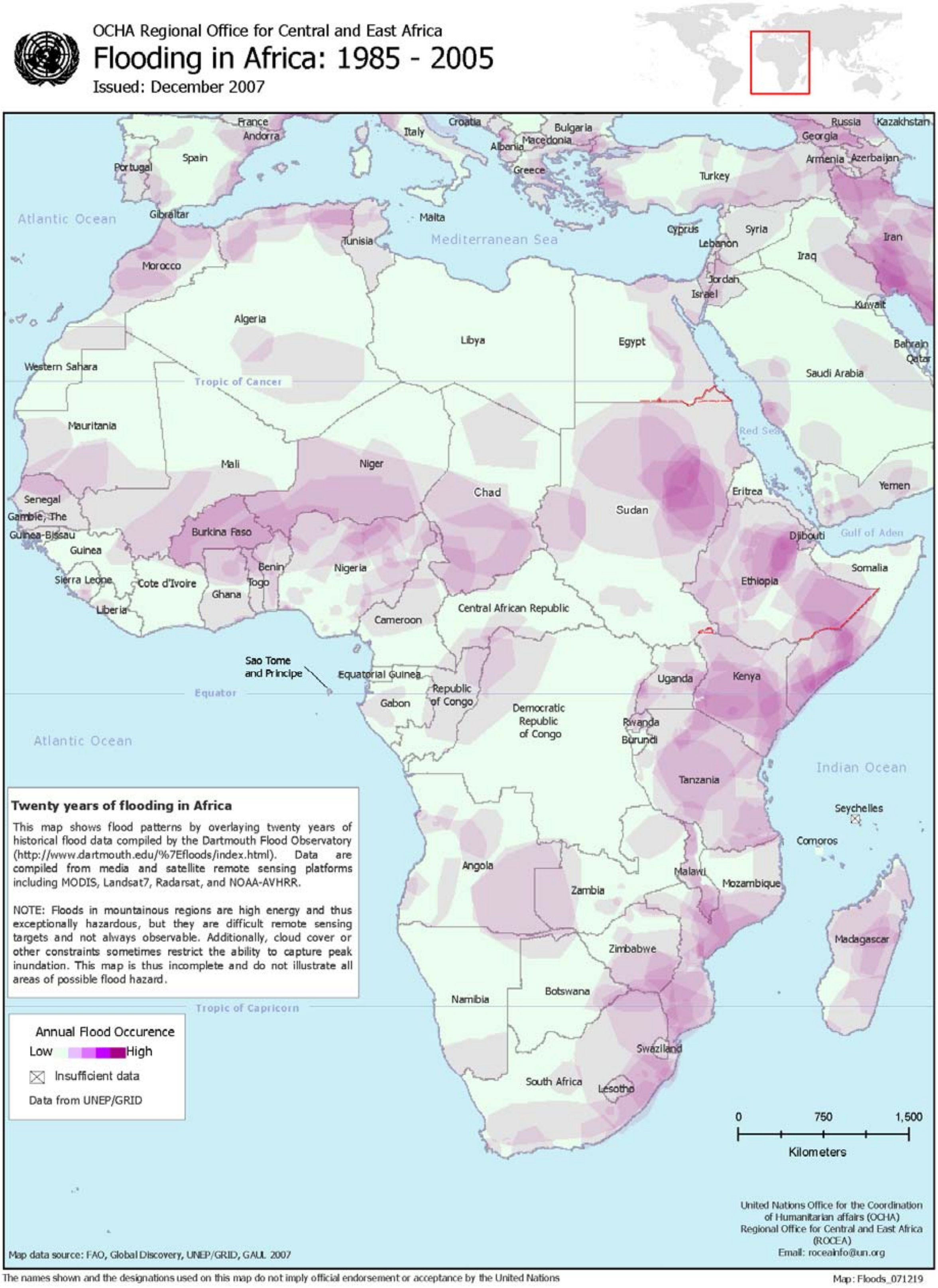


Figure 25: Flood occurrences in Africa between 1985 – 2005 (Source: UN Office for the Coordination of Humanitarian Affairs, OCHA).

5.1.5 Windstorms

Windstorm hazards play a minor role in Africa, affecting largely the coastal areas in the Southeast (Figure 6). However, it is a term that refers to a wide range of phenomena, including tornadoes, cyclones (including hurricanes and typhoons), mid-latitude (i.e. extratropical) storms, lighting, hailstorms, and dust storms. The macroscopic, continental picture for Africa is simple. A sizable tropical storm hazard only exists in the Southeast, where in particular Madagascar and the surrounding island states (e.g. Mauritius, Comoros, Reunion), but also the coastal countries further west (Mozambique, Tanzania, South Africa), and those still within reach of cyclones moving in from the coast (Zimbabwe, Malawi), as shown in green in Figure 26. Additionally there is a minor hazard of extratropical storms affecting South Africa.

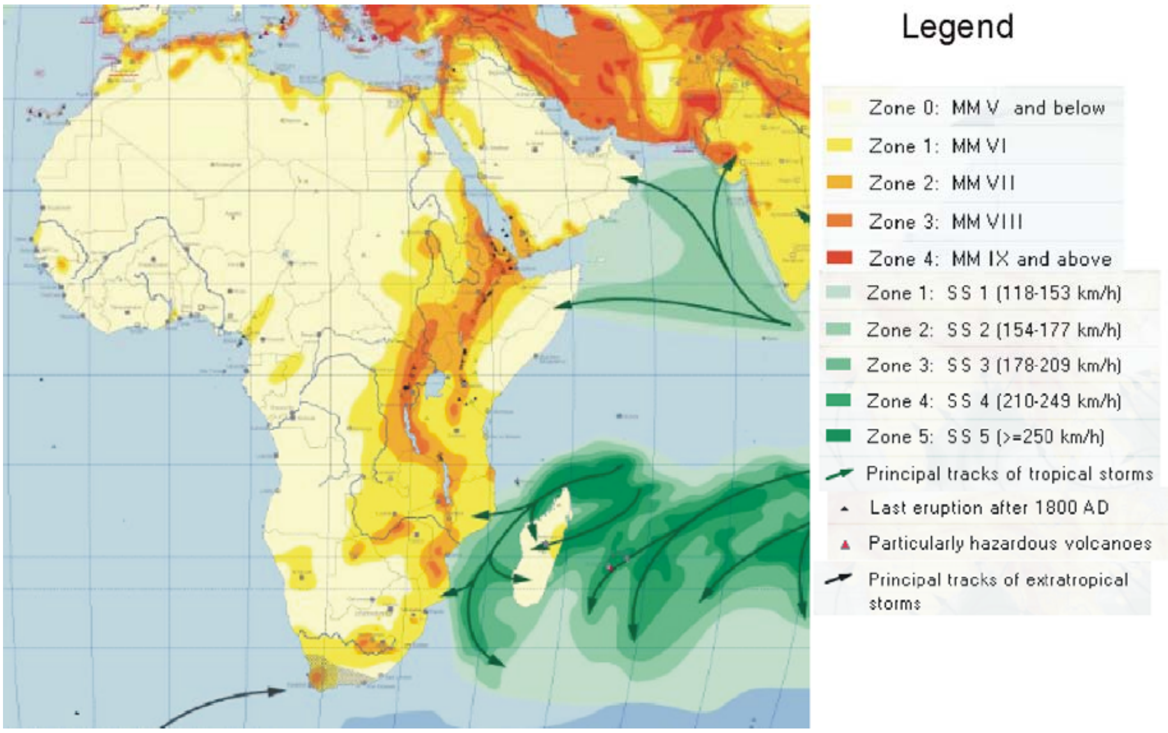


Figure 26: Hazard distribution in Africa (Source; MunichRe Insurance).

Tropical windstorms form a credible hazard in Africa, which has resulted in previous disasters. It was a cyclone that caused weeks of heavy rain that led to the 2000 Mozambique flooding. This means that in addition to the wind factor, the associated rainfall may pose an even greater threat, though a clear separation from the statistics given in section 5.1.4 is not possible. Like flooding, wind storms lead to various consequences: direct casualties and fatalities from falling debris or collapsing structures, destruction of crops, disruption or destruction of lifelines, transport and other service infrastructure, contamination of water supply.

Figure 27 shows that the windstorm hazard, in particular for cyclonic events, is quite realistic for Southeast Africa, with some areas near Madagascar having a 50% probability of experiencing a tropical cyclone per year (Goliger and Retief, 2007).

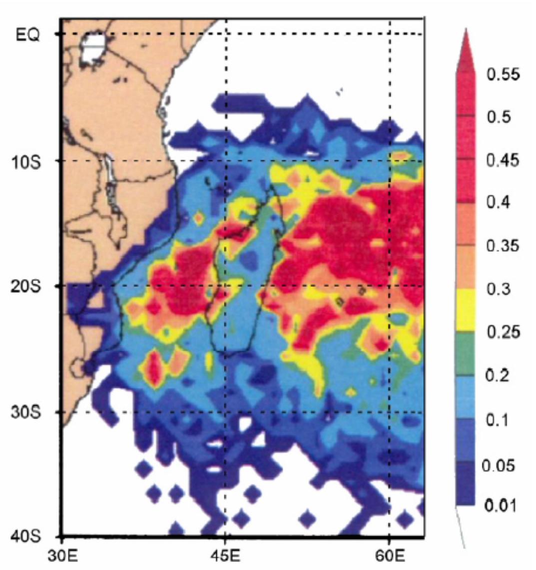


Figure 27: Annual rate of occurrence of cyclones in Southeast Africa (Source: Goliger and Retief, 2007).

In such direct exposure the actual wind hazard plays an important role, posing a substantial damage potential. Below the main characteristics and expected damage for the 5 tropical storm categories are given (adapted from NBC, wrc.weatherplus.com/).

Category 1: winds of 119-153 km/hr, with surges of about 1.5m above normal. Minor damage to trees/shrubbery and poorly constructed buildings.

Category 2: winds of 154-177 km/hr, with surges of 2 – 2.5 m above normal. Medium damage to roofs, windows; considerable damage to trees/shrubbery, piers, mobile homes, and poorly constructed buildings.

Category 3: winds of 178-209 km/hr, with surges of 3-4 m above normal. Blockage of low-lying evacuation routes, destruction of smaller coastal structures and severe battering of larger buildings, low level escape routes are flooded 3 –5 hours before cyclone.

Category 4: winds of 210-249 km/hr, with surges of 4-6m above normal. Extensive damage to doors, windows and building walls, collapsed trees/shrubbery, complete destruction of mobile homes, massive flooding, particularly of areas lower than 3m above sea level, considerable damage due to floating or flying debris. Evacuation needed for inland areas reaching in as far as 10 km.

Category 5: winds greater than 249 km/hr, with surges greater than 6m above normal. Severe and extensive window, building damage, massive flooding for areas lower than 5m above sea level and within 500m of the coast. Evacuation needed for low-level inland areas us to about 16 km from the coast.

In addition to cyclonic windstorm, **tornados** pose a major threat, in particular in southern Africa. Although their geographic reach is comparatively small, their local destructiveness far exceeds that of all but the largest cyclonic events. The US National Oceanic and Atmospheric Administration (NOAA) maps the tornado hazard for Africa as shown as inset in Figure 28. A more detailed view is given in the main image, showing that the threat, while geographically confined, does cover a substantial part of South Africa.

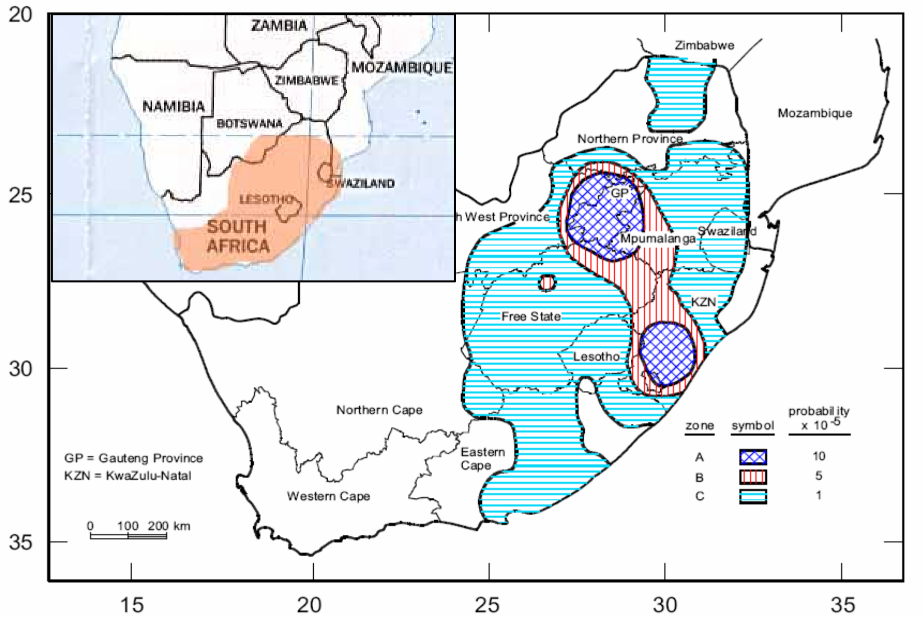


Figure 28: Mean annual rate of occurrence of tornados (Source: Goliger and Retief, 2007), largely corresponding to the NOAA hazard map (inset, Source: www.noaa.gov).

South Africa, as for other hazard types, has been better mapped than most of the rest of the continent, reflecting substantial ongoing indigenous research, with the detailed tornado map in Figure 28 only being one example. While this particular type of windstorm does appear largely limited to the southern part of Africa, similarly detailed studies for other parts of the continent are largely lacking. A reanalysis of atmospheric data between 1948 and 2002 by Brooks et al. (2003) shows that also vast areas in Central Africa have a high potential for severe weather (Figure 29). Areas around the Gulf of Aden experience such favourable conditions for more than 60 days per year on average. A similar picture, also suggesting a large storm hazard for much of tropical Africa, is provided by Figure 30, which shows the number of lightning strikes per month. Indeed, the global maximum lies in tropical Africa. However, a detailed assessment of the actual hazard to people and property posed by such tropical storms does not appear to have been done.

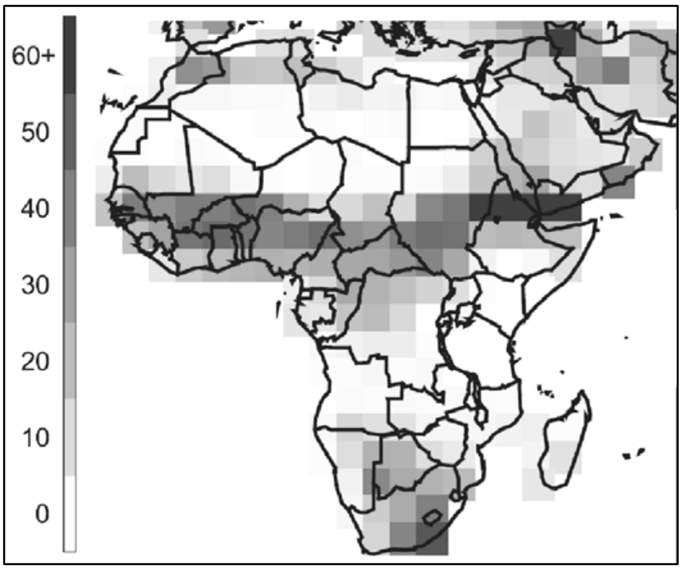


Figure 29: Days per year with favourable parameters for severe weather (Source: Brooks et al., 2003).

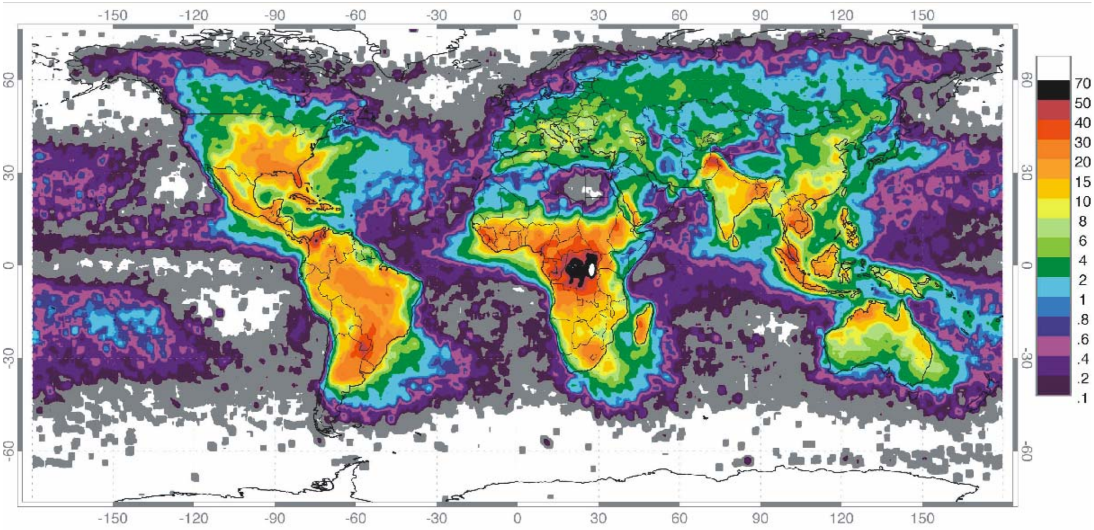


Figure 30: Global distribution of monthly lightning strikes between 1995 and 2003, with a maximum over tropical Africa (Source: NASA, www.nasa.gov).

5.1.6 Tsunamis

Tsunamis have not been historically seen as a major threat in Africa, and have only been more intensively discussed following the 2004 Asian Tsunami that also affected parts of the eastern coast. The EM-DAT database does not list tsunamis as a separate hazard, thus no comprehensive picture is available to compare the threat to other parts of the world. However, what is known is that diverse **sources for tsunami hazard** in Africa exist:

- The seismically active zones in Asia, i.e. the ring of fire, source of the 2004 tsunami. With distance not being relevant, only line of sight and absence of significant landmasses as obstacles are important. This means that the entire eastern coast, from Somalia to South Africa and including the island states including and around Madagascar, is threatened. Mozambique, however, is relatively sheltered because of Madagascar's protective function. With no effective early warning in any of the affected countries, an estimated 1, 13 and 289 people were killed in Kenya, Tanzania and Somalia, respectively during the 2004 event (Wikipedia).
- The volcanic islands of the Canaries. In particular parts of La Palma are unstable and are at risk to breaking off, causing a massive tsunami. However, with the unstable flank being on the northwest side, the tsunami would largely spare the African mainland, with possible minor effects in Mauritania (Figure 31).
- Seismic activity in the Mediterranean. Earthquakes between Africa and Europe have caused tsunamis in the past, with comparatively small effects for mainland coastal stretches, but occasionally with devastating consequences for islands. Much of recent research, also accelerated in the aftermath of the 2004 event, has focused on Europe, but it has been found out that historic tsunamis affected the North African coast, such as an earthquake in 365AD (e.g. Shaw et al., 2008), and another in 1303 that killed many people in Alexandria, Egypt (Hamouda, 2006).

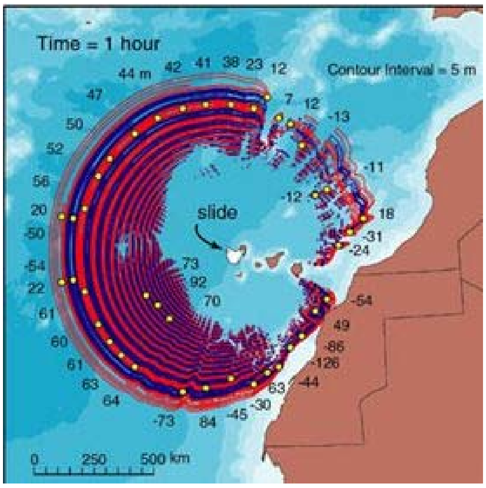


Figure 31: Tsunami hazard posed by collapse on La Palma (Source: www.tsunami-alarm-system.com).

5.1.7 Wildfires

The final natural hazard considered in this CF is wildfires. Considered a natural process, whereby ignition of combustible vegetative matter (forests or grass/bushlands) occurs by lighting or occasionally volcanoes, wild fires are also a tool in agriculture, designed to clear space for planting, while providing nutrients at the same time. They can thus be useful also to clear away dead vegetative matter that may accumulate to form a larger fire hazard, and also help the natural rejuvenation cycle by maintaining biodiversity if occurring at sustainable rates.

The situation becomes problematic if the use of manmade fire for such purposes becomes excessive and fires lead to a degradation of the natural environment as a whole. At such point the risk of fires growing out of control rises, which can lead to a hazard for people and infrastructure. Additionally, though, the massive clearing away of vegetation alters ecosystems, resulting in accelerated desertification as drought is favoured, loss in biodiversity as habitats disappear, and increasing spread of invasive species. Africa is not known for widespread wildfires on the scale as they frequently occur in the western US or in Australia. Indeed, the database at CRED shows an overall minor hazard. Only 8 countries are listed as having experienced wildfires leading to fatalities or affected people (Table 7), and with very modest numbers.

	Number of fatalities	**Number of affected people**
Algeria	30	0
Benin	2	4,000
Central African Rep	1	85
Ghana	4	1,500
Guinea Bissau	3	1,200
South Africa	94	1,000
Sudan	47	0
Swaziland	2	1,500
Total	**183**	**9,285**

Table 7: Number of fatalities and affected people per country in Africa due to wildfires (both forest and bushfires) between 1900-2008 (Source: EM-DAT. OFTA/CRED International Disaster Database, Université Catholique de Louvain).

This, however, does not provide a very accurate picture. It appears that it is more the smaller and more common fires that, although not posing a strong hazard to people and possessions, have a profound accumulative effect. Figure 32 shows an accumulative view of wildfires over 2-week periods for the first half of 2005 for the African continent. It is apparent that essentially all areas that are vegetation experience wildfire activity.

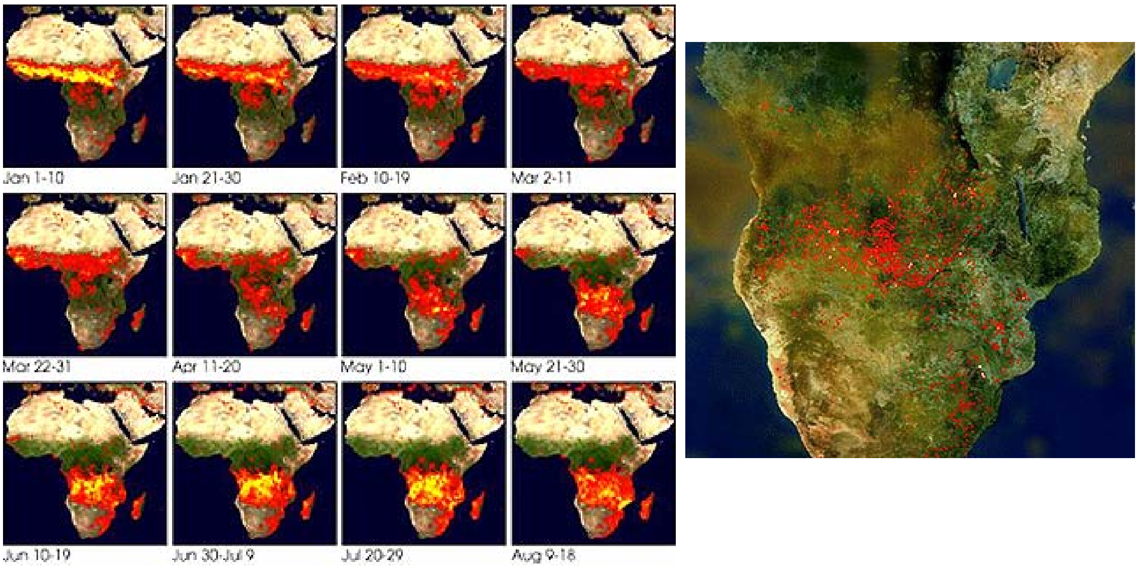


Figure 32: Wildfires mapped in Africa over 2-week periods in the first half of 2005 (left), and MODIS satellite image taken in September 2000 over southern Africa (right; Source: NASA).

Figure 32 may paint an overly dramatic picture with small fire signatures coalescing into a representation that suggest blanket fire coverage over large sections of the continent. That is clearly not the case. The right image in the figure shows an enlarged view for southern Africa for September 2000, where more individual fires are depicted. Nevertheless, the spread and near-permanence of the phenomenon cannot be denied and must be considered alarming. As stated above, wildfires at a local scale may pose less of a threat to life and property than the other hazards discussed in this review. However, accumulatively they cover a larger area, and their secondary and tertiary consequences may altogether pose a larger long-term threat, as the gradually one of Africa's principal economic basic – agricultural land and livestock raining grounds – which is already scarce gets reduced further. Man-started fires already account for an estimated 95% of all wildfires in Africa, and some 30 million hectares out of the subequatorial 122 million hectares burn annually (SEEN, 2001). Goldammer (2001) reported that Africa accounts for 22% of all phytomass burned globally.

Detailed mapping of the firehazard is complicated because of increasingly man-induced fire occurrences. In principle any vegetated terrain is susceptible to burning. In reality it is also a function of vegetation drought condition, elevation (which influences temperatures), wind exposure, and, importantly, vegetation type. This is reflected in Table 8, which shows a regional fire hazard classification used by the Integrated Fire Management in Southern Africa. In particular highly burnable plant species, such as Eucalyptus, and areas on hill slopes with high wind exposure, can face high wildfire hazards.

Hazard Class	Hazard Description	Qualifying Categories
A	Extremely high fire hazard	▪ Montane grassland irregularly burned. ▪ Unmanaged Wattle jungle. ▪ Rural settlements situated on the dangerous, wind-exposed side.
B	High fire hazard	▪ Irregularly burned wetlands. ▪ Industrial sites, e.g. sawmills. ▪ Plantations consisting mainly of *Eucalyptus.*
C	Medium fire hazard	▪ Yearly burned montane grassland. ▪ Yearly burned wetlands. ▪ Plantations consisting mainly of *Pinus.* ▪ *R*ural settlements situated on the less dangerous leeside.
D	Low fire hazard	▪ Overgrazed tribal land. ▪ Managed *Acacia* plantations. ▪ Yearly cultivated (ploughed) lands. ▪ Cultivated mealielands. ▪ Mechanically-prepared and sown, static, grazing camps.

Table 8: Regional fire hazard classes and characterisation used by the Integrated Fire Management in Southern Africa (Source: www.fire.uni-freiburg.de).

5.1.8 Epidemics

One of the hazards AIDA focuses on is epidemics. In section 5.1.4 it was already described how the principal disaster database, EM-DAT, only considers some of the non-chronic epidemics. Thus HIV/AID and tuberculosis are not considered. AIDA also does not include all epidemic types, but rather focuses on malaria, Rift Valley Fewer (RVF), and Avian Flu (H5N1). As such a continental or regional hazard mapping for epidemics as a whole is not possible, as environmental parameters favouring individual types, and vectors spreading the individual diseases vary widely. Hence every type, for both hazard and later also vulnerability, has to be considered separately. Of the above, **RVF** is largely endemic to Africa, with clusters along the Rift valley in Eastern Africa, the South, as well as in Mauretania and Senegal, as shown in Figure 33.

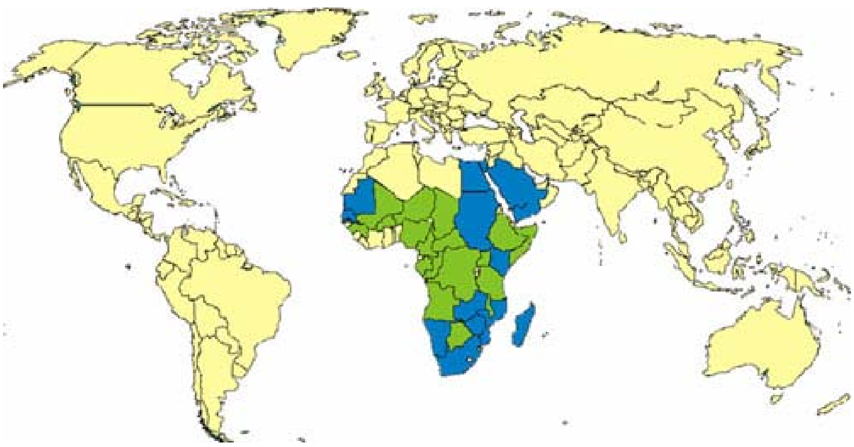


Figure 33: Rift Valley Fever distribution in Africa, with endemic disease presence in blue, and sporadic occurrence in countries marked in green (Source: CDC, US).

RFV is a viral disease affecting predominantly livestock, but can also cross to human hosts, and like malaria, is spread by mosquitoes. However, it can also be passed to humans via infected animal blood and tissue. No human-to-human transmission has been observed. While normally occurring in sporadic and isolated numbers, epidemics are possible and can affect millions of people. First described in the early 1900s in Kenya it has since led to several large-scale epidemic outbreaks. Considered a minor affliction in humans for decades, it generated the first epidemic in the 1970s in Egypt, when over 1 million people were reportedly affected, and several thousand died. Further outbreaks were reported in later years, most recently in 2006/07 in Kenya and Somalia, when at least 75 people died in Kenya. Vaccines are available to protect animals from RVF, thus the hazard can be contained with comprehensive vaccination programs, limiting of animal movement when disease outbreaks occur, and adequate public education. Compared to the natural hazards reviewed above, RVF constitutes a readily manageable hazard, provided adequate attention is given and resources allocated.

Unlike RVF, **Malaria** is a global concern as some 40% of the World's population live in affected areas, and over 500 million people are affected each year, with 1-3 million, mostly in Africa, dying (WHO), see also Figure 17. It thus assumes a dimension incomparable to RVF or, as reviewed below, Bird Flu. Transmitted exclusively through mosquitoes, the disease intensity and regularity is nevertheless a function of rainfall rates, proximity to breeding sites and also mosquito species, leading to endemic and seasonal malaria areas. Similar to drought/famine, malaria must be considered more of a social disease than a natural hazard. This is because spreading of the vector can be contained and minimised with appropriate knowledge about infection and transmission mechanisms and adequate enforcement. Additional, exposure to the vector can also be minimised and, like vaccinations, only incur modest costs. Effective treatment and containment require adequate knowledge about hazard distribution. For malaria this can be done in several ways. In its simplest for an elevation mask can be used, as malaria has historically been limited to areas below approximately 1,500m. This, however, is not valid anymore, as the vector, aided by rising temperatures, has spread to higher elevations. This has been described in detail for Kenya (Shanks et al., 2000), but the same phenomenon is also known in other parts of the world, e.g. in Europe (Kuhn et al., 2003).

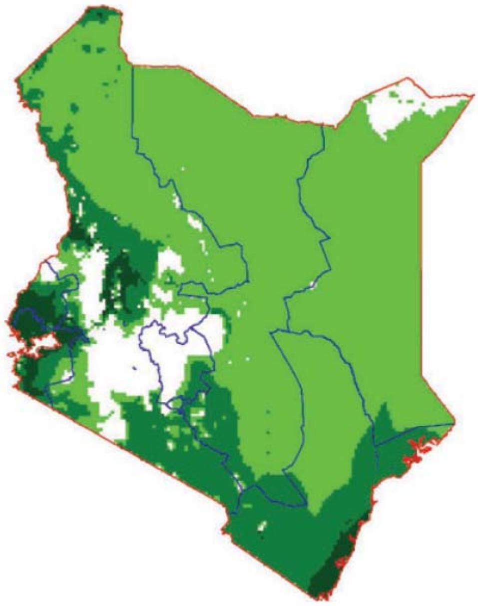


Figure 34: Endemic malaria distribution in Kenya, shown through the Fuzzy Climate Suitability index, ranging from 0 (white) to >0.75 (dark green). This signifies the risk of being suitable for malarial transmission in an average year, from totally unsuitable to highly suitable (Source: Hay et al., 2005).

The extensive research on malaria over the last decades has resulted in detailed knowledge on environmental parameters promoting mosquito breeding. Such knowledge can be integrated in distribution models that give a more detailed view on where the hazard can be expected to be present, and when, as is shown in the example for Kenya in Figure 34. The figure shows the risk of different areas being suitable in a given year (from not at all to highly suitable) for mosquito-based malaria transmission.

Yet another method to map malaria hazard involves empirical modelling based on malaria incidence survey results. Such an approach was described by Kleinschmidt et al. (2001), who used geostatistical methods of malarial occurrence in relation to environmental and climatic variables. Considering parameters such as temperature, precipitation and vegetation and surface water presence, the predicted prevalence for a given year was mapped (Figure 35). This is a clear step forward in detail for the hazard assessment when compared to more global or continental maps such as the one in Figure 17, but also to the one based on elevation only (Figure 34).

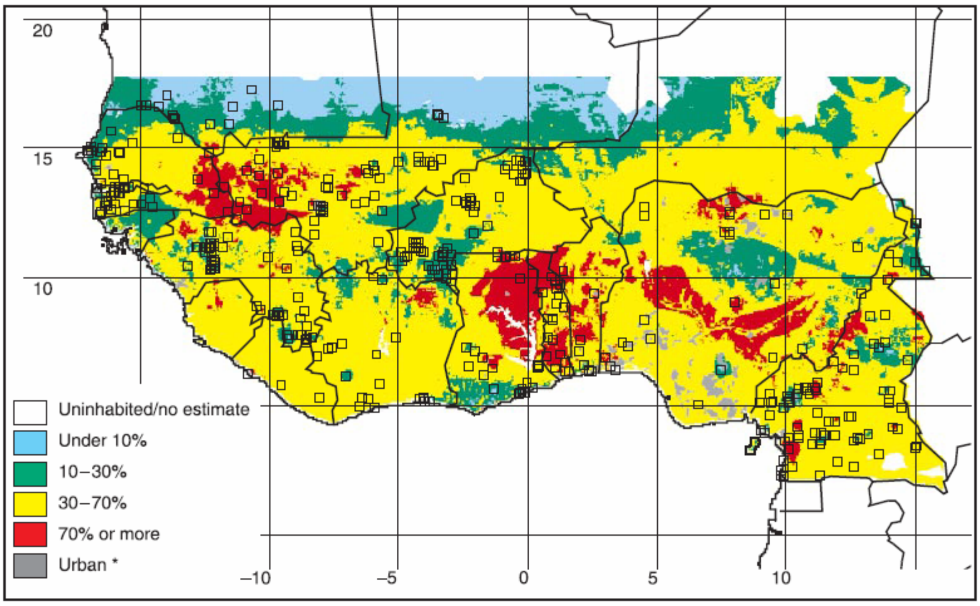


Figure 35: Malaria prevalence in Northwest Africa based on modeled environmental and climatic parameters (Source: Kleinschmidt et al., 2001).

A final malaria hazard assessment method that can be employed is community participation, but this is only feasible at local scales and is thus not considered in this section.

Bird Flu, also known as Avian influenza, is the most recent threat of the epidemic types considered here. Compared to malaria, RVF or other vector-borne biohazards little is known about the disease and thus the hazard it presents. The other commonly used term, H5N1, refers to the variant of bird flu that caused concerns about a pandemic in 2006 and 2007, particularly in Asia. The vector in this case is birds, with the disease primarily posing a threat to the host bird. Bird-to-human transmission is comparatively rare, resulting in a situation where large animal populations were affected or exposed to direct transmission hazard, while actually few people have become affected and died. Depending on the animal and virus types, the host may also not be affected by the disease at all, merely functioning as a potential carrier.

H5N1 appears to be a particularly infectious and deadly bird flu strain which caused the concern about a possible pandemic. It was first identified in 1997 and has since killed millions of birds, in particular poultry. According to the WHO as of late 2007 only 206 people had died of bird flu, illustrating that the transmission between infected birds and humans is not an easy one. However, exposure routes and specific disease transmission characteristics are clearly not well understood.

The disease emerged in Asia and has affected nearly all parts of the continent (Figure 36). From there it spread via migratory birds to Europe and to Africa. First Djibouti was affected, followed by Nigeria, Niger, Egypt, Cameroon, Burkina Faso, Sudan, Ivory Coast, and Togo (Wikepedia). However, in terms of fatalities only 22 have been recorded in Egypt, and 1 in Nigeria, numbers that pale in comparison to fatality rates due to other hazards (WHO, http://www.who.int/csr/disease/avian_influenza/country/en/). However, the threat sis made credible by its ability to infect vast livestock numbers, thus potentially causing a serious economic hazard. Furthermore, with H5N1 being only one variant of bird flu, the potential for other, more deadly virus strains to emerge, is real.

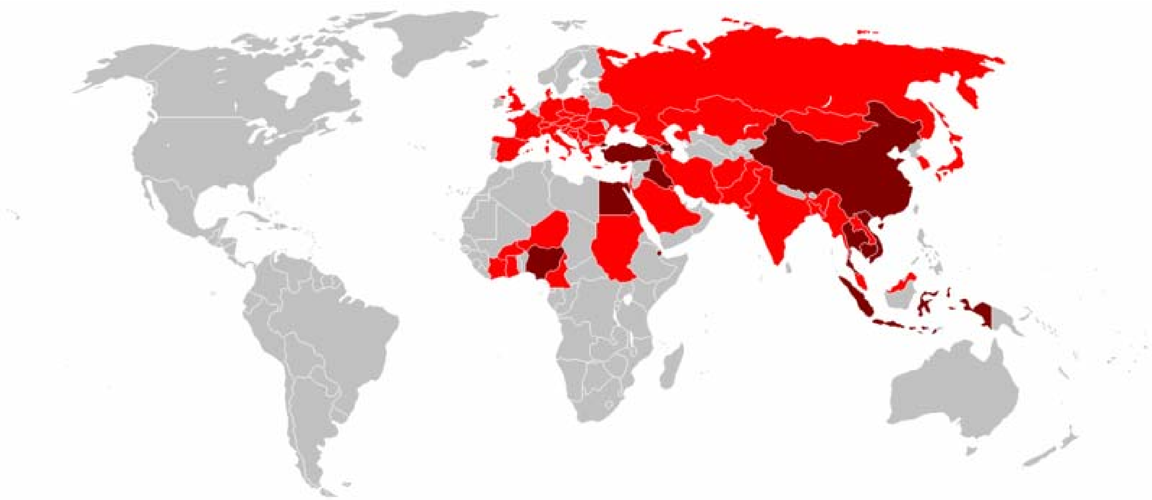


Figure 36: Global spread of H5N1bird flu as of 2007. Red marks countries where birds were killed by H5N1, brown those were also people were infected or killed (Source: Wikipedia).

5.1.9 Hazard from sea level rise

A considerable debate has surrounded the issue of sea level rise for decades. While observations against historic records suggested an increase, and climate models calculated a rise in global sea levels as a result of expected global warming, thermal expansion of ocean water, and due to glacier melting, a detailed and accurate picture only gradually emerged. Only recently have studies been finished that extent the global sea level record to 1870, providing a sufficiently long timeframe for long term trends, and against which to project increases. These studies determined that globally sea level has risen by 195mm between 1870 and 2000, corresponding to a 20th century rate of sea-level rise of 1.7 ± 0.3 mm yr^{-1}. More importantly, though, there has also been an increase in rise of 0.013 ± 0.006 mm yr^{-2} (Church and White, 2006). This means that if these acceleration rates are assumed to be constant, we can expect a sea level increase between 1990 and 2100 of between 280 and 340 mm, which is consistent with the IPCC Third Assessment Report. As climate models still contain uncertainties, especially concerning feedback processes, there is the potential of more drastic increases. The feedback is particularly uncertain for the Arctic and Antarctic. Thus several scenarios exist. If smaller glaciers in those polar regions were to melt, an increase of approximately

0.5 m would be the result. If the entire Greenland ice shield, already receding at record and accelerating rates, were to melt, the sea level on average would rise by about 7.2 m. The Antarctic ice shield, though considered far more stable, could raise sea levels by over 61 m.

To assess the potential consequences of such an increase, several points have to be considered. Sea level rise is not universally constant. It is assessed with respect to land benchmarks, which themselves may be in movement. In particular isostatic adjustments of the Earth's mantle following the melting of glaciers at the end of the last ice age are still ongoing (e.g. in Scandinavia). Similarly, many delta regions in the world have been subsiding, typically resulting from fewer sediments arriving at the river's mouth as dams and dikes regulate water flow. For example, the Nile delta has been subsiding at a rate of about 0.5 cm per year, and is expected to recede in parts up to 30km by the year 2100 (US Global Change Research Information Office). Active oil and gas extraction from delta regions has an even more dramatic effect. Abam (2001) reported on measured rates in the Niger delta of between 2.5 and 12.5 cm per year. Similar to the extraction of oil and gas, excessive ground water removal can lead to the subsidence of urban areas. While this has led to significant problems in low-lying Asian cities such as Bangkok and Jakarta, where subsidence rates of 1-10 cm per year have been measured, no comparable problems are known for Africa. Ericson *et al.* (2006) provide a detailed discussion on the particular challenge of seal-level rise to delta regions. Sea levels are also influenced by atmospheric pressure variations and ocean currents.

Expected sea level rises are gradual, which offers some possibility to adjust to increasing hazard. However, the expected consequences of sea level rise are varied, and include increased coastal erosion, higher storm-surge flooding, inhibition of primary production processes, more extensive coastal inundation, changes in surface water quality and groundwater characteristics, increased loss of property and coastal habitats, increased flood risk and potential loss of life, loss of nonmonetary cultural resources and values, impacts on agriculture and aquaculture through decline in soil and water quality, and loss of tourism, recreation, and transportation functions (IPCC TAR).

Sea level rise has a substantial hazard potential because some 634 million people were estimated in 2007 to be living within 9.1m (30 feet) of sea level (see special issue on "Reducing risks to cities from disasters and climate change" in Environment and Urbanization of April 2007). Additionally, over two thirds of all cities with populations of over 5 million are located in those zones. In particular low-lying island states are threatened by rising sea levels.

The current population of Africa is estimated at 650 million, which is expected to double by the year 2025. At the same time an increase from 200 to 500 inhabitants/km^2 is projected for coastal urban area (Awosika and Folorunsho, 2005), placing additional challenges on preparedness and risk mitigation. Figure 37 shows the elevations of coastal regions relative to sea level. While Africa is a continent marked by comparatively high average elevation, with the central plateau resulting in the highest average for any continent, extensive low-lying coastal and delta regions also exist. The areas shown in Figure 38 are particularly threatened. Those are the Niger delta in Nigeria (A), the Zambeze delta in Mozambique (B), the coastal areas around the Gambia and Senegal rivers, together with the low-lying areas around Bissau (C), and the Nile delta in Egypt (D). However, all coastal areas marked in brown-red-yellow hues in Figure 37 must be considered particularly threatened. Since the maps show low-lying coastal areas they can also be used to locate areas where tsunamis, especially originating in Asia (see section 5.1.6), may progress far inland, as well as area where storm surges associated with tropical storms (see section 5.1.5) may lead to extensive coastal flooding.

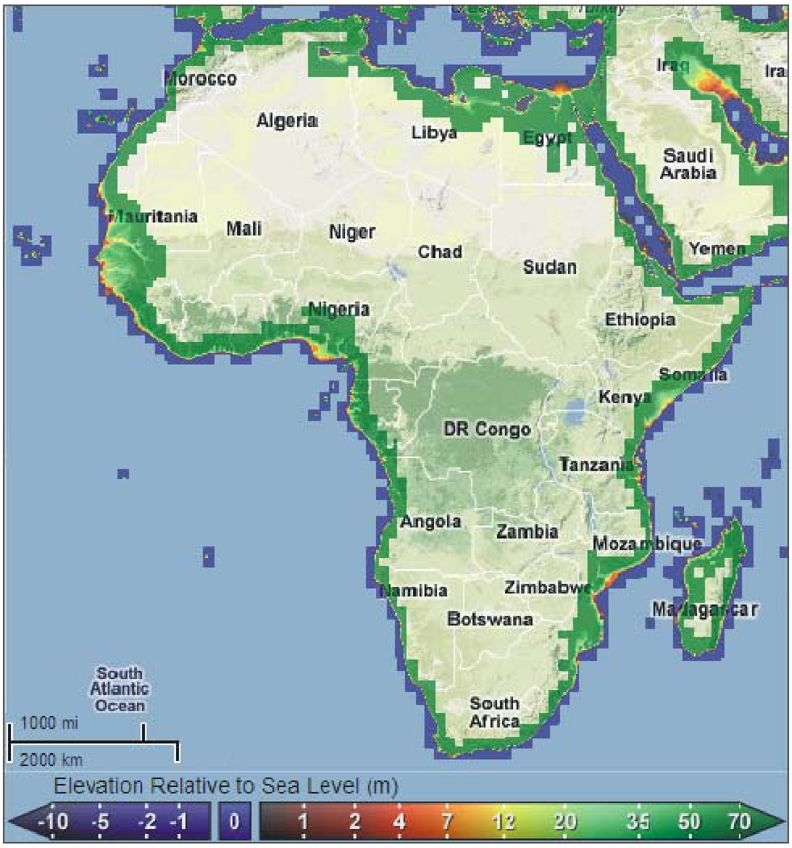


Figure 37: Coastal elevation values for Africa with respect to sea level (Source: www.globalwarmingart.com).

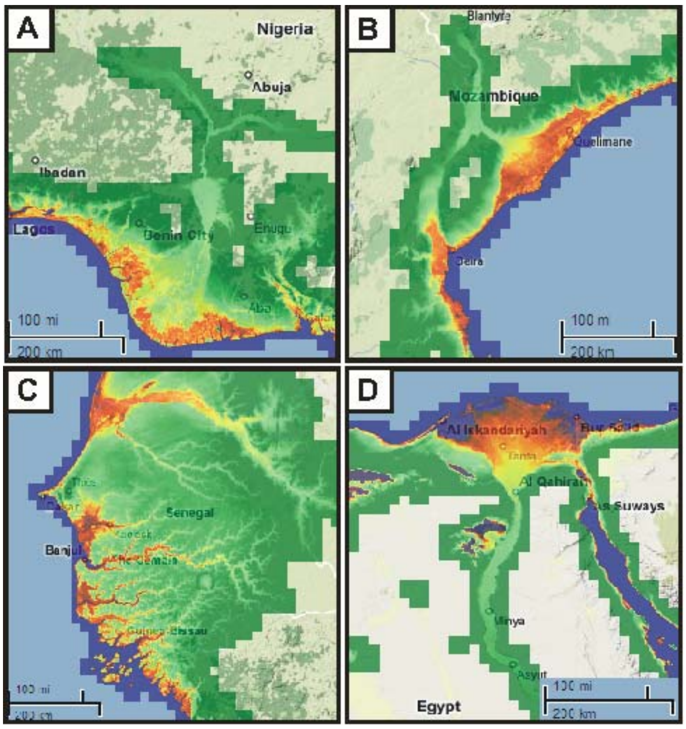


Figure 38: Coastal elevation values for Africa with respect to sea level, showing especially vulnerable regions in Nigeria (A), Mozambique (B), Senegal, Gambia and Guinea-Bissau (C), and Egypt (D). Source: www.globalwarmingart.com.

Compared to the other hazards reviewed in this chapter, sea level rise poses a more long-term, but increasing threat. Linked largely to climate change it has thus similarities to other climate-related hazards, such as desertification and increasing drought, also affecting large parts of the continent. The effects of sea level rise, however, are more predictable and spatially determined. As population and associated activities in coastal areas are certain to increase, appropriate planning for the consequences of a gradual rise, but also the described potential episodic effects, is needed for all countries bordering the oceans, especially for those with extensive low-lying countries as described.

5.1.10 Hazards from grasshoppers and locusts

No other continent is as associated with large-scale insect invasions, in particular through locusts and grasshoppers, as Africa. They normally inhabit some 30 countries (the recession area in Figure 39) and are harmless in small numbers. During a rapid increase in numbers swarming also to neighbouring countries (invasion area) occurs, bringing the total of potentially affected countries to 60, in Africa, the Middle East and parts of Southern Europe, in total some 20% of the Earth's land surface.

A recurrent plague of devastating potential, locust invasions have been described since biblical times, and despite decades of research our capacity to predict and fight invasions remains limited. With the breeding cycle of locusts being more tied to weather than climate, recurrent rainfall during this part of their life cycle accelerates the breeding and is a typical precursor to swarms. The most devastating plagues in the 20th occurred in 1926-1934, 1940-1948, 1949-1963, 1967-1969, and 1986-1989. Highly mobile, locusts can fly at speeds of 15-20 km/h, being able to cover up to 130km per day, and swarms with 40-80 million locusts per km^2 have been recorded. A typical adult locust consumes its body weight (ca. 2 g) in food per day, thus for every million locusts one metric ton of plant material is eaten per day.

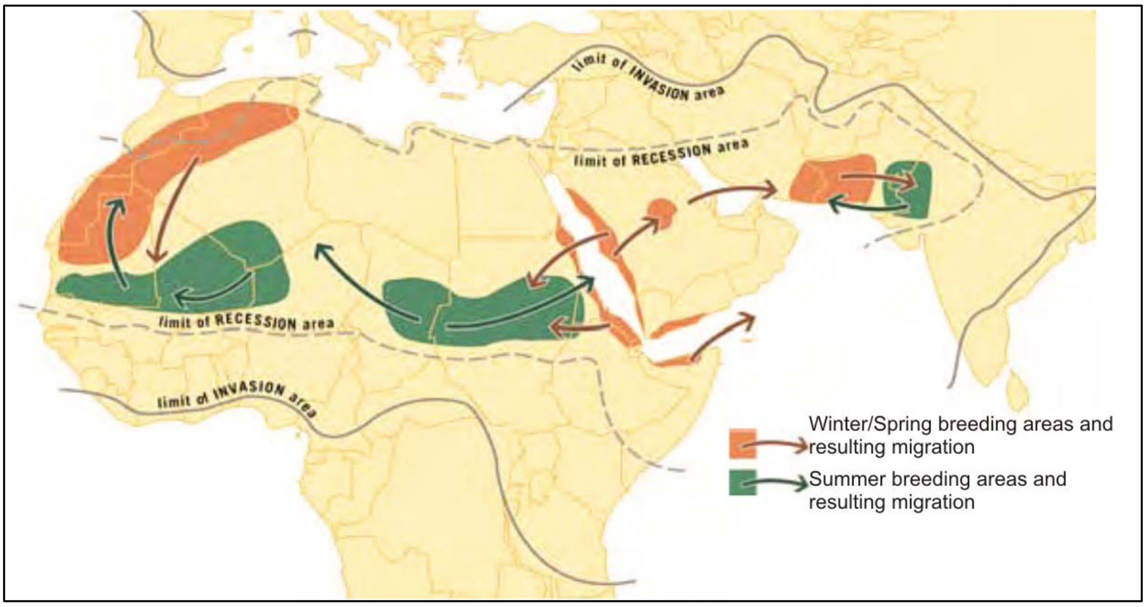


Figure 39 Locust breeding and invasion areas in Africa, the Middle East and Southern Europe (Source: FAO report *Fighting the locusts safely*).

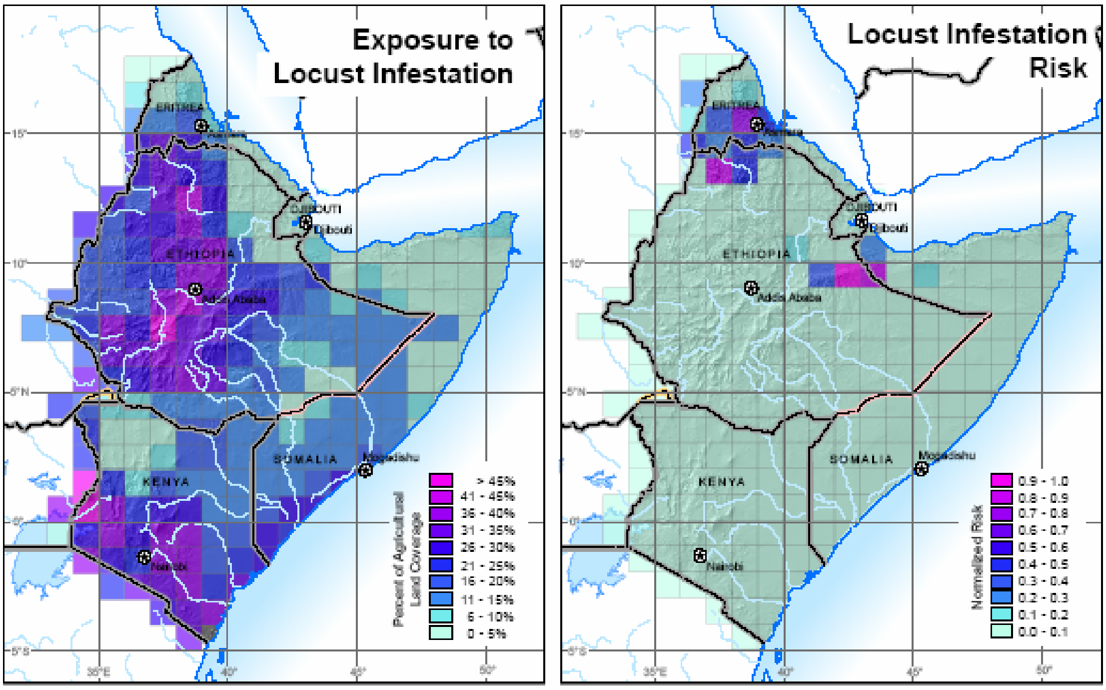


Figure 40: Locust exposure and infestation risk for the Horn of Africa, based on data from 1992-2006 (Source: US Humanitarian Information Unit).

The most recent massive outbreak in Africa occurred in 2004, when 10 Western African nations (Algeria, Burkina Faso, Cap Verde, Chad, Mali, Morocco, Mauritania, Niger, Senegal, and Western Sahara) were affected. Historical infestations were more clustered in northern Eritrea and near the conjunction of Somalia, Ethiopia, and Djibouti. These regions have an annual probability of locust invasions that can exceed 30-40% (www.reliefweb.int). Over the past 15 years there have been 106 documented infestations in the Horn of Africa (HoA) region alone, with 57% occurring in Eritrea, 26% in Ethiopia, and 17% in Somalia, close to some of the main winter breeding areas (Figure 39).

Detailed exposure and risk studies have been carried out for the HoA region, based on 1992-2006 data compiled by the FAO Locust Control Office (Figure 40). While much of the area is potentially exposed, the highest risk of infestation is in Eritrea, close to the winder breeding sites. Satellite remote sensing has long been used to study environmental parameters linked to locust breeding and invasion (see for example Hielkema et al., 1990).

5.2 Summary

The purpose of this chapter was to review the hazard situation in Africa at a continental and regional scale, both for natural and biological threats. From the picture emerge several clear points, briefly summarised here.

- The continent is marked by a large diversity of both natural and biohazards.
- The pattern of the present hazards is highly variable in spatial scale. It ranges from local (most volcanic hazards, tornadoes), to regional (larger, cyclonic

windstorms, seismic hazards) to threats that affect larger sections of the continent (drought, flooding, forest fires, epidemics).

- Hazards are multi-faceted. Most hazards have different expressions that may work on different spatial scales and have variable physical characteristics. An extreme example is volcanic hazard, which can manifest itself in at least 16 forms, which range in impact from global (stratospheric/tropospheric gas and ash injection) to regional (e.g. tsunamis triggered by flank failures of island volcanoes) to very local (e.g. CO_2 clouds or volcanic bombs). Mapping such hazards thus has to be done at various scales and for the individual hazard types. The vulnerability of the potential EaR will also vary highly with the hazard form.
- Hazards can be (i) relatively static (e.g. seismic activity), (ii) episodic or sporadic (e.g. volcanic activity, disease outbreak), and (iii) seasonal (e.g. forest fires, flooding). In risk assessment this frequency is considered, but it must be remembered that non-static or rarely occurring threats (e.g. tsunamis) may be more difficult to assess that static hazards, in part because limited historic data exist as a basis for the frequency analysis.
- Hazards occur not only on variable spatial scales, but are equally temporally dynamic. This has consequences on the lead-time (and the possibility to warn and prepare), the impact energy in terms of present or lacking preparedness, and the duration. It must be understood in detail how a hazardous event can emerge, where it can originate and how long it takes for its impact to be felt, how long it may persist, and how large an area it may cover at which severity level.
- Different hazard types may be linked or compound each other (e.g. an earthquake also destabilizing slopes or dams), potentially leading to secondary disasters. These may be associated with an exposed area of different size, and with different types of vulnerability. For example, while most people may be quite equally vulnerable to a volcanic event at comparable magnitude, following a dam break after and earthquake the young, infirm and less mobile may be more vulnerable that the fitter parts of the population. Risk assessment must reflect that.
- Several hazards are entirely of natural origin (geo or bio), such as seismic or volcanic activity or malaria. Others, such as wild fires, though also originally of natural cause, and increasingly man-induced.

6. From hazard to risk

Hazard assessment can be considered the starting point of risk assessment, as it can provide a detailed overview of the variety of geological, biological or man-made threats, their possible frequency/magnitude relationship, onset and duration, as well as potential multi-hazard interaction. Chapter 5 comprehensively discussed the main geo- and biohazards facing African.

Hazard, however, as explained in chapter 3 is only one aspect on the way to understand risk. Also needed are a detailed understanding of elements at risk (EaR) and their vulnerability. This chapter reviews what is known about the vulnerability and risk situation in Africa.

6.1 Vulnerability in Africa

It is important to remember the issue of scale already introduced in Chapter 4. While an overview of present hazards at continental and regional scales is possible and can be quite useful in an effort to focus scarce resources for DRR, the utility also quickly reaches its limit. This is because hazardous events tends to have more local than regional consequences, as the EaR tend to operate on smaller spatial scales. For example even in a large storm, seismic event or tsunami, it is people, property and infrastructure that may be harmed, and those elements typically have a small spatial extent. Exceptions are hazards such as volcanic stratospheric gas injection (section 5.1.2) that can have continental or global consequences, desertification, where vast swaths of agricultural land may be lost to deserts, or loss of biodiversity, where less the individual EaR, such as an animal, matters, but entire ecosystems suffer. For the other hazards considered in this conceptual framework, and particularly in AIDA, people and their livelihood are the focus, thus necessitating less of a macroscopic look.

What, then, can be said about the vulnerability at a continental scale? While variable, we have to consider here what makes people and their assets vulnerable, as discussed in section 3.3. We find a broad picture of poverty, limited education and capacity, limited financial resources, lacking mitigation, preparedness and early warning systems, and poorly developed command hierarchies within governments (and connecting effectively with entities that have knowledge on hazards and risk), only occasionally punctuated by places where at least some of these points have been addressed effectively, leading to reduced vulnerability, higher capacity, or both. With the various reasons and processes that can lead to and modify the different forms of vulnerability, generalizations for the African continent, or even regions, are at times possible, but frequently meaningless if we accept the role of vulnerability assessment as a step towards understanding and reducing risk. Hazard may be global, but vulnerability is local, and most effectively and sustainable addressed that that scale. If we mapped GDP per country or province we could obtain a picture of poverty. However, in section 3.3 we saw that poverty does not necessarily equate with vulnerability. Equally important are social networks, appropriate housing even if it is simple, and effective mitigation, early warning or evacuation plans that are also possible in countries with limited resources.

One useful approach to consider vulnerability is a look at previous disasters and the specific consequences for people, property and infrastructure. As a general rule, an event with comparable characteristics in terms of extent, magnitude and duration, will lead to comparable results, provided (i) no substantial changes were introduced to reduce vulnerability or increase capacity in the aftermath of a previous event, and (ii) sufficient time passed between the 2 events for reconstruction to occur. After all, damage can be expected to be less if livelihoods are not yet rebuilt, or people not yet moved back from temporary relocation-sites by the time of the second event. What we can see is that renewed episodes of flooding, seismic activity, or drought lead to comparable consequences, suggesting a general stability of vulnerability and capacity, unless a strong outside effort – e.g. by governments or NGOs – is made to change the situation. A closer look then at the consequences of a specific event can provide useful insight into general patterns of vulnerability and capacity. If a prolonged drought occurs, such as in parts of Ethiopia since 2005, widespread famine is likely to result. If another flooding event was to occur in and around Uganda, similar to the one in 2007, we could expect similar outcomes in terms of fatalities, number of affected people and economic damage. This, in turn, allows general vulnerabilities to be identified and acted upon. For example, following previous famines, the Ethiopian government began in 2004 to move up to 1 million people from the highly drought-affected central highlands to more fertile areas, thus likely reducing the vulnerability of these people to drought and famine. Such broad assessments can also be made for other types of vulnerability. For example, given the increasing rate of wild fires over the last years (section 5.1.7), coupled with an understanding of the consequences, for example in terms of soil degradation, it can be modeled which areas are likely going to be facing critical environmental vulnerability given continued burning.

A challenge to such continuity or trend-based assessments of vulnerability are externalities in other parts of the world, and their potential erratic nature. Processes and decisions, especially those in the developed world, may have a strong impact on risk in Africa, primarily via vulnerability. Here we can distinguish between relatively static and more dynamic externalities. A typical quasi-static externality is import tariffs and subsidies in the western world, in particular in the agricultural sector. These subsidies and trade obstacles tend to effect that economies in entire sectors can collapse and stay depressed. Well publicized cases (see for example www.ukfg.org.uk/) have shown how subsidized produce from the EU, sold cheaply in Africa, killed off local production of those products in Africa, where production costs were higher for lack of subsidy and industrial-scale production. For all the potential side-effects – cheaper food – that can quickly disappear (see the problem of local rice production in Haiti, similarly killed by cheap imports from the US, that lead to starvation after prices for imported rice rose), it results in a crippled local economy, a good source for social vulnerability. Dynamic externalities have related effects. Decisions or developments outside the influence of Africa can have sudden consequences for the risk situation in Africa. For example, the sudden and dramatic increase in global food prices in early 2008 had 2 distinct effects on Africans, both increasing the number of starving people. First, it substantially enlarged the number of people with insufficient resources to pay for the higher prices (see the Haiti example), but also affected negatively the assistance by the international donor community. The World Food Program, for example, in April 2008 reported a funding gap of $500 million as a result of the food price increase. Such price increases not only lead to higher numbers of starving people, but clearly also affect vulnerability: (i) malnourished people are weaker and thus more susceptible to external shocks, (ii) people threatened by famine may move to other areas that may have higher hazard exposure (city slums, refugee camps), and (iii) children previously in education are more likely to have that education interrupted (due to the family moving away, or children being needed to help earn a living).

Similarly, it must be understood that rapid risk increases are possible and more likely than rapid decreases. Zimbabwe, for example, as a result of disastrous policies, has created a population now massively at risk. The former major regional food provider how has an estimated 5 million people exposed to food insecurity (FEWSNET, www.fews.net).

6.2 Summary

Thus useful observations about vulnerability and risk at continental or regional scales, which may be used to focus more in-depth analysis or broader structural measures, can be made. However, the risk exists that poverty indicators, as the typically only available measure, is used as a proxy for vulnerability. This is only useful if the limitations of such an approach are understood. More directly actionable risk assessment needs to be done on local scales, where specific data on existing hazards, EaR and their respective vulnerabilities and be collected and used, also in a more quantitative manner. Geoinformatics tools, such as GIS, becomes increasingly useful at those scales.

Part II: Global and international DRM initiatives, and ICT for DRM in Africa

7. Disaster Risk Reduction policies and strategies

Hazards and disasters pose a global threat. Not only can large scale events affect more than one country; activities in one country increasingly have repercussions in neighbouring countries. This is true for both natural and man-made hazards, and, as for hazards and risk in general, works on all spatial scales. For example, excessive emissions of greenhouse gases in one country have consequences in other parts of the works via global warming, while nuclear accidents expose downwind countries to nuclear fallout. A particular responsibility rests on countries that share large river systems with downstream neighbours, as any substantial engineering measure (e.g. building of dams or dikes) will affect the risk of water related disasters (flooding or drought). Several major river systems in Africa illustrate these challenges: Mozambique relies on an effective water management by Zimbabwe that ensures both sufficient water availability and flood control. More dramatic is the situation along the Nile, where the Nile Basin Commission was established to defuse the tension built up by Nile source countries, particularly Ethiopia, demanding a higher share of the water, which will reduce water availability in Egypt.

Not only hazards and risks have to be approached and mitigated in a global or regional manner. Also vulnerability and disaster response are increasingly viewed from a larger perspective. For example, the Food and Agricultural Organisation of the UN (FAO) and the World Food Programme (WFP) require regional approaches when assessing the state of crops or impending famine, while global threats ranging from climate change to species loss can only be tackled in a global forum. Consequently a large number of international efforts aimed at DRM has emerged, which are reviewed in this chapter.

7.1 International Decade for Natural Disaster Reduction (IDNDR)

Motivated by increasing losses to disaster, in late 1987, the UN General Assembly designated the 1990s as the **International Decade for Natural Disaster Reduction** (IDNDR). The UN World Conference on Natural Disaster Reduction in 1994 formed the mid-term review of the decade (resulting in the **Yokohama Strategy**), which then ended in 1999. Initially more oriented towards technological solutions, beginning with the mid-term conference the socio-economic aspects of risk became more prominent. It was further recognised that social factors, such as cultural traditions or religious values, but also economic standing and political accountability, are essential determinants of societal vulnerability and thus central to DRM. One of the central aspects of the IDNDR was thus the realization that a global strategy aimed at reducing the impacts of natural hazards has to include the development of national and sub-national mechanisms for disaster risk reduction, as societal vulnerability as a function of values and traditions can only be effectively addressed at those levels. Hence National Platforms were called for that would facilitate the translation and adaptation of more general disaster risk reduction objectives and approaches to national and local conditions.

The IDNDR was also used as a vehicle to focus research into natural hazards. For example, the **International Association of Volcanology and Chemistry of the Earth's Interior** (IAVCEI) identified 16 volcanoes with unusual history or hazard potential and designated them ‘Decade Volcanoes’. Nyiragongo volcano in the DRC and Teide on Tenerife were identified as Decade Volcanoes in Africa (the latter geographically and geologically, not politically). This led to extensive research into the various volcanic hazards, but also a better understanding of risk to the local population. Additionally, volcano observatories were set up (in Goma, DRC, for Nyiragongo, and the Observatorio del Teide), both serving as research and monitoring focus for larger regions.

7.2 The Geneva Mandate

The goals for the IDNDR had been optimistic and ambitious. However, the number of disasters remained high (EM-DAT lists 5,000 disaster events globally for the decade), and also research foci such as the Decade Volcanoes posed problems (e.g. interruptions by civil war in DRC or in Guatemala, deaths of scientists at designated workshops). Thus it was clear that even a concerted effort for 10 years was insufficient to reduce the disaster risk on a global level. New disasters with large fatality numbers had occurred, both in developing countries (e.g. close to 140,000 following a 1991 cyclone in Bangladesh) and developed countries (e.g. 5,300 fatalities during the 1995 Kobe, Japan, earthquake). This is not surprising, considering first the relatively slow rate of scientific research into the complex processes of natural hazards and their links to socio-economic vulnerability, which subsequently has to be translated into operational hazard reduction, monitoring and early warning/evacuation strategies, as well as approaches to reduce vulnerability of society and environmental and economic systems at all administrative levels. With continuously limited understanding of the complex multi-hazard risk situation, especially at local levels, and limited funds that can be applied towards DRR, it is clearly a long-term ambition. Hence it was decided to extent the IDNDR with a permanent, UN-led initiative, the International Strategy for Disaster Reduction (ISDR), was formed during what was termed the **Geneva Mandate on Disaster Reduction**.

The Geneva Mandate is a declaration of intent, focusing on the following main points:

- Build on the achievements of the IDNDR;
- Continue the course set in the *Yokohama Strategy* and the summarising document of the IDNDR *A Safer World in the 21st Century: Risk and Disaster Reduction*;
- Adopt and implement policy measures at the international, regional, sub-regional, national and local levels aimed at reducing the vulnerability of society to both natural and technological hazards through proactive rather than reactive approaches;
- Employ research in the natural, social and economic sciences, and devise technological and planning applications at all levels and involving a wide range of disciplines to support comprehensive DRR;
- Ensure more effective information exchange and early warning, technology transfer and technical cooperation between all countries;
- A multi-sectoral and interdisciplinary approach to DRR is needed;
- Develop and strengthen regional approaches that reflect local needs and means.

The following statement in the Mandate makes it particularly relevant for AIDA:

> "We recognise the particular need for establishing an institutional arrangement to coordinate disaster reduction in Africa, and in this regard,

invite existing and evolving mechanisms for inter-regional co-operation to accord priority to these concerns."

7.3 International Strategy for Disaster Reduction (ISDR)

The IDSR is meant to continue the efforts started during the IDNDR, as stated in the Geneva Mandate. It is to develop new mechanism for DRM, and to push governments to implement better what is understood about DRR. The overall goal remains to reduce human, social, economic and environmental losses due to natural hazard events, which was extended to include related technological threats. Specifically, the aims are expressed in four major objectives:

- Improve scientific knowledge about disaster reduction;
- Increase public awareness to understand risk, vulnerability and disaster reduction globally;
- Obtain commitment from public authorities to implement disaster reduction policies and actions;
- Stimulate interdisciplinary and inter-sectoral partnerships, including the expansion of risk reduction networks.

Particularly noteworthy are the expressed need to increase public awareness to understand the risks society faces, and the abilities and responsibilities of individuals and population groups to reduce their own vulnerabilities. It is also seen as critical for authorities and decision makers at all levels to be committed to the DRR process. This is because vulnerability is generated at the very local level (e.g. through inadequate planning processes, or inequality within the population), as well as at national scales (e.g. through inadequate planning and infrastructure for supply distribution to prevent famines, but also lacking national education or health care investment). Similarly, hazards can be assessed at regional or national levels, including their potential to spill over from one administrative area into another, while important hazard reduction means, such as dike or drainage construction, is best done locally. Hence, the focus on multi-scale linkage and need for intersectoral and interdisciplinary cooperation is central to effective DRM. The ISDR also encourages the cooperation between authorities and grassroot efforts, e.g. the work of NGOs, who tend to have a better sense of the vulnerability situation at community level, and thus are best placed to implement capacity building and vulnerability reduction measures.

The ISDR is present in Africa through offices in Cairo (for North Africa) and in Nairobi (for the rest of the continent, see http://www.unisdr.org/africa). While the DRM concepts described in the first part of the CF are also applicable in Africa, the specific hazard/vulnerability situation requires a regional adaptation of the ISDR, expressed in the **Africa Regional Strategy for Disaster Risk Reduction** (ARSDRR). Set up with the support of the **New Partnership for African Development** (NEPAD), the Africa Union Commission, UN/ISDR Africa, the African Development Bank (ADB), the UNDP-Bureau for Crisis Prevention and Recovery (BCPR) and UNEP, the ARSDRR focuses specifically on integrating DRR into development programmes. Thus its objectives are:

- To reduce the social, economic and environmental impacts of disasters on African people and economies, for sustainable development.
- To increase understanding and knowledge of DRR as an integral part of sustainable development.
- To increase capacity at sub-regional and national levels for mainstreaming and implementing DRR into development processes.

This is a clear expression of hazard theory moving towards recognising the fundamental socio-economic dimension of risk, as described earlier. In this context ARSDRR sees itself as overarching strategy that fosters appropriate policy and strategy development, awareness in DRR, information and knowledge exchange, and supports networks and partnerships that work towards mainstreaming DRR into the development process. The underlying principles and causes of risk, as well as the need to integrate DRR into the wider sustainable development process are detailed in the principal publication of the ISDR, *Living with Risk* (UN/ISDR, 2004).

7.4 The Hyogo Framework for Action (HFA)

A total of 168 countries and multilateral organizations (including the UN and the World Bank) participated in the UN World Conference on Disaster Reduction in Kobe, Hyogo, Japan in January 2005, which resulted in the Hyogo Framework.
With the full name being **Hyogo Framework for Action** 2005-2015, it is further subtitled *Building the resilience of nations and communities to disasters*. It is particularly the subtitle that makes it clear that the key to DRR is not to eliminate or contain hazards, but rather to reduce vulnerabilities and build capacity, both at national and local scale, for the reasons explained in section 7.3.

The HFA is thus the blueprint for concerted DRR efforts and is, unlike the initial IDNDR, strongly focused on prioritising and promoting practical means for achieving disaster resilience for vulnerable communities. Hence, while similarities to the ISDR and ARSDRR are clear, the stated objectives are more specifically related to institutional and societal capacity building. The strategic goals are:

- The integration of disaster risk reduction into sustainable development policies and planning;
- Development and strengthening of institutions, mechanisms and capacities to build resilience to hazards;
- The systematic incorporation of risk reduction approaches into the implementation of emergency preparedness, response and recovery programmes.

The goals are translated into specific priorities for action:

- Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation.
- Identify, assess and monitor disaster risks and enhance early warning.

- Use knowledge, innovation and education to build a culture of safety and resilience at all levels.
- Reduce the underlying risk factors.
- Strengthen disaster preparedness for effective response at all levels.
- In their approach to disaster risk reduction, States, regional and international organizations and other actors concerned should take into consideration the key activities listed under each of these five priorities and should implement them, as appropriate, to their own circumstances and capacities.

These objectives also suggest that enough is understood about the link between vulnerability, inadequate preparedness, warning and response to an event, and a possible disaster, as research is not listed as a priority anymore. However, this impression is incomplete, as the importance of research, particularly into more effective multi-hazard risk assessment, socio-economic cost-benefit analysis, hazard impact and into vulnerability is made clear in the framework (UN/ISDR, 2005).

On one hand the HFA is surely a conceptual policy documents; on the other it is also a practical guide into required actions, and correctly identifies important cross-cutting issues:

- The need for a multi-hazard approach;
- Consideration of a gender perspective and of cultural diversity;
- Commuity and volunteer participation;
- Capacity building and technology transfer.

The document further elaborates on the implementation of the stated objectives, and calls for particular attention for Africa (together with island states and other least developed countries). It also evaluates the role of various actors in the implementation of the HFA: the States, regional organisations and institutions, and international organisations (including the UN). A chart-based 2-page summary of the HFA can be found on http://www.unisdr.org/eng/hfa/docs/summary-HFP-2005-2015.pdf.

Below the priorities for action, and the steps that need to be taken, which are discussed in depth in the HFA document (Source: http://www.unisdr.org/eng/hfa/hfa.htm), are summarized:

1. Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation
   - (i) National institutional and legislative frameworks
   - (ii) Resources
   - (iii) Community participation

2. Identify, assess and monitor disaster risks and enhance early warning
   - (i) National and local risk assessments
   - (ii) Early warning
   - (iii) Capacity
   - (iv) Regional and emerging risks

3. Use knowledge, innovation and education to build a culture of safety and resilience at all levels

(i) Information management and exchange
(ii) Education and training
(iii) Research
(iv) Public awareness

4. Reduce the underlying risk factors

(i) Environmental and natural resource management
(ii) Social and economic development practices
(iii) Land-use planning and other technical measures

5. Strengthen disaster preparedness for effective response at all levels

(i) Strengthen policy, technical and institutional capacities
(ii) Promote and support dialogue, exchange of information and coordination
(iii) Strengthen and when necessary develop coordinated regional approaches
(iv) Prepare or review and periodically update disaster preparedness and contingency plans
(v) Promote the establishment of emergency funds
(vi) Develop specific mechanisms to engage the active participation and ownership of relevant stakeholders, including communities

All work carried out in the framework of AIDA needs to be HFA-compatible and in support of the strategy.

7.5 Global Facility for Disaster Reduction and Recovery (GFDRR)

The GFDRR provides the link between the ISDR and the HFA, supporting the implementation of the latter. Managed by the World Bank, it operates through various donor funds that enable countries categorized as low- or middle income to implement disaster reduction as integral parts of their national development strategies, as well as their plans to reach the **Millennium Development Goals** (MDG) as defined by the UN. The Charter of the GFDRR was ratified in February 2007, and positions the HFA as a long-term initiative aimed at reversing the trend of ever more and costly disasters. Significantly, it aims at increasing the feeling of ownership of DRR processes by the affected countries themselves.

Being tied into the UN and Word Bank systems the GFDRR links vulnerability reduction to existing development and assistance frameworks, such as poverty reduction strategies (PRSs), country assistance strategies (CASs), UN Development Assistance Frameworks (UNDAFs), and National Adaptation Plans of Action (NAPAs). This reflects clearly that all efforts towards goals such as the MDGs also work directly towards reducing risks by reducing vulnerability and increasing capacity.

7.6 The International Charter “Space and Major Disasters” and GEOSS

Neither the **International Charter** “Space and Major Disasters”, typically termed the Charter, nor GEOSS are DRM policies in the strict sense. Rather they are practical support tools also of relevance to Africa.

The Charter is not a technical solution, but aims at improving the efficiency in the use of existing space technology during a disaster response phase. It was initiated by the European and French space agencies (ESA and CNES) after the UNISPACE III conference held in Vienna, Austria, in July 1999, and was declared formally operational on November 1, 2000. The objective of the Charter is to provide a unified system of space data acquisition and delivery for a rapid response to natural or man-made disasters. To date, the Canadian Space Agency (CSA), the Indian Space Research Organization (ISRO), the Argentine Space Agency (CONAE), the Japan Aerospace Exploration Agency (JAXA), the United States Geological Survey (USGS), NOAA and the DMC-operator DMCII have joined the Charter. Each member agency has committed resources to support the data collection of the Charter to improve the efficiency of data provision for emergency responses globally (disasterscharter.org). To date the Charter has been activated more that 170 times, responding to a variety of natural and technological emergencies (see for example Bessis et al., 2004). Once the Charter is activated, the most suitable and most quickly available space resources of the participating partners are used to obtain imagery of the affected areas. These data are then further processed by Charter partners, such as the German Space Agency (DLR), UNOSAT or SERTIT, who provide map products that are made available via the Global Disaster Alert and Coordination System (GDACS, http://www.gdacs.org/), ReliefWeb (http://www.reliefweb.int) or Reuters's AlertNet (http://www.alertnet.org/). Such organisational improvements are arguably of greater value than the mere launching of more satellites. Typically the time-consuming aspect is not the data acquisition itself, but rather the transfer, processing and dissemination of useful products to emergency response personnel in the field, a requirement well served by Charter-like activities.

The **Global Earth Observation System of System** (GEOSS), is the principal aim of the 10-year implementation plan (2005-2015) of the **Group on Earth Observation** (GEO, http://www.earthobservations.org/). GEOSS seeks to promote and support the role of RS for EO and all global issues of relevance, which is reflected in the 9 societal benefit areas (SBA, Figure 41). Disasters are the first of those SBAs. The SS part of GEOSS, i.e. the system of system notion, reflects the realisation that all aspects of the environment, and human interaction with and activity within it, can be supported and monitored with various means that are typically highly specific. Many of the hazards introduced in Chapter 5, as well as the ICT-based monitoring systems discussed in Chapter 9, are based on monitoring systems that form parts of GEOSS. Those can include ground- or ocean based instrument networks or air- or spaceborne infrastructure.

Figure 41: Overview of the societal benefit areas of the Global Earth Observation System of System (GEOSS). Source: http://www.earthobservations.org/.

As many natural systems, as well as DRM aspects, are interlinked, such as precipitation, drought and famine, an interlinking observation system based on common standards and data sharing is needed. The system must be robust, redundant in critical places, and long-term oriented. The GEOSS system by design is based on open data-sharing principles, with information and analysis results being available directly by the user via a **GEOPortal** (www.geoportal.org). This serves as a single point entry to all data and information GEOSS provides, including information on the monitoring GEOSS does, the products generated, clearinghouses to search for and download data, visualisation of information, decision support tools, and listings of service providers and education material. For users without access to high-speed internet services, GEO has established **GEONETCast** (see section 10.1 for details).

The European contribution to GEOSS is the **Global Monitoring for Environment and Security** (GMES), in 2008 renamed **Kopernikus**. It is a joint activity of the European Commission and the European Space Agency (ESA). Started in 2001 Kopernikus"s aim is to provide automated and comprehensive environmental monitoring by 2008. It is strongly focused on multiple use of space infrastructure (see for example Chapter 9 on how a single satellite, such as Meteosat Second Generation, can provide monitoring of hazards as diverse a drought, windstorm or wild fires). Similar to GEOSS in general, Kopernikus is based on several main pillars, a space segment, in-situ/ground measurements, data harmonisation and standardisation, and service provision to users. Three fast-track services (FTS) have been set up to spearhead operationalisation: Ocean FTS, Land FTS and Emergency FTS. Additional foci on the atmosphere as well as on security will be added. Kopernikus is considered the second flagship of the European Space Policy next to **Galileo**, the satellite position system.

7.7 Initiatives within Africa

The notion of ownership of the DRR process is critical, and, as explained above, has been realized in the HFA and the GFDRR. Thus, in addition to the global strategies DRR also must be anchored in African structures. This is the case, for example in the African Union (AU). The ARSDRR mentioned before was partly set up by NEPAD, which is a special programme of the AU.

Additionally, in late 2004 the AU launched the *Programme of Action for the Implementation of the Africa Regional Strategy for Disaster Risk Reduction*. Realising the threat disasters pose to the ambition of achieving the MDGs, as well as seeing that Africa was the only continent whose global disaster share increased in the 1990s, a 5-year strategy (2006-2010) was laid out, which followed a series of meetings and workshops in the previous years between the AU, NEPAD, ISDR and the ADB. The strategy recognised that DRR policies, as well as relevant institutional mechanism exist, but that they are insufficiently developed and applied. Importantly, prior to the launch of the strategy a study on the status of DRR in Africa was carried out, which identified the gaps in several main areas: institutional frameworks, risk identification, knowledge management, governance and emergency response. As a consequence a series of documents has been developed:

- Regional Review of Disaster Reduction;
- Regional Strategy for Disaster Risk Management;
- Guidelines for mainstreaming disaster risk reduction into sustainable development.

Identification of limitations and gaps is relatively straightforward; overcoming those problems will prove much harder. Therefore, the AU and NEPAD are in the process of developing an implementation programme to integrate DRR into sustainable development planning and activities in Africa. The goals being pursued largely mirror those of the HFA and the ISDR. The strategy, available at www.africa-union.org/Agriculture/Disaster_Risk_Reduction/Programme_of_Action.doc, provides a detailed assessment of required and suitable mechanism, which, importantly, put emphasis on public awareness as well as small-scale, local projects. Emphasis, especially for DRR efforts from national levels down towards the local scale, is on understanding the DRR concept, and how vulnerability, hazard, risk and disaster are connected, to establish a grassroot culture of disaster prevention with which national programmes can connect. The expected outcomes of the strategy are important for AIDA, as all ICT solutions have to build on or connect to those outcomes, as quoted here from the Programme of Action:

- Increased understanding of the importance of implementing the African Regional Strategy on DRR and of adopting guidelines for mainstreaming disaster risk reduction in development among policy and decision makers in African countries;
- Increased competence of Africans in disaster risk reduction and integrating disaster risk reduction in development planning and programmes at all levels - from regional to local levels;
- Training materials developed, which can be easily justified for training at different levels in order to address various needs in disaster risk reduction at regional, sub-regional, national and local levels;
- Successes and lessons learnt from pilot projects documented for wider and large scale adoption of guidelines for mainstreaming disaster risk reduction in development;
- More programmes developed for further implementation of the strategy and larger adoption of the guidelines;
- Improved policy environment for the implementation of Disaster Risk Reduction strategies and practices.

7.8 Summary

Comprehensive DRR requires a theoretical framework that explains the links and interactions between natural and socio-economic systems, and a solid understanding of how hazard exposure can be determined, those hazards reduced or eliminated, where vulnerability of all affected systems is rooted and how it can be reduced, how capacity, again of all affected systems, can be increased, leading together to reduced and acceptable risk. It also requires a strategy, or series of interlinking strategies from global to national and local levels, that lay out how the theoretical understanding can be translated into actionable goals, and, critically, how those actions must be linked to existing plans for development, poverty reduction and sustainable capacity building.

This chapter has reviewed international and continental DRR strategies, beginning with the IDNDR in the 1990s, and later including milestone agreements such as the Hyogo Framework for Action and the ISDR. In Africa, too, the need for DRR has been realized by the African Union and integrated conceptually with developments plans and actions.

From this several important lessons emerge:

- The detrimental effects of natural disasters on sustainable developments and on reaching the MDGs have been understood, and DRR is seen as a critical undertaking to reduce those effects.
- This has to be done in a multi-level manner, where at regional, national and local specific efforts must be made that only together can reduce the present multi-hazard risk.
- The need to involve communities, specifically to increase the understanding of DRR concepts and to build capacity and resilience has been realised.
- It is clear that every action taken towards DRR is also an action towards sustainable development, as those two are intricately linked; hence DRR is fundamental to development.

8. The role of ICT for DRM in Africa

Natural disasters are continuously increasing in number globally, and there is agreement that (i) vulnerability is rising worldwide, and (ii) that disasters constitute a severe impediment to economic growth. This is especially true for developing countries, which have suffered more than 90% of all fatalities, and have been disproportionally burdened by the cost as well, due to, amongst other reasons, their lower GDP, limited reserves, and an under-developed insurance industry. While Asia has been confronted with the largest absolute number of annual natural disasters, Africa has seen the most rapid increase in recent years. Given the spatial nature of all aspects of a disaster – such as hazards, vulnerability, risk or damage – spatial data are required to study, prepare for and respond to such emergencies, a proposition most suitably supported by ICT.

In Chapter 5 the natural hazard situation in Africa was assessed. In fact, most of the information shown in the hazard, vulnerability or risk maps was derived with geoinformatics tools, often of remote sensing nature, and analysed and visualised in a GIS framework. Hence it is clear that ICT is already being used extensively for DRM in Africa. The purpose of this chapter is to (i) review the concept and scope of ICT, and the ICT situation in Africa, (ii) international ICT-based DRM efforts directed towards or including Africa, and (iii) ICT efforts originating on the continent. As before, the scope is limited to continental, regional and national efforts. It must be distinguished between experimental/short-term efforts, and mature/continuous programmes, as well as between those focusing on a single country but with potential to be transferred or adapted, and projects of explicitly continental or regional reach.

8.1 Information and Communication Technology (ICT)

ICT is a summary term that encompasses the technologies and methods to manipulate and communicate information. It is frequently seen as synonymous with IT, and thus more focused on hardware and software concepts than is useful in the AIDA or DRM context. This is because of the spatial nature of DRM-related information, as described above. Hence it is more useful to address the technological side as Geoinformatics and Communication (GIC). Geoinformatics can be formally described as "combining geospatial analysis and modeling, development of geospatial databases, information systems design, human-computer interaction, and both wired and wireless networking technologies" (Wikipedia). Simply put, it is the digital processing, analysis and visualization of spatial data. It is based on remote sensing and ground-based data that are organised in a geographic information system (GIS) environment, allowing the preparation of base data (e.g. National Spatial Data Infrastructures, or NSDIs), and the extraction, analysis and modelling of specific environmental information. It is thus suitable for the assessment of environmental hazards, vulnerability, risk of different disasters, as well as to guide appropriate response and reconstruction activities following an emergency. In light of the methods introduced in section 3.4.3, the limitation to *digital* information collection and processing must be relaxed, as also manual methods, such as sketchmaps, are of great value in community-based hazard, vulnerability and risk assessment.

8.2 Communication technology in Africa

GIC has brought about a democratisation of technology, as well as a means for **leapfrog development**. While perhaps the role of remote sensing satellites appears central to ICT-based DRM in Africa, as it allows synoptic and continuous monitoring of essentially all hazards, both natural and man-made, other major ICT developments that play central roles need to be discussed first. These are the increasing provision of **internet access** on the continent, and the provision of **cell phone services** that is already reaching most population clusters in Africa. These key technologies cover the communication part of GIC, and without those the geoinformatics part would be meaningless. Both communication backbones are also more strongly developed than the geoinformatics side, and are briefly reviewed here.

In a global comparison the ICT provision in Africa is poor. Figure 42 shows that only 3% of all Africans have access to fixed telephone service, and that broadband internet access is nearly non-existent. However, while also general internet access at 5% lies much below the global average and rates reached on other continents, mobile phone penetration lies at 27% percent. More important is the penetration growth, as shown in Figure 43. While starting much later than developed countries, the developing world has shows the fastest growth rates since about 2004.

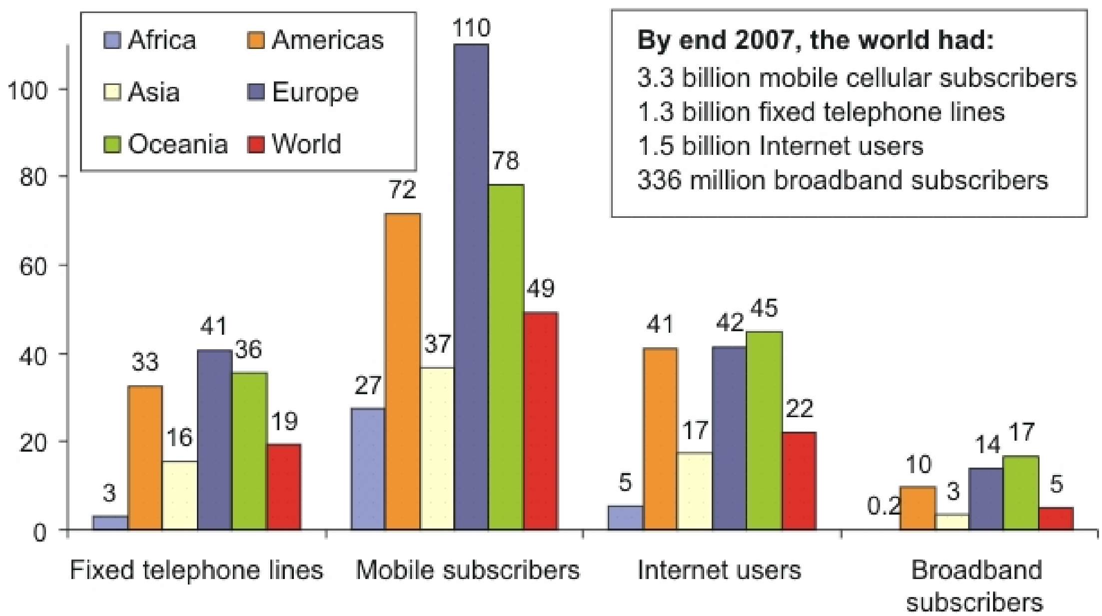


Figure 42: ICT penetration rates for 100 inhabitants in 2007 (Source: ITU World Telecommunication/ ICT Indicators database).

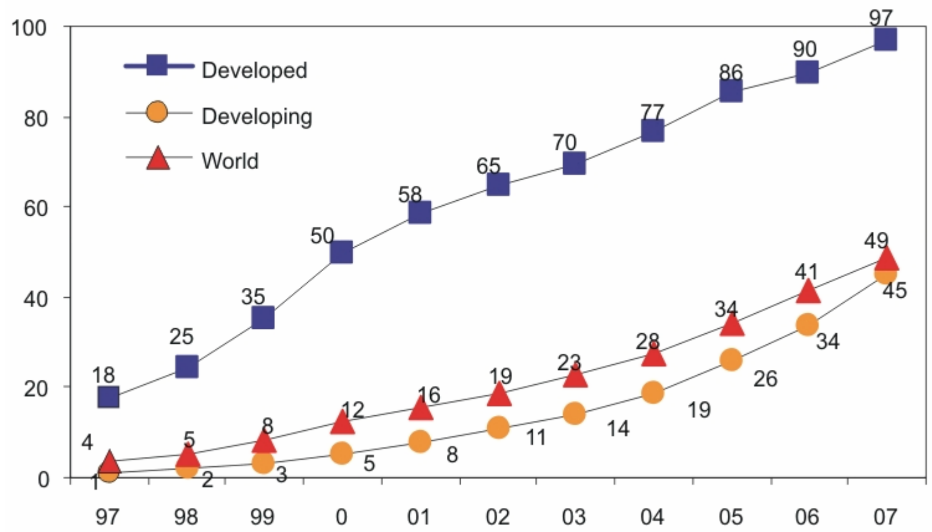


Figure 43: Mobile phone subscribers per 100 inhabitants between 1997 and 2007 (Source: ITU World Telecommunication/ ICT Indicators database).

This trend is also apparent in Figure 44, which shows that mobile phone penetration is reaching the 50% mark in Africa, while subscriber numbers are nearing 500 million. This makes the mobile phone is mass communication tool that can be employed in DRM, be it for hazard and vulnerability assessment, early warning and evacuation, as well as damage reporting. With mobile phones systems also being less centralised than traditional fixed line systems, also greater system resilience during a disaster event can be expected.

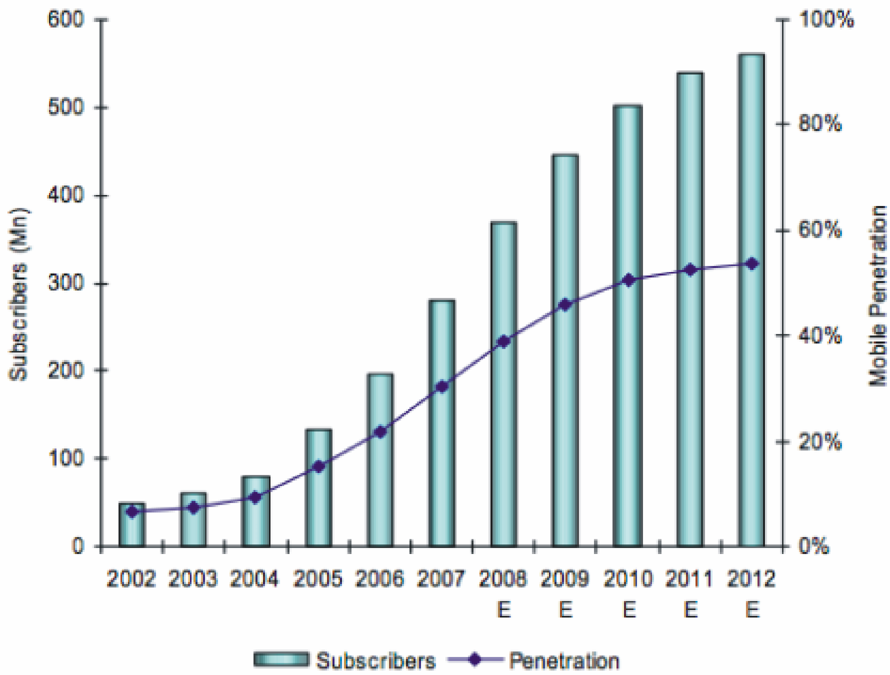


Figure 44: Mobile phone subscriber numbers and penetration between 2002 and 2012 in Africa (Source: African Mobile Factbook, 2007).

However, the situation in Africa is far from uniform. In other words, a “digital divide” also exists on the continent itself, in particular for fixed line service. According to the International Telecommunication Union (ITU), sub-Saharan Africa (excluding South Africa) in 2006 had a average teledensity of only 1%, while North Africa averaged at 11%, with some 75% of all fixed lines being found in 6 out of 55 countries. Mobile phone provision, however, being easier to set up, have begun to equalise the situation.

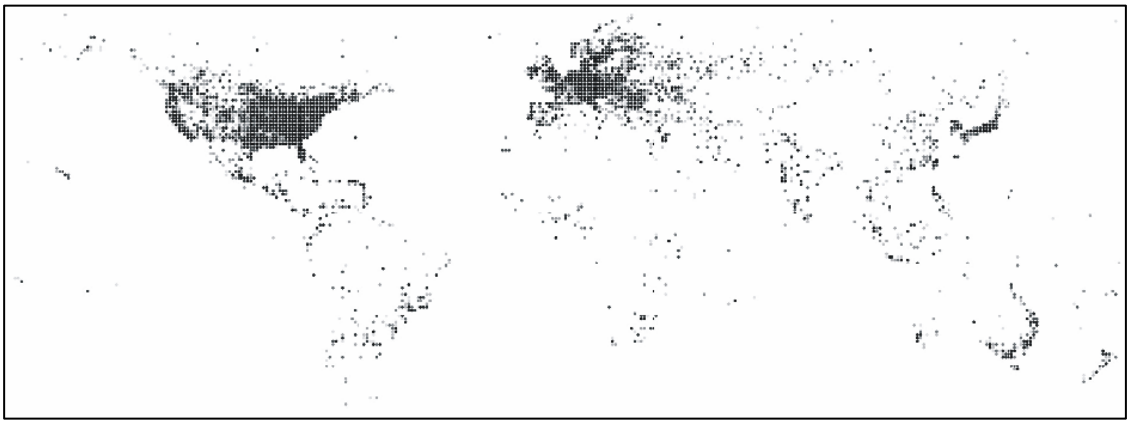


Figure 45: Global internet connection density as of February 2007 (Source: The Dimes Project; Chris Harrison).

The internet access situation in Africa is less favourable, as was already indicated in Figure 42. Figure 45 shows that the internet connection density in Africa is the lowest in the world, explained in part by limited provision of highspeed fibreglass cables (Figure 46). While mobile phones have particular utility for the short-terms DRM aspects explained above, the internet has different strengths of relevance here. It provides information, serves as an education tool, is well suited to provide information on hazards, vulnerability and risk, and, importantly, is the backbone to obtain real-time DRM information from international data providers and partners, and to share information within the continent. In other words, to take advantage of DRM support provided by international community, e.g. by the FAO or WFP, internet access is a necessity.

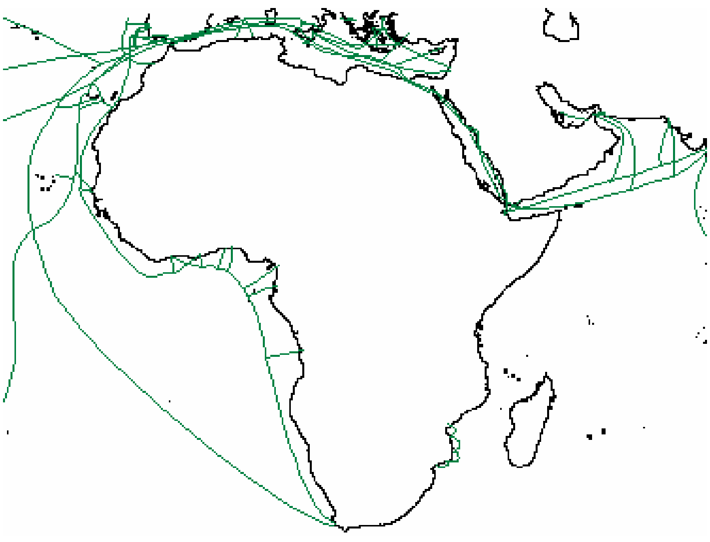


Figure 46: Map of optical fiber submarine cables connecting Africa, illustrating significant gaps in connectivity along the Eastern coast (Source: African Marine Atlas).

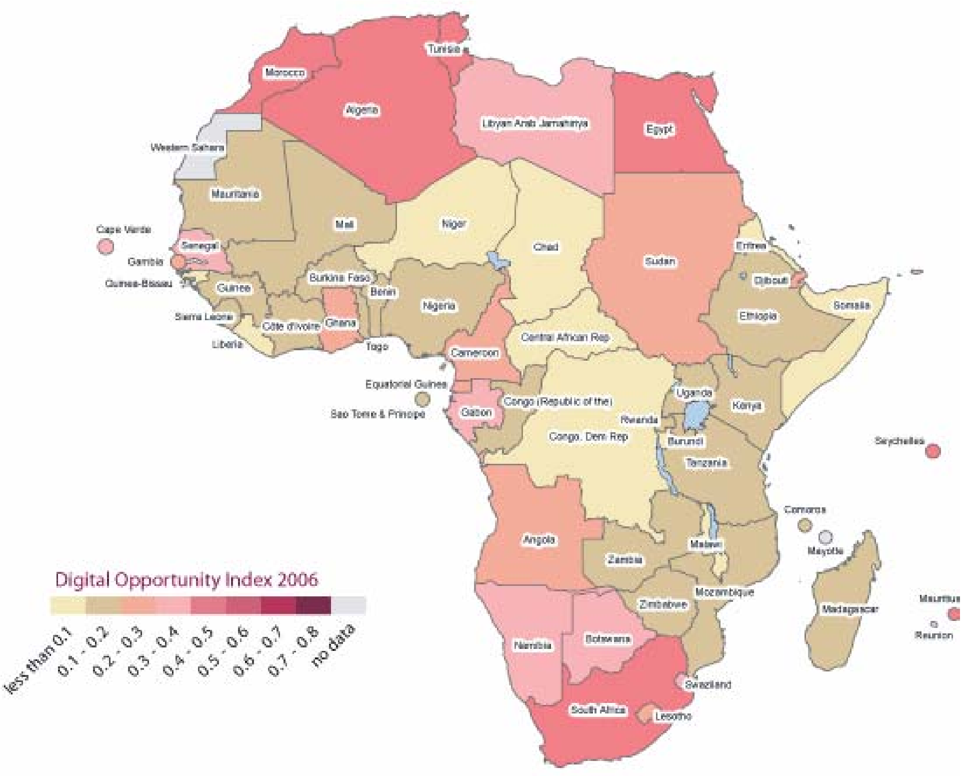


Figure 47: Digital Opportunity Index (DOI) for Africa in 2006, with higher index values signaling higher digital opportunity (Source: International Telecommunication Union).

Hence access to ICT is an important component of DRM, and a **Digital Opportunity Index** (DOI) has been created by the ITU to express and compare the status of the information society. Based on 11 ICT indicators in the opportunity, infrastructure and utilisation categories, the DOI was calculated for the years 2004-2006. Figure 47 shows how the countries especially along the Mediterranean and in southern Africa tend to have far higher DOI values than central and inner African nations. For AIDA this can serve as a guide when determining how local ICT means, particularly mobile phones and the internet, can be employed in DRM.

9. International ICT-based DRM efforts directed towards or including Africa

Existing GIC efforts can be categorised in different ways. In this section those originating outside Africa, but also serving the continent, are reviewed by hazard type, in the sequence used in Chapter 5. The focus here is on the geoinformatics aspect, information derived form which can be communicated via the channels assessed above.

9.1 Seismic hazard

Seismic activity lends itself well to synoptic assessment. This is because seismicity is typically linked to tectonic or volcanic features (only rarely are they caused by subsidence as a result of mining or ground water extraction activity), which are assessed on large geologic scales. Furthermore, seismic waves have a long reach and are thus well recordable even in a coarse monitoring system with few seismometers.

Several seismic networks also covering Africa exist, integrated in the **Global Seismographic Network** (GSN, see www.iris.edu/hq/programs/gsn/). The system comprises more than 150 seismic stations (Figure 48), and is coordinated by the United States Geological Survey (USGS), the National Science Foundation (NSF) and the Incorporated Research Institutions for Seismology (IRIS). The collected data serve monitoring as well as research purposes. Alerts on measured seismic events are sent out to subscribed users via an email notification system.

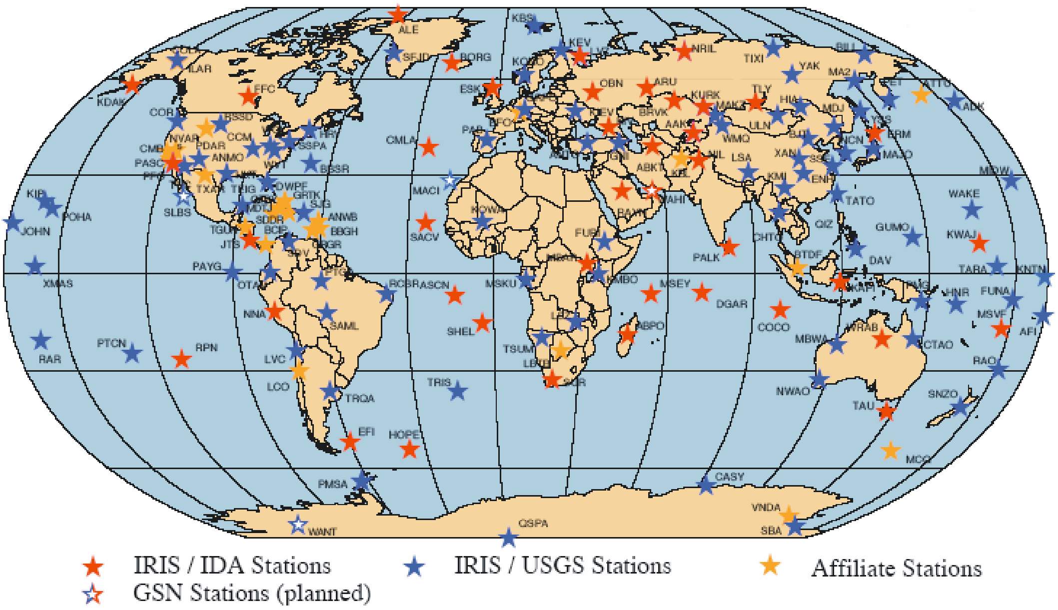


Figure 48: Global Seismographic Network (GSN) as of May 2008 (Source: IRIS – Incorporated Research Institutions for Seismology).

The **Digital Broadband Seismograph Stations** network comprises almost 900 stations around the world, 32 of which are in Africa (Figure 49). Close to 50 additional stations worldwide have been proposed or are being planned by the more than 70 organisations, seismic networks and data centers making up the FDSN (see www.fdsn.org).

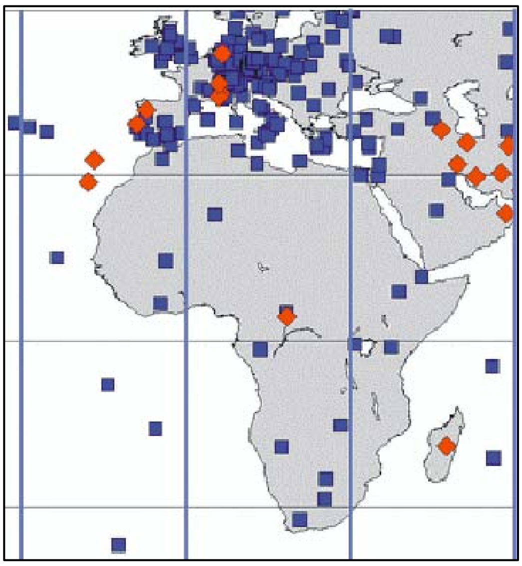


Figure 49: Digital Broadband Seismograph Stations, of which 32 are located in Africa (blue – existing, red – planned; Source: International Federation of Digital Seismograph Networks (FDSN)).

In addition to the GSN and the FDSN, more regional systems relevant to Africa exist. The **Western Mediterranean Broadband Seismic Network**, together with the planned **Ocean Bottom Seismic** network (OBS, Figure 50), covers the Ibero-Maghrebian region, where the Eurasian and the African plats collide. Two seismometers in this network are placed in Morocco.

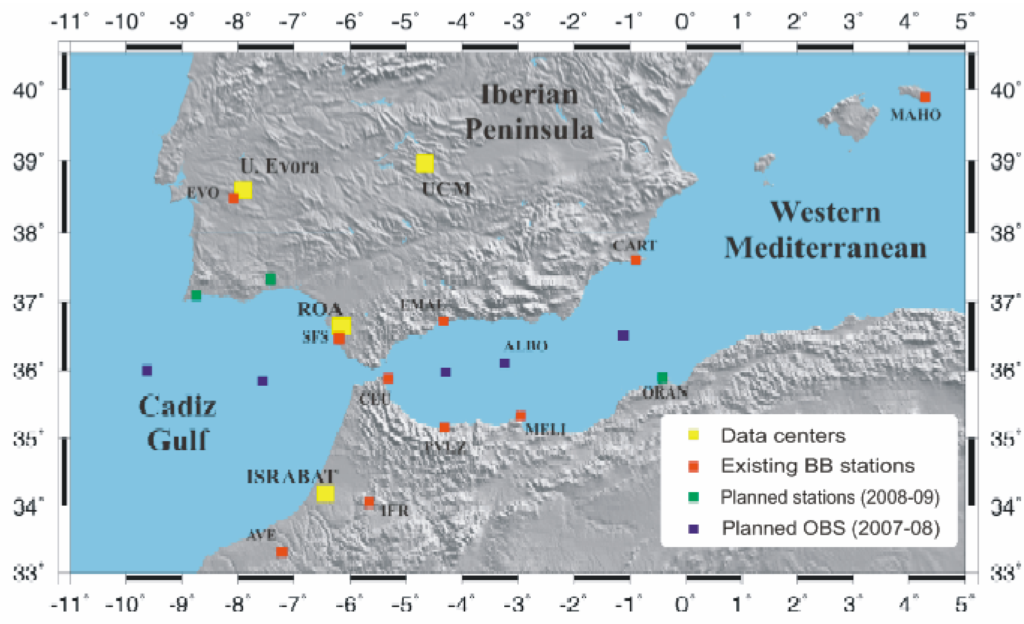


Figure 50: Western Mediterranean Broadband Seismic Network, together with the "FOMAR" Ocean Bottom Seismic network (OBS; Source: International Federation of Digital Seismograph Networks (FDSN)).

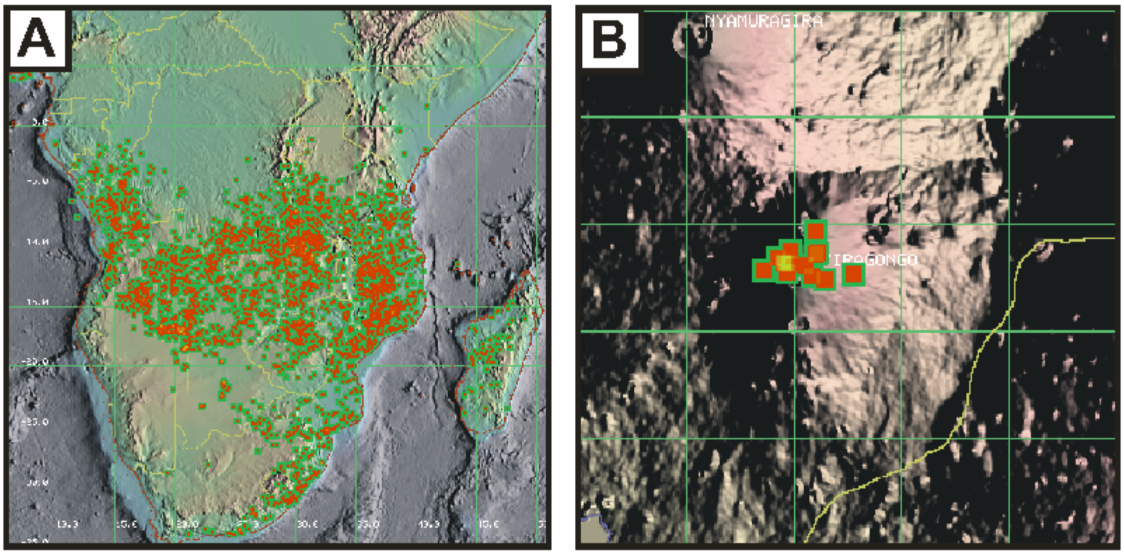


Figure 51: MODIS-detected hotspots (wild fires or magmatic activity) during 1 week in early September 2008 in Southern Africa (A), and activity at Nyiragongo volcano in DRC (Source: HIGP, University of Hawaii).

9.2 Volcanic hazard

As explained in section 5.1.2, many of the hazards volcanoes pose are well detectable with remote sensing instruments. As such monitoring can often be automated, global monitoring systems have been established. Additionally, because of the threat posed to aviation by explosive eruptions, timely warning from those events also needs to be ensured.

A global hotspot detection system based on MODIS data is operated by the Hawai'i Institute of Geophysics and Planetology (HIGP, http://modis.higp.hawaii.edu/) at the University of Hawaii. The **HIGP MODIS Thermal Alert System** provides worldwide near-real time information on thermal anomalies, using the MODVOLC algorithm (Wright et al., 2004; Rothery et al., 2005). Based on 1km data from the MODIS sensor it is sensitive to significant heat emissions such as those occurring during wildfires or magmatic activity (Figure 51). Nearly all observed anomalies, especially in southern Africa (A) correspond to fires. As the system is pixel-based and cannot distinguish automatically between the type of heat source, a zoom function for all potentially active volcanoes is provided (B). However, as anomalies can also correspond to wildfires on the flank of a volcano, the system is most useful to confirm uncertain reports of magmatic activity at a given volcano.

Africa particularly benefits from EUMETSAT's Meteosat Second Generation (MSG). Like all previous Meteosat instruments it was built primarily to serve weather forecasting in Europe. However, the necessity of a geostationary orbit (in 36,000 km above the Earth) dictates that the satellite has to be positioned above the equator, in this case over the Gulf of Guinea at zero degrees longitude (Figure 52). This results in complete coverage of Africa even with less distortion than for the primary target, Europe. The main instrument, the Spinning Enhanced Visible and Infrared Imager (SEVERI), has many potential uses. Essentially a now-casting and numerical weather prediction instrument, it provides information for the entire area shown in Figure 52 every 15 minutes, primarily at a resolution of 3km, but in one band also at 1km resolution. With weather data for Africa being obtained as something of a by-product, they now serve an increasing demand in Africa (see section 9.5). However, it also has applicability for volcano monitoring.

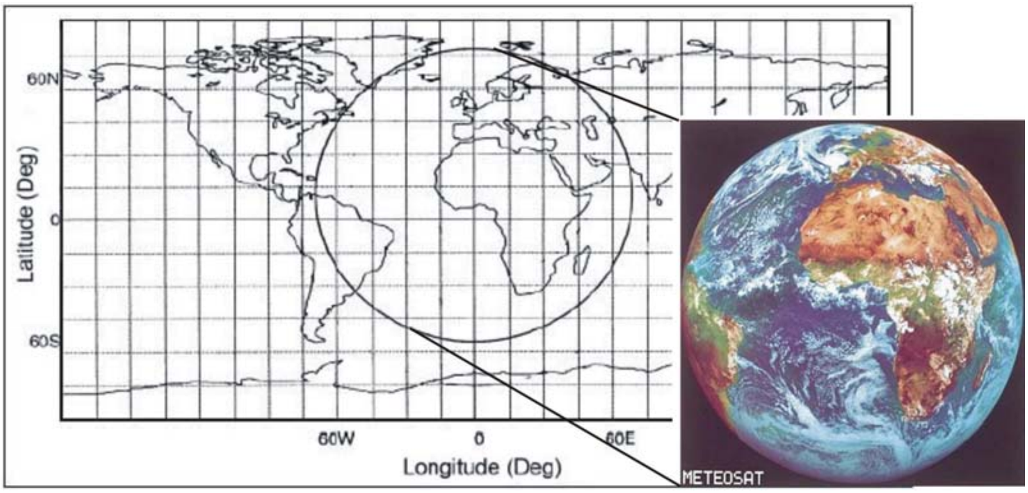


Figure 52: Footprint of Meteosat Second Generation (MSG), positioned where the Prime Meridian meets the equator.

SEVIRI is the first spaceborne instrument both with ideal temporal and spectral characteristics to offer automated, continent-wide observations of thermal anomalies. Given the magnitude of radiance of magmatic features, even at 3km resolution SEVIRI's 9 spectral channels in the mid-and thermal infrared allow not only detection but quantification of volcanic thermal activity. Extensive work has been carried out on algorithms to use SEVIRI data for wild fire detection, with feasibility recently shown (Roberts and Wooster, 2008). In addition to the thermal signatures that can also be detected for magmatic activity, SEVIRI data are also useful to map ash emitted by volcanic eruptions (Prata and Kerkmann, 2007), which pose a substantial threat to aircraft (see section 5.1.2). In 1995 the International Civil Aviation Organization (ICAO) founded the **Volcanic Ash Advisory Centers** (VAAC), providing an interface between volcano observatories, meteorological agencies and air traffic control centers. The world was divided into 9 regions, for each of which a VAAC would monitor volcanic activity based on information from volcano observatories, pilots reporting eruptions, but also remote sensing data. The VAAC covering Africa is situated in Toulouse, see http://www.meteo.fr/aeroweb/info/vaac/homepage/eindex.html. Working heavily with MSG data, the Toulouse VAAC frequently issues aviation warnings based on satellite observations, either as text or graphic (Figure 53). Hence while an operational system for thermal anomaly detection with MSG data does not yet exist, the algorithms have already been developed, and the data are available at near-real time and practically for free. A system for volcanic ash detection is already operational.

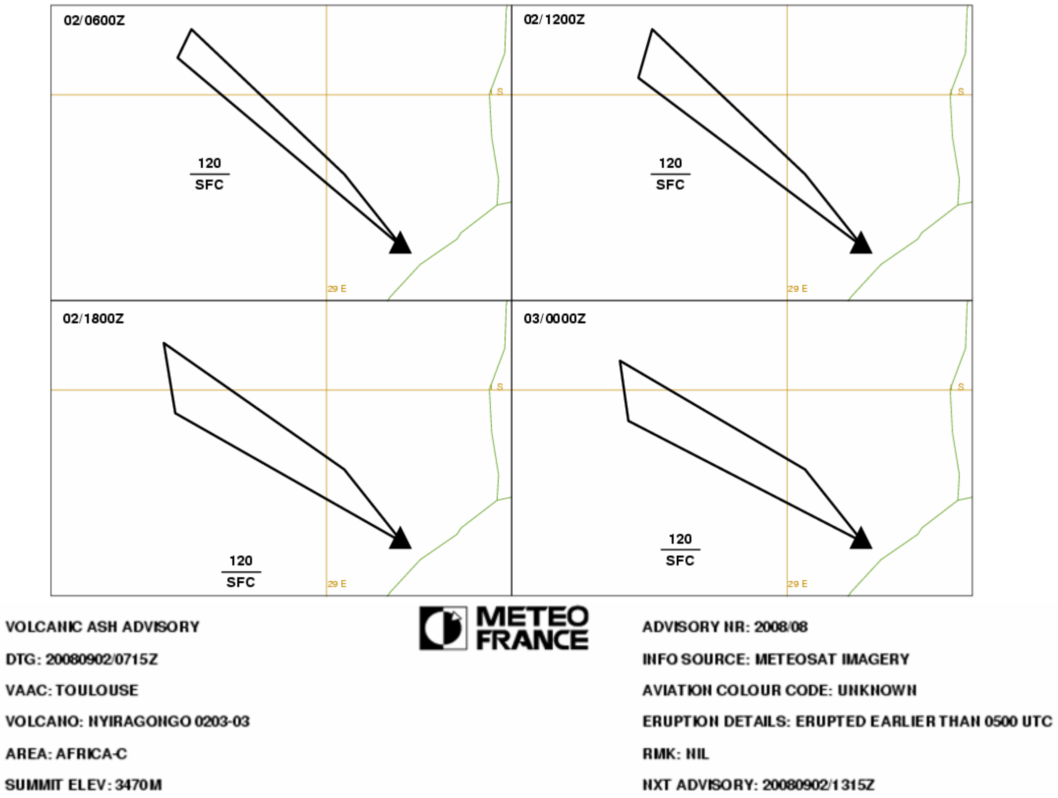


Figure 53: volcanic ash advisory for Nyiragongo volcano (DRC) for 2 September 2008, corresponding to the activity also seen in the MODIS data for that period, see Figure 51 (Source: VAAC Toulouse, Metro France).

9.3 Drought hazard

As described in section 5.1.3, drought is highly dynamic. Therefore, the drought hazard maps, such as the one shown in Figure 22, are a guide only as to the severity of the potential problem. Assessing actual drought, its tendency, and the link to vegetative and crop cycles, requires incessant monitoring. In particular vegetation state monitoring is critical, as crop failure is the most threatening consequence of drought. Given the sparse network of ground-based stations, especially in Africa, this is best done with space-based remote sensing, either from polar orbiters, i.e. low-flying (500-900 km above the Earth) platforms that have revisit times of 1-3 days, or better if several satellites are used in a network, or from geostationary ones such as MSG, placed permanently at 36,000 km altitude, and thus capable of providing regular observations, up to every 15 minutes. Both systems are being used to provide drought and crop monitoring for Africa.

The US National Oceanic and Atmospheric Administration (NOAA) operates a system based on the Advanced Very High Resolution Radiometer (AVHRR) that observes all land areas at least twice a day at a resolution of 1.1 km. The utility of these data for drought monitoring and even yield estimation for specific crops was already shown over 10 years ago (e.g. Unganai and Kogan, 1998). However, Africa-focused monitoring based on this system already goes back to 1994, when the **African Desk** was established (see http://www.cpc.ncep.noaa.gov/products/african_desk/). Working together with the **National Centre for Environmental Prediction** (NCEP) and meteorological agencies in Africa in 33 countries (Figure 54B), it provides short-term climate monitoring and prediction, which includes current and accumulative rainfall data, weekly and seasonal outlooks. Those are provided as reports, tables and graphics (e.g. Figure 54A).

The AVHRR sensors are well complemented by another space asset, which is focused specifically on precipitation mapping: TRMM. The **Tropical Rainfall Measuring Mission**, operated by NASA and the Japanese Space Agency (JAXA), has been monitoring and studying tropical rainfall since 1997. Using radar and optical instruments it allows the study of cloud structure and the estimation of precipitation amounts and anomalies (Figure 55). It is further an important platform from which atmospheric energy and circulation studies are carried out, providing an important contribution to climate models and forecasts.

The critical aspect of drought is less the actual precipitation amount, but rather its effect on vegetation growth, i.e. more when it rains instead of how much it rains. Hence products such as rainfall anomalies (Figure 55A) can be used to assess where shortages (but also a flood hazard) may exist. Even more specific is an assessment of actual vegetation health. This can be done via the **Normalised Difference Vegetation Index** (NDVI), which measures the chlorophyll content of vegetative matter, and thus its health. An anomaly map (Figure 55B) then shows the vegetation state at a given time with respect to a long-term average or a healthy-vegetation benchmark.

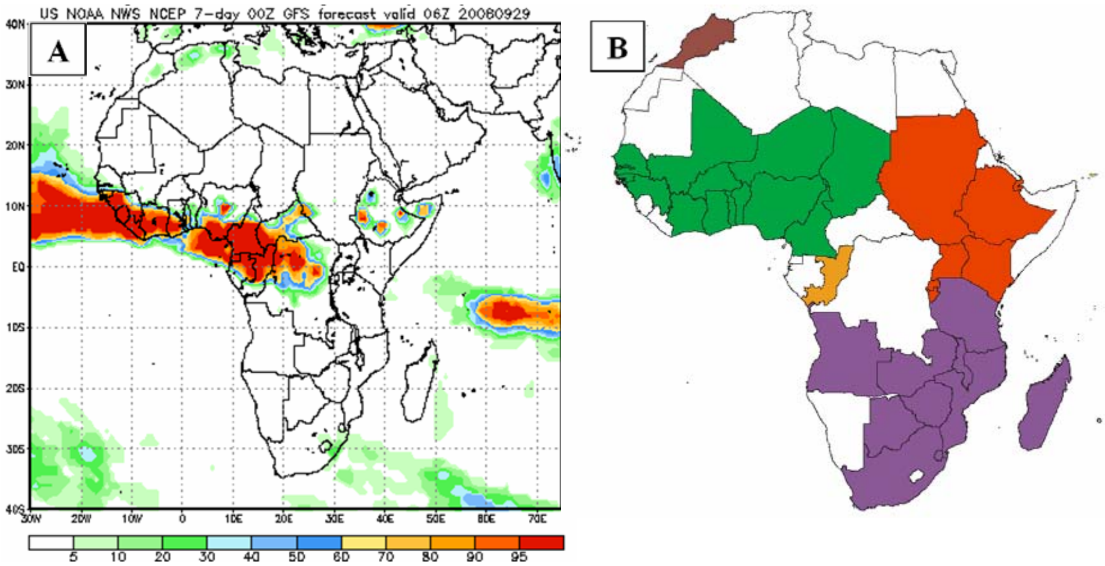


Figure 54: Probability of 7-day total precipitation exceeding 50 mm, beginning 1 week after forecast data (A), and countries participating in the network, grouped by region (B; Source: NCEP).

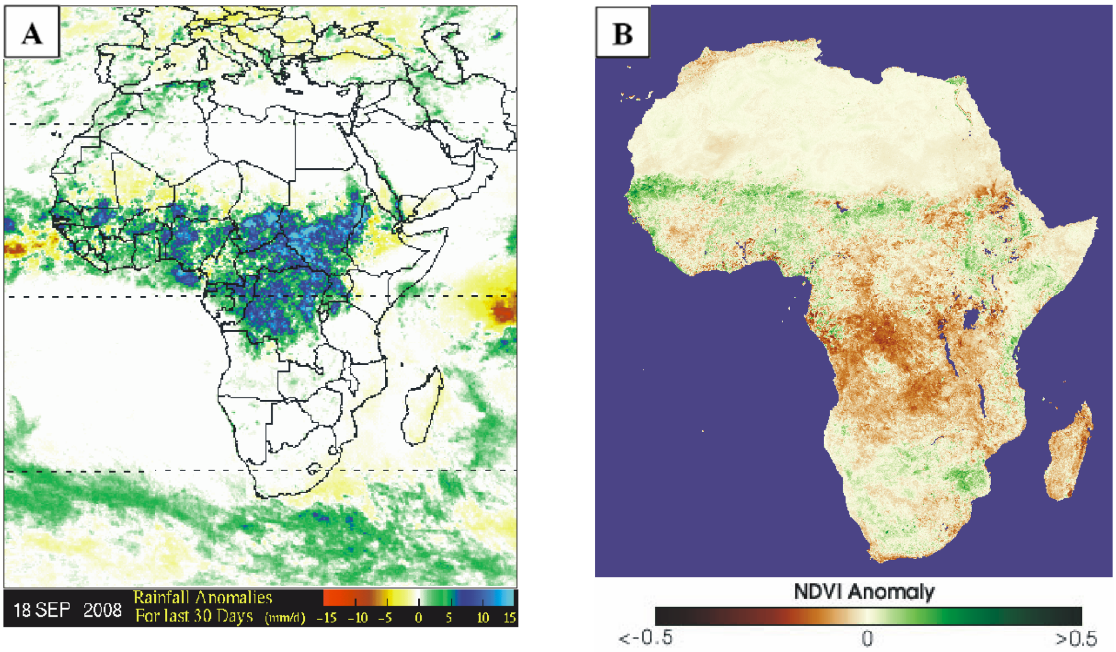


Figure 55: Precipitation anomalies for a 30-day period over Africa, mapped by TRMM (A; Source: NASA/TRMM), and NDVI anomaly based on AVHRR observations (B; Source: NASA).

Clearly the raw information on precipitation status, NDVI anomalies etc. is of limited practical value, as this knowledge has to be integrated into a more comprehensive framework that considers local agriculture patterns, regional and national drought and famine mitigation strategies, and relief distribution systems. Hence, NOAA's African Desk collaborates with the USAID/**Famine Early Warning System** (FEWS). For Africa organised in the Famine Early Warning System Network (FEWSNET, www.fews.net), it was set up in 1986 by USAID as a response to the 1984-85 famine in Ethiopia, and is aimed at predicting and responding to famines. The *network* part of the name reflects a more recent policy move toward establishing local and regional networks for famine warning and response. This is necessary as famine is only in part a result of insufficient precipitation that can be mapped from space (see section 5.1.3); it is equally a result of vulnerability of communities, inadequate access to and distribution of assets within countries, as well as unsuitable agricultural practices, such as use of water or fertilizer. Hence local information that can point at impending drought and famine problems are critical, as local adaptive measures. The data provided by FEWSNET are an important planning basis, both for authorities in the affected countries, but also international donors, as famines are best avoided or mitigated when some lead and response time is available. Thus FEWSNET not only provides graphic situation assessments but also food security reports, alerts and market studies (Figure 56).

The second main international effort focused on drought and famine in Africa comes from the FAO. Founded in 1945, the FAO has not been free from criticism with respect to its efforts to promote increased agricultural productivity, self-sufficiency in food production, or the avoidance of and response to famine. Nevertheless, the FAO has also shown an increasing reliance on geodata, and has developed important tools to assess and model the effect of precipitation on crops and livelihoods. These tools include AgroMetShell, a specific software tool box for crop yield forecasting, the Dynamic Atlas (http://www.fao.org/gtos/atlas.html), designed for the integration of spatial (map), tabular (spreadsheet), and unstructured (document) data and metadata. Using dynamic Web Map Server technology it allows data from various sources to be integrated and customised online maps to be produced. This allows for example organisations in the affected countries to assume a greater responsibility by facilitating the processing of their own country-specific data, together with those globally derived by the FAO. The Dynamic Atlas is a component of the Global Terrestrial Observing System (GTOS). Set up in 1996 together with other UN organisations, GTOS focuses on comprehensive terrestrial ecosystem observation, though it is based strongly on local data. That means it directs users to identified data sources, and thus also stimulates the development of new such sources.

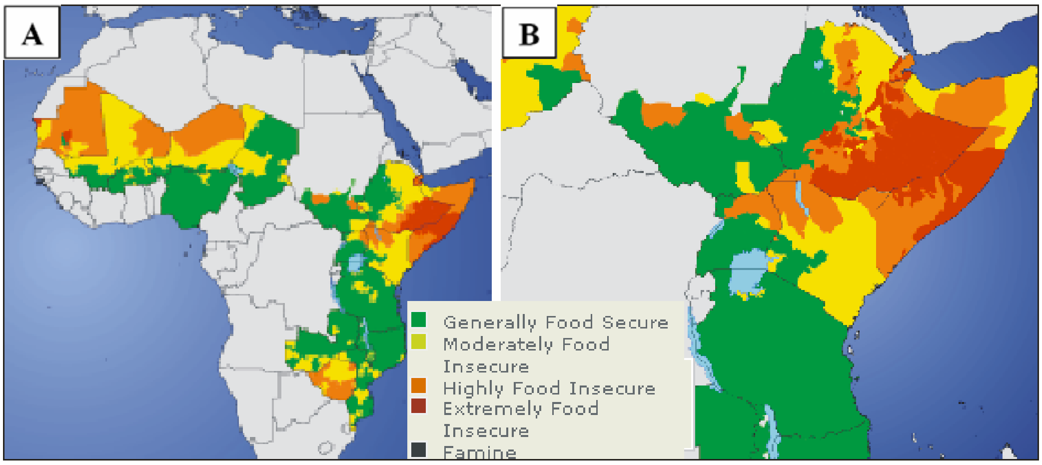


Figure 56: Projected food security situation for the 4th quarter 2008 (A), also available at a country scale (B: Source: FEWSNET).

A further central effort by the FAO is the **Global Information and Early Warning System** (GIEWS). Its objective is to monitor the global food supply and demand situation, and to provide early warnings for impending crises. In addition to food prospect and crop forecast reports, the GIEWS Workstation, also based on Web Map technology, also allows customised analysis and map generation. It also forms part of the Geonetwork (www.fao.org/geonetwork), designed to facilitate access to and analysis of spatial information, as well as decision making. It provides access to maps, satellite imagery and GIS layers. The FAO lastly also operates a site aimed at making information and resources related to food security available, see http://www.foodsec.org/.

Section 9.2 already introduced the MSG satellite system, which was primarily designed for meteorological observations. EUMETSAT, the operator of MSG, also supports drought monitoring in Africa, via the **Land Satellite Application Facility (LANDSAF,** http://landsaf.meteo.pt/**)**. It is part of a network of SAFs, each led by the National Meteorological Service (NMS) of a EUMETSAT Member State. LANDSAF produces parameters on vegetation, soil moisture and evapotranspiration, which are distributed free of charge via the EUMETCAST system.

9.4 Flooding Hazard

Flooding is a result of the interplay between precipitation, in terms of intensity and duration, with local topography, landcover, engineering water regulation measures (dams, dikes, etc.), and soil type and condition. Thus knowledge on rainfall alone is of limited value. Studies such as the one by Harris et al. (2007) showed how data from TRMM (section 9.3) can be used in model flooding. However, as detailed topographic and landcover information is necessary for such models, they are typically done at catchment level (e.g. Asante et al., 2007). However, in cases where the river systems and the effect of rainfall in the catchment are well understood, satellite observations can be used to forecast flooding, as was shown by Artan at al. (2007) for the Nile river. It must also be remembered here that river flooding is but one type of flood. Inundations as a result of dam overspill or break, as well as flash floods, can not be forecast with satellite data.

The MSG satellite and data distribution system described in sections 9.2 and 9.3 also provides flood information. However, with a spatial resolution of only 1-3 km, and floods typically being associated with clouds that prevent the flood to register on the imagery, the data are less useful for flood extent mapping. Hence, the most useful are the MSG nowcasting products related to precipitation estimates. Though only providing information every 1-2 days, MODIS data have been used to map flood extent, often in the context of an activation of the International Charter “Space and Major Disasters” (see section 7.6). The UNOSAT website (www.unosat.org) shows many examples of such maps.

Most useful for flood mapping are cloud-penetrating radar sensors. However, only a small number of operational radar instruments mounted on polar orbiting platforms exists, providing costly data, and often with low temporal resolution. This means that a given satellite may only be able to observe a given site once every 3 or 4 weeks, thus are of limited use for operational flood mapping.

In sum, the data and the methods to estimate and forecast precipitation for the whole of Africa exist, as do the maps to map the presence and extent of larger floods. Actual flood modelling, i.e. to estimate which areas may be inundated as a result of a given rainfall event, and the duration and depth of the water, is more difficult. Models exist but require detailed data on the parameters listed above, and tend to be expensive. Furthermore, due to the complexity of the models, they are typically done on a catchment level only.

9.5 Windstorm hazard

It was explained in section 5.1.5 how remote sensing data are particularly suitable to detect and track large cyclonic systems, such as those threatening the southeastern part of the continent (see Figure 26). MSG is well-suited to detect and monitor such developing storms, and EUMETSAT strives to build capacity on the continent to analyse the incoming data through the **African Satellite Meteorology Education & Training** (ASMET) programme. This will increasingly allow African meterologists to analyse MSG data themselves, including the forecasting of cyclonic events but also other weather phenomena. The ASMET training includes the following components:

- Tropical Cyclones over the Southwest Indian Ocean
- Combining Satellite Imagery and Model Output in Weather Forecasting (e.g. Figure 57)
- Integrating Satellite Imagery of the ITCZ into Analyses
- Satellite Meteorology in Africa

Thus with proper training the MSG data provided by EUMETSAT can be used at a national or local level for weather forecasting activities. Given the strongly local dimension of weather, as opposed to climate, such processing is best done at a national or sub-national scale, though taking advantage of the excellent MSG data.

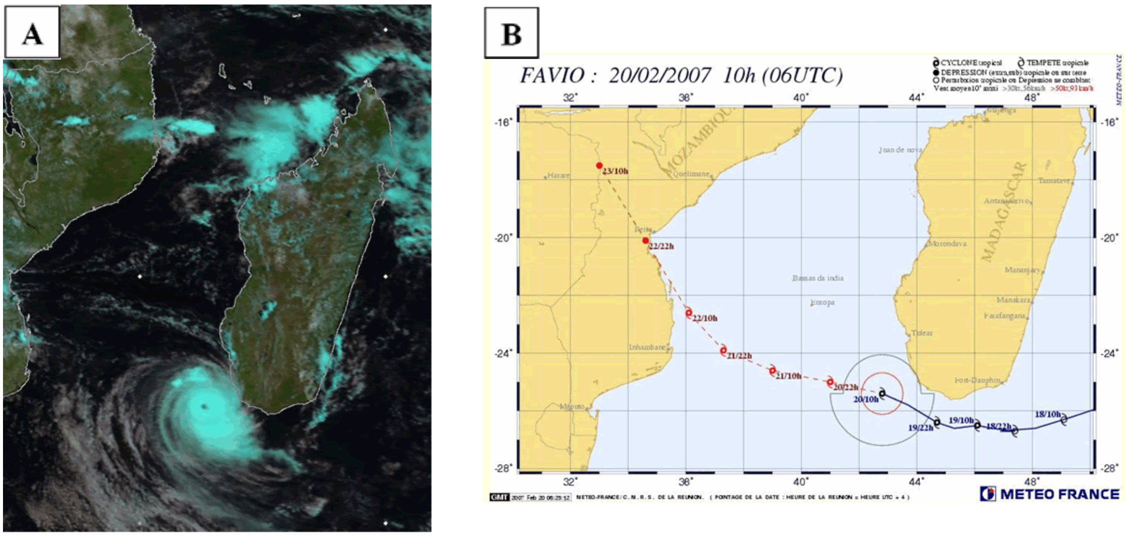


Figure 57: MSG image of cyclone Favio approaching Mozambique in February 2007, and storm track forecast base on the frequent data provided by the satellite (Source: South African Weather Service; Meteo France).

9.6 Tsunami hazard

A result of the 2004 Asian tsunami, an Indian Ocean Tsunami Warning System was agreed on in 2005. The event illustrated well how a seaquake close to Indonesia also affected several coastal countries in Africa (see section 5.1.6 and Figure 58).

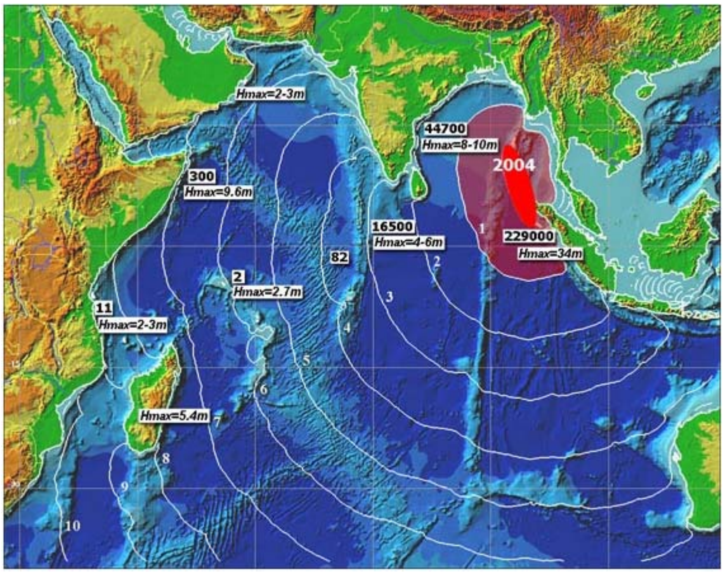


Figure 58: Travel times of the 2004 Asian Tsunami, and illustration of the countries exposed in Africa to tsunami events in Asia (Source: Tsunami Lab, Institute of Computational Mathematics and Mathematical Geophysics, Russia).

It is also apparent that the propagation time for tsunami waves originating in Asia is at least 7 hours, providing ample time for early warnings to be issued. In 2005 the Intergovernmental Coordination Group for the **Indian Ocean Tsunami Warning and Mitigation System** (ICG/IOTWS) was formed. Subsequently, led by UNESCO's

Intergovernmental Oceanographic Commission (IOC), which has already been successfully operating the **Pacific Tsunami Warning System** since 1968, the **Indian Ocean Tsunami Warning System** was finalised in 2006, under technical leadership of the GFZ in Potsdam, Germany. Designed as a circum-oceanic system it includes seismic stations in Asia and Africa, as well as ocean-floor pressure sensors and buoys spread over the Indian Ocean (Figure 59). Regional Tsunami Warning Centers, similar to the one on Hawaii for the Pacific, have yet to be established, and warnings are currently issued from Japan. However, Kenya, Tanzania and Somalia are planned as hosts for regional warning centers.

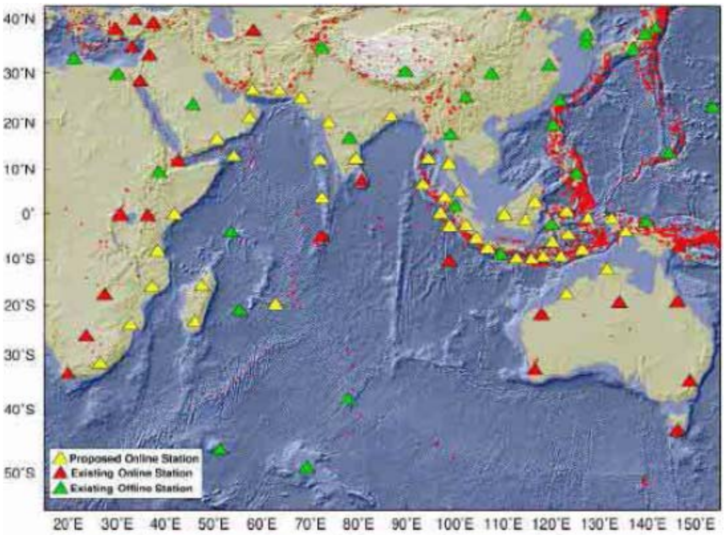


Figure 59: Envisioned design of the Indian Ocean Tsunami Warning System, currently comprising online (red) and offline (green), as well as proposed (yellow) stations (Source: UNU-IEHS).

A remaining shortcoming of the system is limited visibility, be it in form of a central internet presence, information material, or training information on information and alerts generated by the system and how to respond. Equally lacking appears to be an efficient early warning strategy. During the 2004 tsunami there was enough time to issue warnings to coastal populations along Africa's east coast, but no effective alerting means were in place and, as in most of the affected parts in Asia, people lacked knowledge on tsunamis as a hazard. Similar to Hawaii, where a loudspeaker system warns of impending tsunamis, it has been recommended to use the existing speaker systems on mosques in Islamic countries. However, for other potentially affected nations effective awareness campaigns and alert communication means have yet to be established.

9.7 Wildfire hazard

Section 9.2 already explained how MODIS data are used in a system designed to map volcanic thermal anomalies. However, the MODVOLC setup in practice detects primarily wildfires, which occur far more frequently (see Figure 51). The system operated by the University of Hawaii is well suited to obtain daily or weekly fire situation summaries. However, with the maps only being updated daily (Rothery et al., 2005), the operational use of the information is limited. Additionally, the map display is limited to a 50 x 50 km grid, a resolution that may not be sufficient for alerts or wildfire response.

The ability of MSG to map thermal features was also shown in section 9.2 already. Roberts and Wooster (2008) showed how fires can be effectively mapped with

MSG data. However, low-intensity pixels (with radiation of <50MW) are missed, leading to an overall underestimation of mapped fire energy as compared to what MODIS data with higher spatial resolution can provide. Nevertheless, with the high temporal resolution MSG can monitor fire dynamics far better, and also detect fire incidents of shorter duration. Additionally, the sensor sensitivity is such that, despite the 3 x 3 km pixel size, also very small fires can be detected. Theoretical calculations by Wooster and Roberts (2004) showed that a volcanic hotspot (>1200 K) of 90 m^2 would be required to be detectable on night-time SEVIRI (see Figure 60).

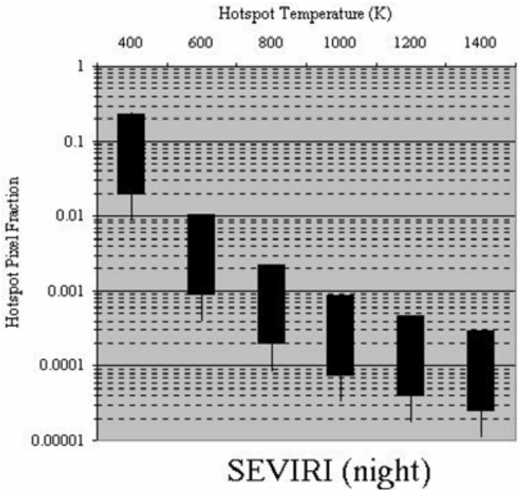


Figure 60: Estimated minimum hotspot detectability (lower bar limit) of MSG's SEVIRI night-time data, expressed as pixel fractions. Source: Wooster and Roberts (2004).

More recently they reported a minimum detectability with MSG data for wild fires of only 0.02-0.4 ha extent, for smoldering (650K) and flaming (1350K) fires, respectively (Roberts and Wooster, 2008).

The **Global Fire Monitoring Center** (GFMC) at the University of Freiburg (http://www.fire.uni-freiburg.de/) maintains an information portal on wild fires, including the current global fire status, early warning, fire inventories, etc. Working together with the ISDR, the portal is less a real-time fire information provider, but rather serves to provide comprehensive information on the wild fire phenomenon, professional meetings, and links to relevant data centers and information sources. Thus the site provides daily and 10-day global fire summaries (also based on MODIS) data.

Work is also ongoing to set up a **Global Early Warning System for Wildland Fire**. It is meant to form part of the Global Multi-Hazard Early Warning System that was agreed on as part of the Hyogo Framework. For now, detailed information for Africa provided by the GFMC is limited to what is provided by the Advanced Fire Information System (AFIS, see http://divenos.meraka.csir.co.za/afis/ and section 11.3.3).

9.8 Epidemics

Epidemics are a hazard that must be considered in a macroscopic perspective in terms of hazard source and distribution pattern, strongly coupled with local effects. Additionally, more than with the other hazards discussed so far, significant uncertainly as to hazard patterns persists, which is also true concerning means to reduce the hazard or the vulnerability.

A distinction must be made for epidemics hazards of local or regional original, such as Malaria. The main contribution from outside Africa is not of ICT nature, but concerns research into vaccines, as well as funding for education and eradication campaigns, as well as for distribution of mosquito nets. However, ICT is also being used to understand better the spread of the vector and the seasonal hazard patterns that result. The work by Hay et al. (2005) and Shanks et al. (2000) showed how malaria risk can be modelled, as already discussed in section 5.1.8. As the actual risk, however, is strongly related to availability of local breeding sites and vulnerability due to lacking anti-malaria medication or mosquito nets, malaria does not lend itself to global ICT-based hazard monitoring. With Rift Valley Fewer also being distributed by mosquitoes, similar limitations apply. ICT does remain relevant from an international perspective in that web-based information sources on the HVR associated with malaria can be accessed, together with best practices for risk assessment and mitigation. Various global portals provide such information, such as the Malaria Foundation International (http://www.malaria.org/) or, at a more technical level, the **Centers for Disease Control and Prevention** (CDC) in Atlanta (http://www.cdc.gov/malaria/).

The situation is different for H5N1 bird flu, as here mean exist to track affected migrating birds that frequently enter Africa from Europe and Asia. As those migration routes are well understood, and tracking of flocks is routines done with GPS-based tools, warnings can be given to African countries likely to be affected. However, this is hindered somewhat by the incomplete understanding on the virus-transfer to human hosts or domestic animals. This means that, while hazard mapping and monitoring to some extent can be done, thus allowing some early warning, local risk mitigation is made difficult as limited knowledge is hard to translate into specific best practice rules.

ICT does play several roles with respect to international support action. For example, research has been carried out on how satellite remote sensing can be used to map and monitor climate and landscape dynamics related to bird migration (Xiao et al., 2007). Major portals also exist that address the avian flu hazard, providing information, monitoring information and alerts. The PandemicFlu.gov and AvianFlu.gov (www.pandemicflu.gov/) portal is an example. It provides comprehensive background information on the virus, and what is known about the transmission mechanisms, infection consequences, and previous outbreaks. It also links to specific global monitoring information. One of those, the Epidemic and Pandemic Alert and Response (EPR) of the **World Health Organisation** (WHO) links human and technical resources worldwide for rapid outbreak identification, confirmation and response. It also issues maps of affected countries as discussed in section 5.1.8 (see also www.who.int).

Lastly, ICT-based distance learning means are being used to train health workers in potentially affected countries on how to mitigate the risk of virus transmission (Macario et al., 2007), again stressing the importance of the communication aspect of ICT (see section 8.1.

It is clear though that epidemics resulting from contact with infected hosts, be it malaria, RFV or bird flu, are a strong function of human exposure and vulnerability, and thus how the threat is being responded to locally. While breeding sites for mosquitoes can be contained, and outbreaks of bird flu minimised by rapid action in the source regions (typically Asia), the hazard can not be eliminated, reducing the reduction possibilities to improved vulnerability reduction. However, with hazard distribution and disease outbreak, in particular for more episodic threats posed by RVF and bird flu, occurring at a more regional scale and often involving clusters of countries, efficient ICT-based threat detection and early warning must be based on the continent.

9.9 Sea level rise

Sea levels are effectively measured and monitored using satellites observations, and networks of buoys and tide gauges. As it is also strongly linked to global warming and thus subject of ongoing scientific research and modelling, and is a global concern, international efforts are well suited to provide the needed information for Africa, without a specific need for a continental monitoring system.

Annual sea level rise rates have been identified to be low, though accelerating (Church and White, 2006), with changes being carefully monitored by the international community. The central designated campaign for sea level rise monitoring is the **Global Sea Level Observing System** (GLOSS), a joint effort of the WMO, ICO and the Joint **Technical Commission for Oceanography and Marine Meteorology** (JCOMM, http://www.gloss-sealevel.org/). Aiming at mapping and monitoring the global sea surface level, it is based primarily on a network of 290 sea level stations (Figure 61).

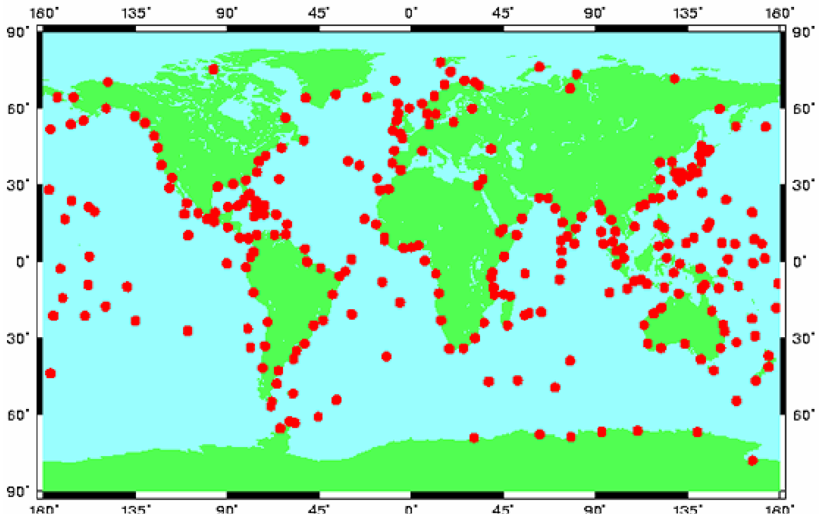


Figure 61: Map of global sea level stations that comprise the Global Sea Level Observing System (GLOSS). Source: GLOSS, http://www.gloss-sealevel.org/**.**

Some of the gauge sites will be equipped with GPS receiver for long-term trend forecasting. The effort is also supported by a dedicated satellite monitoring missions. The Ocean Surface Topography Mission (OSTM, http://www.osd.noaa.gov/ostm/), also called Jason 2, was launched in June 2008. It is a collaboration between NASA, NOAA, the French space agency (**Centre National d'Etudes Spatiales** (CNES)), and EUMETSAT. It will carry out satellite altimetry, thus providing global information on sea level rise, as a follow up of previous successful missions (TOPEX/POSEIDON and Jason 1). Other sites provide detailed information on the phenomenon of sea level rise, historic developments, and expected consequences, such as **Commonwealth Scientific and Industrial Research Organisation** (CSIRO)'s Sea Level Rise project (http://www.cmar.csiro.au/sealevel/index.html).

The **Permanent Service for Mean Sea Level** (PSMSL) operates a global tide gauge network (http://www.pol.ac.uk/psmsl/), though the African part of the network is considered too sparse, and additional stations are being installed, in cooperation with the IOC.

9.10 Locusts/grasshoppers

As explained in section 5.1.10, locust and grasshopper invasions are regional problems that reflect an interplay of breeding grounds and invasion areas. Hence, while local measures can be taken to eradicate invading locust populations, typically done by large-scale spraying with insecticides while the insects are on the ground, monitoring has to be synoptic. The FAO operates such a monitoring system that encompasses all affected areas in northern/central Africa and the Middle East. The **Emergency Centre for Locust Operations** (ECLO) contains the Locust Watch (www.fao.org/ag/locusts/) that provides situation reports, maps of affected areas, as well as background information on the locust/grasshopper phenomenon. Using Web Map technology, the ECLO Locust Mapper (tecproda01.fao.org/msapps/eclo/en/mapper.phtml) provides functions for customised map generation (Figure 62). The Locust Watch site provides status reports on observed breeding site, and areas under threat of invasion (Figure 63).

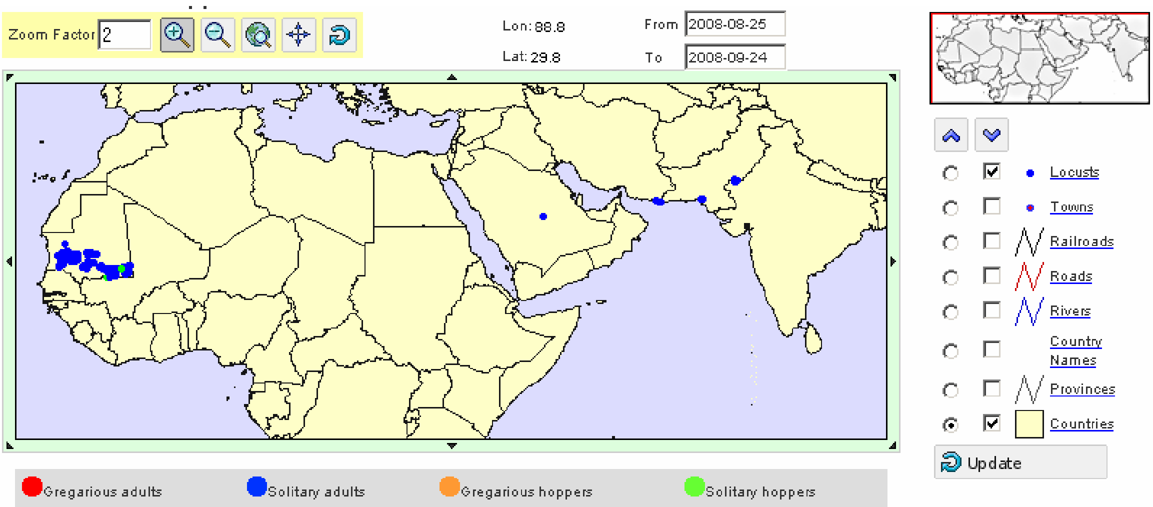


Figure 62: ECLO Locust Mapper of the FAO (Source: tecproda01.fao.org/msapps/eclo/en/mapper.phtml).

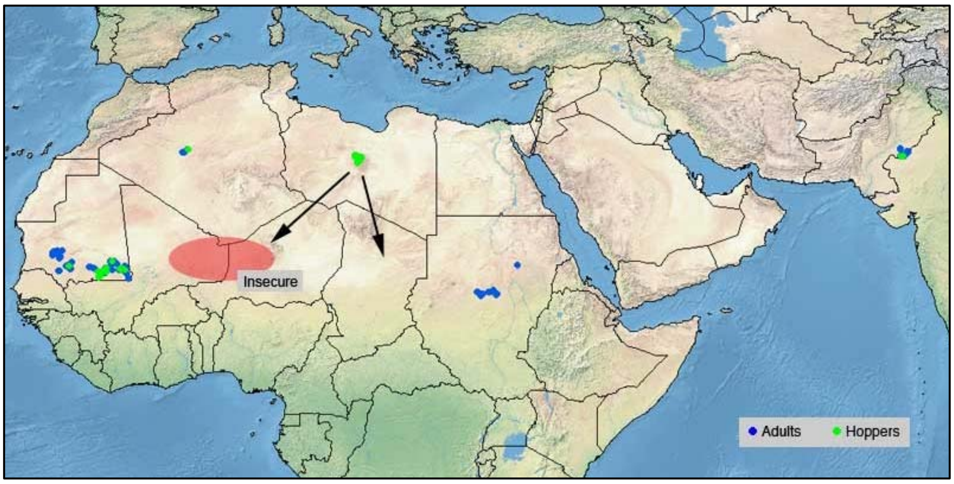


Figure 63: Locust situation report for 2 September 2008 (Source: FAO Locust Watch).

10. Tools for information transfer and use – beyond the internet

The various sources on hazard information introduced in chapter 9 are only of use if the information can be obtained in a timely and comprehensive manner. This means that for some hazard types, e.g. sea level rise, summary reports with an overview map on an annual basis may be sufficient, while for others, such as forest fires or tsunamis, such information must be available within hours. In some hazard cases, for example aviation hazard (Figure 53), a simple annotated text report may suffice. For others, such as for meteorological hazard information, in particular in light of the wish to build up African data analysis capacity, larger data amounts need to be transferred with high frequency. In this chapter this issue of data transfer is briefly addressed, focusing on specific data and information transfer mechanisms that go beyond direct access to and information retrieval from the internet sites mentioned in chapter 9. However, the chapter will have to be expanded and updated with input from the African AIDA partners, and the results of the country-level studies.

10.1 GEONETCast

Meteorological data were described above as highly suitable to address a range of hazards, including volcanic, cyclones and wild fires. With MSG data being acquired of all of Africa 96 times per day, a more efficient means to transfer the data to Africa than the internet is needed. Labeled as a nerve system for the planet, GEONETCast is a global low-cost network of satellite based data dissemination systems designed to provide environmental data to a world-global user community in near-real time. A part of the Group on Earth Observation (GEO)'s Work Plan, and thus also the GEOSS (see section 7.6), it is a joint effort by EUMETSAT, the WMO, and partners in China and the US, such as the Chinese Meteorological Administration (CMA), NOAA and NASA (Figure 64).

The system was designed for the distribution not only of meteorological imagery, but also satellite data related to the oceans or vegetation cover. This is seen as an important contribution to the GEO objectives, which aim at making multi-type geodata and information available in support of the 9 GEO Societal Benefit Areas (see www.earthobservations.org). Central to GEONETCast is the idea of making geodata available via communication satellites, and without the need for an internet connection. Instead a simple receiving station in form of a simple satellite dish with a PC can be used, at an installation cost of only about $1,500-2,000. This means that without landlines or a standing high-speed internet connection data can be received 24 hours a day.

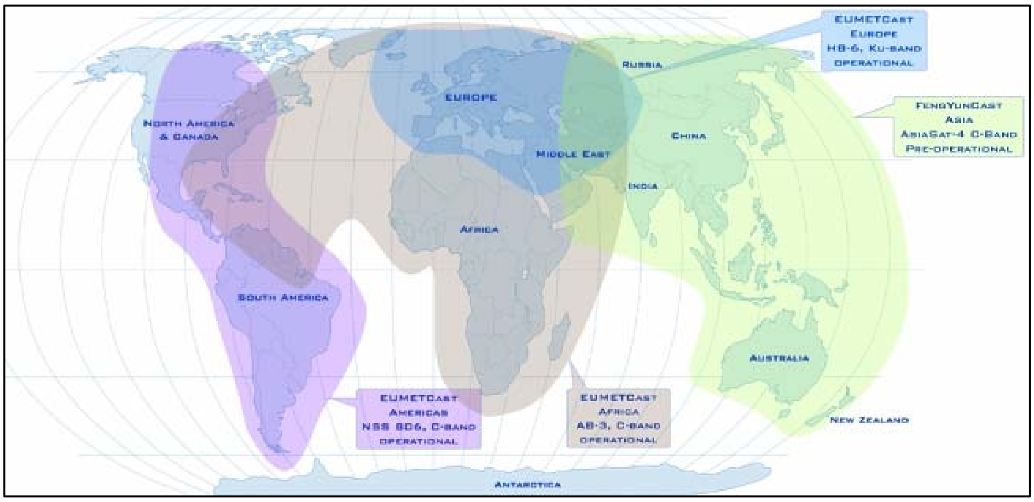


Figure 64: Setup of the GEONETCast system, comprising 4 regional systems, including EUMETCast Africa (Source: EUMETSAT).

As the GEOSS systems include all aspects of environmental monitoring, e.g. information on cyclone activity, erosion and desertification, vegetation health, or ocean temperatures, data are provided that enables broad DRR measures. GEONETCast is an umbrella for various types of data transmission. For example, EUMETCast Africa distributes results from the VGT4AFRICA project that provides vegetation data for the continent derived from SPOT satellites (http://www.vgt4africa.org). Further distributed are the meteorological data from EUMETSAT (see sections 9.2, 9.3 and 9.5), but also the LANDSAF system (section 9.3), and EUMETSAT's "SAF to support Nowcasting and Very Short Range Forecasting" (SAFNWC, http://www.meteorologie.eu.org/safnwc/).

Given the large amount of data and product types, the physical possibility of downloading data alone is not sufficient, with MSG alone collecting in excess of 1GB of data per day. The data are received and processed in Darmstadt, Germany, and are available approximately 5 minutes later. Via a ground station in Italy they are relayed by the Atlantic Bird satellite, and broadcasted in C-band for African users. At ITC a GEONETCast Toolbox has been developed to facilitate the selection, download and processing of required data products for a required area. Implemented in the open source GIS programme ILWIS (**Integrated Land and Water Information System**, www.itc.nl/ilwis) version 3.5. It contains a comprehensive file manger to select the data, product types and processing levels needed (Figure 65), comprehensive processing and visualisation tools (Figure 66). It is versatile and flexible tool built around the extensive GIS capabilities of ILWIS, available free of charge. Help on how to use the MSG products can also be obtained through a dedicated Yahoo discussion group (tech.groups.yahoo.com/group/MSG-1/).

Similar to GEONETCast, the **African Monitoring of the Environed for Sustainable Development** (AMESD, www.amesd.org/) project also distributes Meteosat data. A joint effort of the European Union and the African Union, it also focused on environmental monitoring, and contains a number of subprojects, for example addressing water resources (CEMAG - Central Africa: Management of Water Resources). However, it is less operational than GEONETCast and more limited in scope.

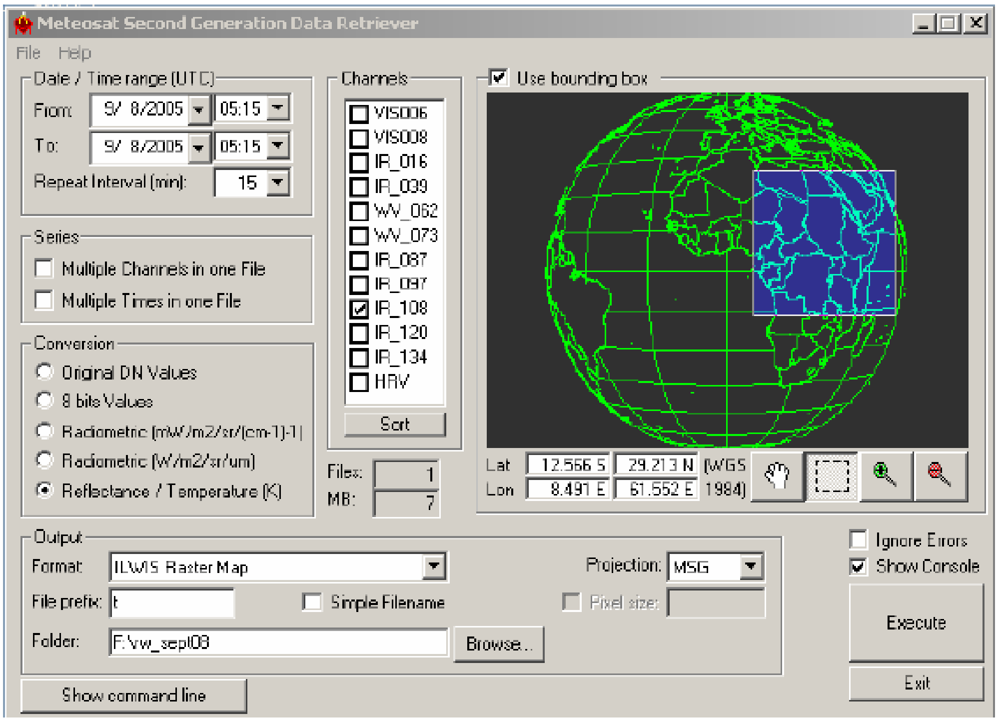


Figure 65: MSG data retriever of the GEONETCast Toolbox (Source: ITC lecture notes; Ben Maathuis).

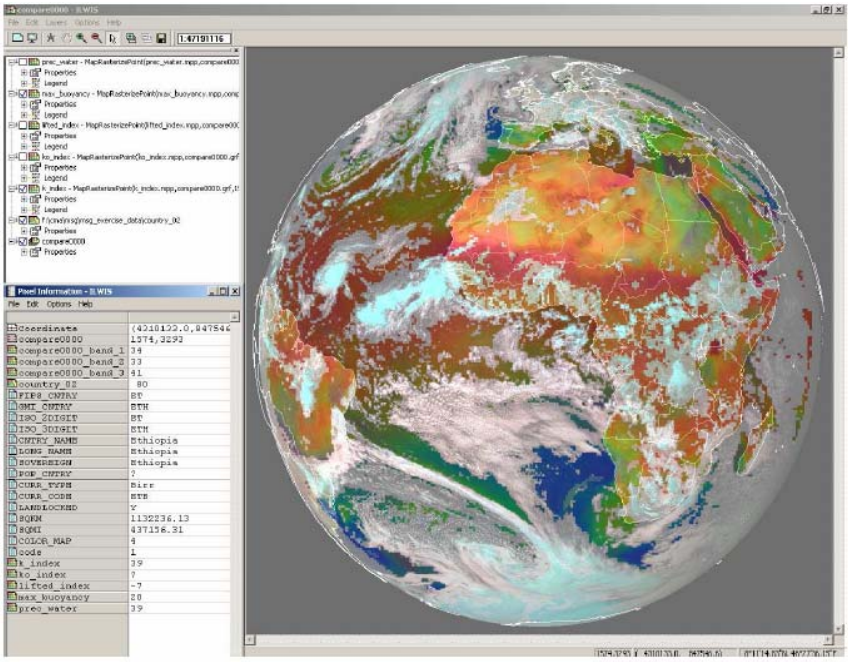


Figure 66: Example of cloud data processing and visualization possibilities in the Toolbox (Source: Source: ITC lecture notes; Ben Maathuis).

11. African ICT initiatives

Whilst being able to take advantage of a large number of ICT-based mapping, monitoring and analysis projects with relevance to DRM in Africa, significant developments have also taken place on the continent itself. Essentially driven by individual nations or organisations most have a focus limited to the operating horizons of the initiator. Others are supported by regional development bodies such as the **South African Development Community** (SADC) and thus cover several countries, or even the African Union or scientific bodies operating on a continental scale, such as the **International Science Council Unions** (ICSU). A consequent development towards effective and comprehensive multi-hazard DRM must be based on better cross-border cooperation. In particular countries operating their own space technology have an important role to play, as their technical means can easily be expanded to allow neighbouring countries to join, thereby also providing more effective control on hazards that easily move across national boundaries.

11.1 Earth observation and space communication technology

The second **UN Conference on Exploitation and Peaceful Uses of Outer Space** (UNISPACE) held in Vienna (Austria) in 1982, recommended that the UN programme on Space Applications (UN-SPA) should focus on the development of indigenous capabilities in Space Technology and at the local level. As a result South Africa was the space technology pioneer on the continent, launching SUNSAT-1 (Stellenbosch UNiversity SATellite) in 1999. Built mostly by graduate students the microsatellite collected 15m resolution data, but failed in 2001 (see http://research.ee.sun.ac.za/sunsat/). This has led to a situation where South Africa is the only country that has ever designed and developed its own satellite, and has the most comprehensive ground control infrastructure, but does not currently have a dedicated space agency nor operational satellites. On the continent 6 satellites are in operation, 3 serving Earth observation purposes, 3 facilitating communication. The countries operating the infrastructure are Egypt, Algeria and Nigeria.

In **Egypt** the National Authority for Remote Sensing and Space Sciences (NARSS) has been leading space efforts that go back to the early 1970s. Since then Egypt has developed a reputation for capacity in space technology engineering as well as image processing, having brought about not only Earth observation means, but also one of the largest telecom companies in the world, ORASCOM. For all the visibility of the latter, Egypt's space technology activities are not very transparent. In 2001, NARSS awarded a contract to a Ukrainian company, Yuzhnoe, to build a remote sensing satellite, an effort that also focused on building local space engineering capacity. The resulting satellite, EgyptSat-1, launched in 2007, has been alternately described as spy or Earth observation satellite, with only limited information available on the device itself. Suspected to be a microsatellite of between 100 and 160kg, it is thought to carry panchromatic and multi-spectral sensors with up to 4 m spatial resolution. However, the official NARSS site does not give any detailed information (http://www.narss.sci.eg).

Egypt has another satellite under development, tentatively called DesertSat, currently being built in collaboration in Italy. It is also a microsatellite with a strong knowledge transfer component. No information on capabilities or expected launch dates have been made available yet. There have further been reports on other satellites to follow up on the EgytSat-1 project, called EgyptSat-2 and SaharaSat.

The country has more experience with communication satellite development. Already in 1998 and in 2000 the Nilesat 101 and Nilesat 102 platforms were launched, respectively. Built by Astrium and launched by ESA, both are geosynchronous satellites designed for radio and TV broadcasting (see www.nilesat.com.eg/).

More significant from a DRM perspective has been the development of the **Disaster Monitoring Constellation** (DMC). An international satellite program for rapid global response to natural or man-made disasters, it was initially proposed in 1996 and led by Surrey Satellite Technology Ltd (SSTL), Surrey, UK. The objective of the constellation is daily global imaging capability by means of a network of five affordable micro-satellites, which collect medium resolution (28–32 m) images in 3 or 4 multispectral bands (corresponding to LandsatTM bands 2, 3, 4 and 1, 2, 3, 4, respectively) (Sweeting and Chen, 1996). Significant from an AIDA perspective, and surprising considering the initial leading role of South Africa, the DMC consortium consists of partners from China, Turkey and the UK, as well as **Algeria**, and **Nigeria**. Similar to the Egyptian efforts, the satellite design and construction phases also involved capacity building of engineers from the country that later owned the individual satellites. The five low-cost micro-satellites that were launched as the first Earth observation constellation, provide daily images for global disaster monitoring (da Silva Curiel et al., 2005). AlgeriaSat-1 and Nigeria-Sat1 were launched in 2004. In addition to daily revisits, another substantial strength of the DMC satellites is the large ground coverage in tiles up to 600 km wide, as well as its global reach. For example, NigeriaSat-1 was the first civilian satellite to image the Gulf areas affected by Hurricane Katrina in 2005.

In the meantime, through the National Space Research and Development Agency (NASRDA) that has been leading Nigeria's space efforts since 1999, work has been ongoing on NigeriaSat-2, meant to make use of the knowledge transfer that accompanied the construction of the first satellites. However, it is still essentially being built by SSTL. In addition to the wide-coverage, medium-resolution sensor of NigeriaSat-

1, it will also have a high-resolution instrument to provide 2.5 m panchromatic, and 5 m multi-spectral data, which launch scheduled for late 2009.

Nigeria has also been actively pursuing a telecom project. In 2004 an agreement as reached with the Chinese China Great Wall Industry Corporation, which resulted in Nigeria's first telecommunications satellite, NigComSat-1, launched in 2007 by a Chinese rocket. It provides telecom services, but is also meant to be used for telemedicine and tele-education, also connecting to several teaching hospital and federal primary heath centers. NASRDA has also been working on the construction of a ground station in the national capital, Abuja, referred to as the Obasanjo Space Centre, as well as on the Centre for Space Transport and Propulsion, located near Lagos. The long-term ambition of Nigeria is to be able to design, built and launch satellites without international assistance.

Algeria also owns one of the DMC satellites, AlgeriaSat-1, also referred to as Alsat-1. Lead by the Algerian Space Agency (ASAL), created in 2002, the country is pushing for technological development in a collaborative and multilateral way. The launch of AlgeriaSat-1 is only the beginning of a 15-year National Space Programme (2006 to 2020). The ambitious plan includes the setup of the Satellite Development Centre (CDS), a Satellite Applications Centre (CAS), a Telecommunications Satellite Operations Centre (CEST), and a Doctoral School of Space Technologies and Applications (EDTAS).

ASAL is also working on a series of new satellite missions, both for EO and telecommunication purposes. These include the Alsat-1B, Alsat-2, Alsat-3, and Alsat-4 EO satellites, and the Alcomsat-1 telecoms platform. Two Alsat-2 satellites are already being built by EADS Astrium, again involving a large number of Algerian engineers to facilitate knowledge transfer. While Alsat-2A is being built at the Astrium facilities, the 2B satellites is meant to be built at CDS. Similar to the improved spatial resolution planned for Nigeria-Sat2, Alsat-2 will also provide 2.5 m panchromatic, and 10m multi-spectral imaging capabilities, with a 3-day revisit time. The Alcomsat-1 program is not as advanced as the EO efforts, and no specifications are yet available.

As the largest economy on the continent, there has clearly been pressure for **South Africa** to regain some of its earlier competitive advantage. As a result, the country's second EO satellite, Sumbandila, is scheduled to be launched in late 2008. A joint effort of Stellenbosch University, SunSpace and the Council for Scientific and Industrial Research (CSIR). It will provide 6.5 m resolution multi-spectral imagery. In particular SunSpace has been making great progress in developing its technical capacity, developed together with European contributions, now being able to offer various satellite platforms. There are finally also plans to establish an official South African Space Agency (SASA). Though lacking the leadership of a formal space agency, South Africa has been operating a receiving station at its Satellite Applications Centre (SAC), allowing it to receive image data from all important EO satellite missions.

However, what Africa requires, in particular in light of the regional hazards and disasters discussed in this CF, is more multi-lateral efforts. At the moment, for example, existing satellites such as NigeriaSat-1 or Alsat-1 have little benefit for neighbouring countries. This is, on one hand, a result of a limiting image product marketing agreement. The DMC data are centrally marketed by the DMC International Imaging Ltd. DMCII, located in the UK. This means that interested countries have to purchase the data at commercial rates. Coupled with limited human and technological capacity in most of those countries this means that almost no use is made of available data. On the other hand, though, there is also little multi-national cooperation, also where it affects risks that are shared by neighbouring countries. This was evident at an international workshop on the use of regionally owned space infrastructure organized by ITC, together with

NASRDA and the **National Emergency Management Agency** (NEMA), in Nigeria in 2007, where cross-border or regional efforts did not receive significant attention.

However, there are now plans for an African Resource Management Satellite (ARMS) constellation, involving Algeria, Nigeria, South Africa, and Kenya. While some technical specifications have already been agreed on (e.g. to include 3m panchromatic and a 12m multi-spectral sensors), a declaration of intent still has to be signed, thus the project has not yet neared the implementation phase.

11.2 Capacity building in ICT

Nearly all satellite developments projects were lead by non-African companies and organisations, yet also included technical capacity and knowledge transfer components. While there is more to operating a satellites fleet than being able to manufacture such infrastructure, this is a promising approach. However, what is equally important is a capacity building focus on the use of the acquired data. For example, while NASRDA has organised a workshop focusing on the development data of Nigeriasat data applications, no widespread use of the data in the country occurs.

More has been achieved by the UN programme for space science and technology education (see for example http://www.unoosa.org/oosa/SAP/centres/index.html), which has resulted in the establishment of **Regional Centres for Space Science and Technology Education**. Two of those centers operate in Africa, the francophone **African Centre for Space Science and Technology** (CRASTE-LF) in Morocco, and the anglophone **Regional Centre for Space Science and Technology Education** (RECTAS) in Nigeria. Both centers operate regional post-graduate training courses in geoinformatics and remote sensing, in part in collaboration with international institutes. For example, RECTAS operates a joint MSc course, also focusing on the use of geoinformatics for DRM, with the ITC in the Netherlands.

Another important capacity building facility is the **Regional Centre for Mapping of Resources for Development** (RCMRD, www.rcmrd.org). Initiated by the **UN Economic Commission for Africa** (UNECA), the center has been operating in Nairobi, Kenya, since 1975, providing training services to 14 contracting member countries (Botswana, Comoros, Ethiopia, Kenya, Lesotho, Malawi, Mauritius, Namibia, Somalia, Sudan, Swaziland, Tanzania, Uganda and Zambia) in geoinformatics, resource mapping and management.

For the SADC region the **Regional Remote Sensing Project** (RRSU, www.sadc.int/fanr/aims/rrsu/index.php) in Botswana is of significance. A regional center of excellence, the RRSU provides capacity building in GIS, remote sensing and agro-meteorology. Initiated in 1988 with support from Japan, and supported by the FAO and the European Commission since 1994 and 1998, respectively, the center provides training, but also early warning for food security, support for DRM and for natural resource management.

In addition to these centers of regional focus, various universities have begun to setup degree courses on environmental, resource or disaster management, many with geoinformatics components. One of those has grown to attain the status of a dedicated center, the **Disaster Management Training Centre** (DMTC) at Ardhi University in Dar Es Salaam, Tanzania. To improve the human capacity of these universities in their focus on geoinformatics for DRM, a university network was initiated by ITC in 2005 in Kampala, Uganda. The **University Network for Disaster Risk Reduction in Africa** (UNEDRA, www.itc.nl/unu/dgim/unedra/default.asp) is meant to foster greater interaction between universities, currently with focus on East and West Africa, to share experience, build joint DRM courses with staff and student exchange, and to facilitate joint funding acquisition and research. Many UNEDRA activities, in particular training courses and workshops have already been organised.

11.3 Regional ICT efforts for DRM

As shown in the previous sections, many ICT-based initiatives that include or focus on Africa have been carried out, and monitoring and data dissemination networks established. In Africa itself the importance of space infrastructure has been recognised and significant achievements made. In addition to the networks providing monitoring or early warning information reviewed in chapter 9, also some African efforts exist that are summarised in this section. It must be noted, however, that with increasing focus the number of smaller initiatives increases that are relevant for AIDA, but fall outside the scope of the CF. There may also be larger activities that are missed here, thus this section of the document needs to be updated based on the findings of the planned detailed work at national level. Below only some examples of initiatives of wider importance are given.

11.3.1 Ocean Data and Information Network for Africa (ODINAFRICA)

The **Ocean Data and Information Network for Africa** (ODINAFRICA, http://www.odinafrica.org/) comprises marine institutions from 25 member states of the IOC of UNESCO from Africa (Algeria, Angola, Benin, Cameroon, Comoros, Congo, Cote d'Ivoire, Egypt, Gabon, Ghana, Guinea, Kenya, Madagascar, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Nigeria, Senegal, Seychelles, South Africa, United Republic of Tanzania, Togo, and Tunisia). It is aimed at integrated coastal zone management that includes coastal zone monitoring, data and information management and exchange, but also more advanced analysis of the data to form a basis for decision making. As such capacity building of member state organisations is central to ODINAFRICA.

One of the main products of the network has been the Africa Marine Atlas (http://www.africanmarineatlas.net/, Figure 67), launched in 2007. It is meant to be a central repository for information on all aspects of coastal zone management, and forms part of the International Coastal Atlas Network (ICAN, ican.science.oregonstate.edu).

Figure 67: African Marine Atlas (Source: http://www.africanmarineatlas.net/).

11.3.2 AfricaArray for seismic monitoring

Launched in 2005, the AfricaArray is an initiative for continent-wide geophysical monitoring, coupled with a strong capacity building component, and with plans to expand (africaarray.psu.edu/). Hence the initiative is subtitled "AfricaArray: Training a Scientific Workforce for Africa's Natural Resource Sector". The network's initial focus has been geophysics, with seismic from the AfricaArray observatories being archived and distributed by the IRIS Data Management Center (www.iris.washington.edu), and data also being made available for research by African students. The monitoring network underlying the array is still being expanded, and is scheduled to be completed in 2014 (Figure 68).

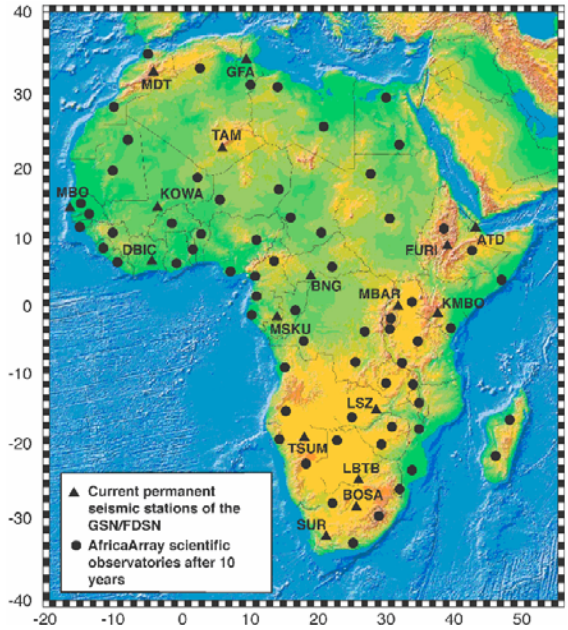


Figure 68: Map of the current and envisioned measurement structure of the AfricaArray (Source: africaarray.psu.edu).

11.3.3 Regional Subsahara Wildland Fire Network (Afrifirenet)

Like AfricaArray, Afrifirenet is a contribution to the NEPAD environmental programme, thus contributing to promote sustainable development by fostering a healthy and productive environment. It is supported by the ISDR and the Global Fire Monitoring Center (GFMC). Afrifirenet is meant to enhance local, national and regional fire management capabilities, aiming at reducing the effect of devastating wild fires on poverty, health, the environment and thus sustainable development. It includes information management and dissemination, technology transfer and capacity building, aiming at bringing up-to-date knowledge of fire management to the local level. The objectives, therefore, include the creation of a comprehensive communication network, a wildfire early warning system, fuel status monitoring, fire impact assessment, and research into wildfire management and technological development (see www.fire.uni-freiburg.de/GlobalNetworks/Africa/Afrifirenet.html).

Part of Afrifirenet is the **Advanced Fire Information System** (AFIS), which will deliver fire information products to the respective protection agencies and disaster managers in Southern Africa, thus supporting effective decision-making in the monitoring of natural and manmade fires over the SADC region (see wamis.co.za). The AFIS

Sensor Web Mapper tool is a web map service for efficient fire information distribution (see Figure 69).

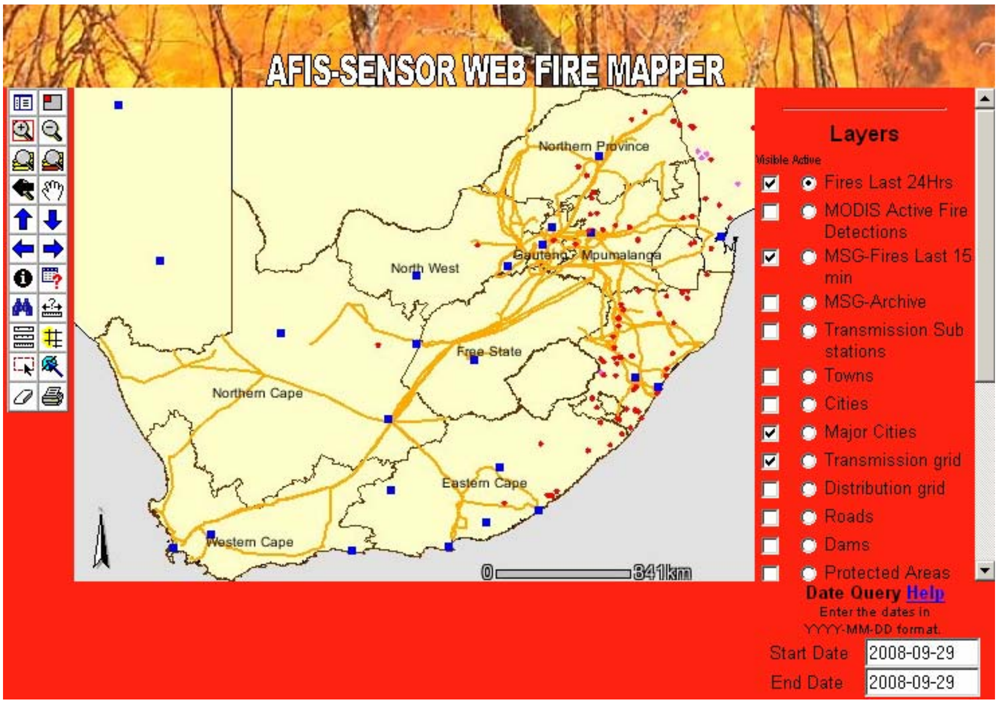


Figure 69: AFIS Sensor Web Fire Mapper tool of the Advanced Fire Information System (AFIS). Source: www.wamis.co.za.

12. Summary

The purpose of the CF was to review the concepts of DRM, define all relevant terms, to assess the hazard, risk and disaster situation in Africa, to introduce global initiatives aimed at DRM support on the continent, to discuss the role of ICT in Africa, to inventorise international hazard and early warning systems that include or focus on Africa, and to highlight ICT initiatives that originate on the continent itself. The sheer size and variability of the continent, and the scale-dependency of hazard, vulnerability and risk, result in a situation where an inventorisation by necessity must have limitations. Aimed at setting the stage for the in-depth regional and country-level studies, only the overview of previous disasters includes the country scale. All concepts and initiatives related to ICT are only reviewed and discussed at continental to regional levels. In Chapter 2 the disaster situation was evaluated, showing that Africa is seeing the largest increase in disaster numbers, but also highlighting regional hotspots and patterns. Emphasis was placed on the need for correct interpretation of disaster statistics. Significant in Chapter 3 was that a strong conceptual framework exists to assess multi-hazard risk. The discussion also made it clear how risk, as a function of hazard, vulnerability in its various forms, and capacity, can best be reduced. It can thus serve as a basis on which to decide how to spent limited resources to reduce local risk. The next chapters summarised what is known about the various hazards present in Africa (Chapter 5), how this information can be used in risk assessment (Chapter 6), and which international DRR strategies exist to provide conceptual approaches and practical networks (Chapter 7). Chapter 8 highlighted the limited telecommunication means in

Africa as a serious bottleneck in DRR, in that they prevent ready access to the vast amount of risk-related data and information, as well as networking and collaboration of African institutions amongst each other and with those outside the continent. However, it also showed how unique approaches, such as a the leapfrogging straight to mobile telecommunication, also offer hope that communication and information provision to most populated places in Africa via mobile phones will soon be possible, where needed aided by direct satellite reception as offered by GEONETCast (Chapter 10). Lastly, it was shown that Africa itself has brought about a range of regional DRM initiatives that are conceptually and technically sound, and well linked in with related international networks and initiatives, thus reflecting the spirit of GEOSS. From the information synthesised in the CF several important observations emerge:

- Africa has shown the highest growth in disaster numbers of any continent.
- It also shows the highest population growth, resulting in more elements at risk, more pressure on resources, and thus a high probability of rising vulnerability and hazard exposure, the latter by more marginalized people being forced to move into hazardous areas.
- Hazards and disasters show regional patterns, linked to structural geology (seismic and volcanic), circulation patterns, etc. Understanding of those underlying causes will help to understand hazard better, especially in terms of their frequency and magnitude.
- Disasters are primarily a social phenomenon, linked to high vulnerability and limited capacity. ICT must address these aspects, e.g. via education and capacity building, early warning, but also community involvement.
- Risk may include a number of hazards that interact or even compound each other. Only a thorough understanding of the multi-hazard risk situation, one that also considers the different types of vulnerability, will allow DRR.
- Quantification of risk is challenging as units vary or a ready assignment, such as a monetary value of life, is not possible. Thus agreement is needed on risk units to ensure comparability.
- Different means exist to assess risk, ranging from more qualitative approaches, often including community participation, to quantitative, GIS-supported techniques.
- Hazards may have broad patterns and may thus be efficient to monitor with ICT, in particular space assets. However, vulnerability is an inherently local phenomenon. Thus if regional risk assessment is carried out (such as for malaria in figure 36), the limitations of such approaches must be understood. Ideally risk is assessed and reduced locally. Risk is fundamentally scalable.
- Much is known about the hazard situation in Africa, the result of much dedicated research and monitoring, often by international organizations, but also efforts of African scientists and organizations.
- However, many hazard types that are easily summarized but in fact have many different facets, each with its own scale and hazard characteristics. Extreme examples are seismic hazards where areas likely to experience shocks of a certain magnitude are quite easily identified, while local results are more a function of soil type and thickness that determines liquefaction potential. Also volcanoes pose many hazard types with effects that range from very local to global.

- Hazards can be highly dynamics in space and time, may be entirely of natural origin, other are increasingly man-induced or amplified.
- The analysis supports the AIDA approach to carry our country- and local-level investigations as this is where risk reduction measures are most effective.
- African DRM is already well linked in at a broad conceptual level, with international DRM strategies. The African Union has adopted international strategies (e.g. the HFA) – the priority now must be to carry what is known about DRR to national and local levels, and to link it to all ongoing sustainable development efforts. Everything that works towards reducing poverty, safeguarding the environment, or otherwise achieving the Millennium Development Goals of the UN will also reduce the risk situation.
- With DRR being a global concern, many countries have developed effective monitoring, early warning and DRR strategies. However, a simple transfer of those approaches likely will not work as important differences exist in Africa, especially with respect to infrastructure, but also in terms of culture. Far more effective than a technological solution can be to educate, promote and support a local champion, one who can assist a community in making the right decision when faced with a hazardous situation. Acceptance of centralized DRR ideas may also only be possible via community-involvement.
- A convincing demonstration of simple yet effective means to reduce multi-hazard risk can be implemented, e.g. how the cleaning of ditches and canals can reduce malaria, flooding and intestinal disease. Only broad acceptance and ownership by the community will lead to the needed local support.
- Essentially all hazards at regional to country level are already being effectively monitored by existing initiatives. However, more detailed monitoring at sub-national level, in particular reflecting the specific local hazards, is needed. For some hazards, such as meteorological, existing data from MSG suffice, with only local technical capacity building being needed to produce local weather products. For other hazards, e.g. seismic, changes in methodology are needed for seismic microzonation at local levels.
- Many data types, especially those derived from spaceborne RS, are useful for different purposes, thus multi-use to increase efficiency is useful. GEONETCast was identified as a novel, versatile and low-cost means to access geospatial data from a range of monitoring projects at any place in Africa, even where no traditional communication means exist.
- An increasing emphasis on open source and free software tools for data access, processing and modeling means that, together with the many free datasets available via the internet or GEONETCast, even organizations with very limited budgets can now carry out DRM-related data processing. The remaining bottleneck – limited human capacity – should receive much stronger attention, as only then the available technical mean can be utilized.
- Africa itself has shown strong technical capacity and readiness to participate on advanced ICT-based DRM solutions. Four countries have already operated space technology and invested heavily on human and technological capacity to further these developments. What is needed is stronger international cooperation, where also countries without such technology but that share common hazards and risks can benefit. Still too often DRM is seen as a purely national endeavour.

13. Acronym list

ADB	African Development Bank
AFIS	Advanced Fire Information System
ARMS	African Resource Management Satellite
ARSDRR	Africa Regional Strategy for Disaster Risk Reduction
ASAL	Algerian Space Agency
ASMET	African Satellite Meteorology Education & Training
AU	African Union
AVHRR	Advanced Very High Resolution Radiometer
BCPR	UNDP-Bureau for Crisis Prevention and Recovery
CAS	Country Assistance Strategies; Satellite Applications Centre (Algeria)
CDC	Centers for Disease Control and Prevention
CDS	Satellite Development Centre (Algeria)
CEST	Telecommunications Satellite Operations Centre (Algeria)
CF	Conceptual framework
CMA	Chinese Meteorological Administration
CNES	Centre National d'Etudes Spatiales
CONAE	Argentine Space Agency
CRASTE-LF	African Centre for Space Science and Technology (Morocco)
CRED	Center for Research on the Epidemiology of Disasters
CSA	Canadian Space Agency
CSIR	Council for Scientific and Industrial Research (South Africa)
DLR	German Space Agency
DM	Disaster management
DMC	Disaster Monitoring Constellation
DMTC	Disaster Management Training Centre
DRC	Democratic Republic of Congo
DRM	Disaster risk management
DRR	Disaster risk reduction
EaR	Element at risk
ECLO	Emergency Centre for Locust Operations
EDTAS	Doctoral School of Space Technologies and Applications (Algeria)
EM-DAT	Emergency Events Database
ENEP	National Centre for Environmental Prediction (US)
EO	Earth observation
EPR	Epidemic and Pandemic Alert and Response
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAO	Food and Agricultural Organisation of the UN
FEWS	Famine Early Warning System
FEWSNET	Famine Early Warning System Network
GDACS	Global Disaster Alert and Coordination System
GEO	Group on Earth Observation
GEOSS	Global Earth Observation System of System
GFMC	Global Fire Monitoring Center
GFDRR	Global Facility for Disaster Reduction and Recovery
GIC	Geoinformatics and Communication
GIEWS	Global Information and Early Warning System of the FAO
GIS	Geographic Information Systems; Geoinformation systems
GLOSS	Global Sea Level Observing System
GTOS	Global Terrestrial Observing System of the FAO
HoA	Horn of Africa
HFA	Hyogo Framework for Action

HVR	Hazard, vulnerability, risk
IAVCEI	International Association of Volcanology and Chemistry of the Earth's Interior
ICAN	International Coastal Atlas Network
ICAO	International Civil Aviation Organization
ICG/IOTWS	Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System
ICSU	International Science Council Unions
ICT	Information and Communication Technology
IDNDR	International Decade for Natural Disaster Reduction
ILWIS	Integrated Land and Water Information System
IOC	Intergovernmental Oceanographic Commission
ISDR	International Strategy for Disaster Reduction
ISRO	Indian Space Research Organization
ITU	International Telecommunication Union
JAXA	Japan Aerospace Exploration Agency
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology
MDG	Millennium Development Goals
MFG	Meteosat Second Generation
MODIS	Moderate Resolution Imaging Spectroradiometer
NAPA	National Adaptation Plans of Action
NARSS	National Authority for Remote Sensing and Space Sciences
NASA	National Aeronautics and Space Administration
NASRDA	National Space Research and Development Agency (Nigeria)
NDVI	Normalised Difference Vegetation Index
NEMA	National Emergency Management Agency (Nigeria)
NEPAD	New Partnership for Africa’s Development
NGO	Non-governmental Organisation
NOAA	National Oceanic and Atmospheric Administration
NSDI	National Spatial Data Infrastructures
ODINAFRICA	Ocean Data and Information Network for Africa
OSTM	Ocean Surface Topography Mission
PGIS	Participatory GIS
PRS	Poverty Reduction Strategies
PSMSL	Permanent Service for Mean Sea Level
PV	Physical vulnerability
RECTAS	Regional Centre for Space Science and Technology Education (Nigeria)
RS	Remote sensing
RVF	Rift Valley Fewer
SADC	South African Development Community
SAF	Land Satellite Application Facility
SASA	South African Space Agency
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SMCE	Spatial Multi-Criteria Evaluation
SSTL	Surrey Satellite Technology Ltd (UK)
SUNSAT	Stellenbosch University Satellite (South Africa)
SV	Social vulnerability
TRMM	Tropical Rainfall Measuring Mission
UNDAF	UN Development Assistance Frameworks
UNECA	UN Economic Commission for Africa
UNEP	United Nations Environment Programme
UNISPACE	Conference on Exploitation and Peaceful Uses of Outer Space
UNSPA	United Nations Programme on Space Applications
USAID	United States Agency for International Development
USGS	United States Geological Survey

WHO	World Health Organisation
WFP	World Food Programme

14. References

Abam, T.K.S., 2001, Regional hydrological research perspectives in the Niger Delta: Hydrological Sciences Journal-Journal Des Sciences Hydrologiques, v. 46, p. 13-25.

Afrane, Y.A., Zhou, G., Lawson, B.W., Githeko, A.K., and Yan, G., 2007, Life-table analysis of Anopheles arabiensis in western Kenya highlands: Effects of land covers on larval and adult survivorship: American Journal of Tropical Medicine and Hygiene, v. 77, p. 660-666.

Alexander, D., 1991, Natural disasters: a framework for research and teaching: Disasters, v. 15, p. 209-226.

Allen, K.M., 2006, Community-based disaster preparedness and climate adaptation: local capacity-building in the Philippines: Disasters, v. 30, p. 81-101.

Anderson, M.B., and Woodrow, P.J., 1998, Rising from the Ashes: Development Strategies in Times of Disaster, Lynne Rienner Publishers, 338 p.

Artan, G., Gadain, H., Smith, J.L., Asante, K., Bandaragoda, C.J., and Verdin, J.P., 2007, Adequacy of satellite derived rainfall data for stream flow modeling: Natural Hazards, v. 43, p. 167-185.

Asante, K.O., Macuacua, R.D., Artan, G.A., Lietzow, R.W., and Verdin, J.P., 2007, Developing a flood monitoring system from remotely sensed data for the Limpopo basin: IEEE Transactions on Geoscience and Remote Sensing, v. 45, p. 1709-1714.

Awosika, L., and Folorunsho, R., 2005, Natural and anthropogenic hazards in the African coastal and ocean environment: need for holistic and pragmatic early warning system and management approach, OCEANS, 2005; Proceedings of MTS/IEEE, Washington, D.C., 891 - 899, Vol 1., 18-23 September, 2005,

Bessis, J.L., Bequignon, J., and Mahmood, A., 2004, Three typical examples of activation of the International Charter "Space and Major Disasters", Monitoring of Changes Related to Natural and Manmade Hazards Using Space Technology, Volume 33: Advances in Space Research, p. 244-248.

Blaikie, P., Cannon, T., Davis, I., and Wisner, B., 1994, At risk: natural hazards, people's vulnerability, and disasters: London ; New York, Routledge, 284 p.

Brooks, H.E., Lee, J.W., and Craven, J.P., 2003, The spatial distribution of severe thunderstorm and tornado environments from global reanalysis data: Atmospheric Research, v. 67-8, p. 73-94.

Brooks, N., Adger, W.N., and Kelly, P.M., 2005, The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation: Global Environmental Change-Human and Policy Dimensions, v. 15, p. 151-163.

Bryant, E., 2004, Natural Hazards, Cambridge University Press, 328 p.

Cardona, O.D., Hurtado, J.E., Duque, G., Moreno, A., Chardon, A.C., Velásquez, L.S., and Prieto, S.D., 2003, The notion of disaster risk. Conceptual framework for integrated risk management: IDB/IDEA Program on Indicators for Disaster Risk Management, Universidad Nacional de Colombia, Manizales, p. 38.

Church, J.A., and White, N.J., 2006, A 20th century acceleration in global sea-level rise: Geophysical Research Letters, v. 33.

Clark, G.E., Moser, S.C., Ratick, S.J., Dow, K., Meyer, W.B., Emani, S., Jin, W., Kasperson, J.X., Kasperson, R.E., and Schwarz, H.E., 1998, Assessing the vulnerability of coastal communities to extreme storms: the case of Revere, MA., USA: Mitigation and Adaptation Strategies for Global Change, v. 3, p. 59-82.

CRED, 2008, EM-DAT: The OFDA/CRED International Disaster Database, URL: www.em-dat.net,

Cutter, S.L., Boruff, B.J., and Lynn Shirley, W., 2003, Social vulnerability to environmental hazards: Social Science Quarterly, v. 84, p. 242-261.

da Silva Curiel, A., Boland, L., Cooksley, J., Bekhti, M., Stephens, P., Sun, W., and Sweeting, M.N., 2005, First results from the disaster monitoring constellation (DMC): Acta Astronautica, v. 56, p. 261-271.

Day, S.J., 1996, Hydrothermal pore fluid pressure and the stability of porous, permeable volcanoes, *in* McGuire, W.J., Jones, A.P., and Neuberg, J., eds., Volcano Instability on the Earth and other Planets, Volume 110, Geological Society Special Publication, p. 77-93.

Douglas, J., 2007, Physical vulnerability modelling in natural hazard risk assessment: Natural Hazards and Earth System Sciences, v. 7, p. 283-288.

Ericson, J.P., Vorosmarty, C.J., Dingman, S.L., Ward, L.G., and Meybeck, M., 2006, Effective sea-level rise and deltas: Causes of change and human dimension implications: Global and Planetary Change, v. 50, p. 63-82.

Fat-Helbary, R.E., and Tealb, A.A., 2002, A study of seismicity and earthquake hazard at the proposed Kalabsha Dam site, Aswan, Egypt: Natural Hazards, v. 25, p. 117-133.

Flint, C.G., and Luloff, A.E., 2005, Natural resource-based communities, risk, and disaster: An intersection of theories: Society & Natural Resources, v. 18, p. 399-412.

Goldammer, J.G., 2001, Africa region fire assessment, FRA Global Forest Fire Assessment 1990-2000. Forest Resources Assessment Programme. Working Paper 55: Rome, FAO, p. 30-37.

Goliger, A.M., and Retief, J.V., 2007, Severe wind phenomena in Southern Africa and the related damage: Journal of Wind Engineering and Industrial Aerodynamics, v. 95, p. 1065-1078.

Gregory, P.J., Ingram, J.S.I., and Brklacich, M., 2005, Climate change and food security: Philosophical Transactions of the Royal Society B-Biological Sciences, v. 360, p. 2139-2148.

Guffanti, M., Ewert, J.W., Gallina, G.M., Bluth, G.J.S., and Swanson, G.L., 2005, Volcanic-ash hazard to aviation during the 2003-2004 eruptive activity of Anatahan volcano, Commonwealth of the Northern Mariana Islands: Journal of Volcanology and Geothermal Research, v. 146, p. 241-255.

Hall, T.M., and Jewson, S., 2008, Comparison of local and basinwide methods for risk assessment of tropical cyclone landfall: Journal of Applied Meteorology and Climatology, v. 47, p. 361-367.

Harris, A., Rahman, S., Hossain, F., Yarborough, L., Bagtzoglou, A.C., and Easson, G., 2007, Satellite-based flood modeling using TRMM-based rainfall products: Sensors, v. 7, p. 3416-3427.

Hay, S.I., Noor, A.M., Nelson, A., and Tatem, A.J., 2005, The accuracy of human population maps for public health application: Tropical Medicine & International Health, v. 10, p. 1073-1086.

Hewitt, K., 1983, The idea of calamity in a technocratic age, *in* Hewitt, K., ed., Interpretations of Calamity: London, Unwin-Hyman, p. 3-32.

Hielkema, J.U., Popov, G.B., Williams, J.B., Saunders, R.W., and Milford, J.R., 1990, Satellite Environmental Monitoring for Migrant Pest Forecasting by FAO: The ARTEMIS System [and Discussion]: Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, v. 328, p. 705-717.

Hollenstein, K., 1997, Analyse, Bewertung und Management von Naturrisiken: Zurich, Switzerland, Hochschulverlag AG of the ETH Zürich, 191 p.

Intergovernmental Panel On Climate Change (IPCC), 2007, Climate Change 2007: the physical science basis, summary for policy-makers, contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: New York, Cambridge Press.

International Strategy for Disaster Reduction (ISDR), 2006, Disaster statistics 1991-2005, URL: http://www.unisdr.org/disaster-statistics/introduction.htm, accessed 19 August 2008.

Kelly, P.M., and Adger, W.N., 2000, Theory and practice in assessing vulnerability to climate change and facilitating adaptation: Climatic Change, v. 47, p. 325-352.

Kleinschmidt, I., Omumbo, J., Briet, O., van de Giesen, N., Sogoba, N., Mensah, N.K., Windmeijer, P., Moussa, M., and Teuscher, T., 2001, An empirical malaria distribution map for West Africa: Tropical Medicine & International Health, v. 6, p. 779-786.

Kuhn, K.G., Campbell-Lendrum, D.H., Armstrong, B., and Davies, C.R., 2003, Malaria in Britain: Past, present, and future: Proceedings of the National Academy of Sciences of the United States of America, v. 100, p. 9997-10001.

Leichenko, R., and O'Brien, K., 2002, The dynamics of rural vulnerability to global change: the case of Southern Africa: Mitigation and Adaptation Strategies for Global Change, v. 7, p. 1-18.

Macario, E., Benton, L.D., Yuen, J., Torres, M., Macias-Reynolds, V., Holsclaw, P., Nakahara, N., and Jones, M.C., 2007, Preparing public health nurses for pandemic influenza through distance learning: Public Health Nursing, v. 24, p. 66-72.

Marti, J., and Ernst, G. (eds), 2005, Volcanoes and the Environment, p. 488.

Maskrey, A., 1998, Module on community based disaster risk management: Bangkok, Thailand, Asian Disaster Preparedness Center.

Midzi, V., Hlatywayo, D.J., Chapola, L.S., Kebede, F., Atakan, K., Lombe, D.K., Turyomurugyendo, G., and Tugume, F.A., 1999, Seismic hazard assessment in Eastern and Southern Africa: Annali Di Geofisica, v. 42, p. 1067-1083.

Munda, G., Nijkamp, P., and Rietveld, P., 1994, Qualitative multicriteria evaluation for environmental management: Ecological Economics, v. 10, p. 97-112.

Myburgh, D.W., 1994, The response of farmers to the drought hazard in the Karoo environment: GeoJournal, v. 33, p. 401-410.

Naidoo, A., and Patric, K., 2002, Cholera: a continuous epidemic in Africa: Journal of the Royal Society for the Promotion of Health, v. 122, p. 89-94.

Papathoma-Kohle, M., Neuhauser, B., Ratzinger, K., Wenzel, H., and Dominey-Howes, D., 2007, Elements at risk as a framework for assessing the vulnerability of communities to landslides: Natural Hazards and Earth System Sciences, v. 7, p. 765-779.

Prata, A.J., and Kerkmann, J., 2007, Simultaneous retrieval of volcanic ash and SO2 using MSG-SEVIRI measurements: Geophysical Research Letters, v. 34.

Raaijmakers, R., Krywkow, J., and van der Veen, A., 2008, Flood risk perceptions and spatial multi-criteria analysis: an exploratory research for hazard mitigation: Natural Hazards, v. 46, p. 307-322.

Rashed, T., and Weeks, J., 2003, Assessing vulnerability to earthquake hazards through spatial multicriteria analysis of urban areas: International Journal of Geographical Information Science, v. 17, p. 547-576.

Roberts, G.J., and Wooster, M.J., 2008, Fire detection and fire characterization over Africa using Meteosat SEVIRI: IEEE Transactions on Geoscience and Remote Sensing, v. 46, p. 1200-1218.

Rothery, D.A., Coppola, D., and Saunders, C., 2005, Analysis of volcanic activity patterns using MODIS thermal alerts: Bulletin of volcanology, v. 67, p. 539-556.

Scott, K.M., Macías, J.L., Naranjo, J.A., Rodríguez, S., and McGeehin, J.P., 2001, Catastrophic debris flows transformed from landslides in volcanic terrains: mobility, hazard assessment, and mitigation strategies, Professional Paper 1630, U.S. Geological Survey, p. 71.

SEEN, 2001, SEEN Environmental Learning Information Sheet no. 8 - Velt Fires: Supporting Environmental Education in Namibia, www.nied.edu.na.

Shanks, G.D., Biomndo, K., Hay, S.I., and Snow, R.W., 2000, Changing patterns of clinical malaria since 1965 among a tea estate population located in the Kenyan highlands: Transactions of the Royal Society of Tropical Medicine and Hygiene, v. 94, p. 253-255.

Simpson, J.J., Hufford, G.L., Pieri, D., Servranckx, R., Berg, J.S., and Bauer, C., 2002, The February 2001 eruption of Mount Cleveland, Alaska: Case study of an aviation hazard: Weather and Forecasting, v. 17, p. 691-704.

Skobelev, S.F., Hanon, M., Klerkx, J., Govorova, N.N., Lukina, N.V., and Kazmin, V.G., 2004, Active faults in Africa: a review: Tectonophysics, v. 380, p. 131-137.

Smit, B., and Pilifosova, O., 2003, From adaptation to adaptive capacity and vulnerability reduction, *in* Huq, S., Smith, J., and Klein, R.T.J., eds., Enhancing the capacity of developing countries to adapt to climate change: London, Imperial College Press.

Smith, K., 2001, Environmental Hazards: London and New York, Routledge, 392 p.

Sweeting, M., and Chen, F., 1996, Network of low cost small satellites for monitoring & mitigation of natural disasters, Proceedings of the 47th International Astronautical Congress, Beijing, China, 7-11 October 1996,

Tabara, D., Sauri, D., and Cerdan, R., 2003, Forest fire risk management and public participation in changing socioenvironmental conditions: A case study in a Mediterranean region: Risk Analysis, v. 23, p. 249-260.

UN/ISDR, 2004, Living with Risk: A Global Review of Disaster Reduction Initiatives, UN/ISDR.

—, 2005, Hyogo Framework for Action 2005— 2015: building the resilience of nations and communities to disasters, p. 25, http://www.unisdr.org/eng/hfa/docs/Hyogo-framework-for-action-english.pdf.

Unganai, L.S., and Kogan, F.N., 1998, Drought monitoring and corn yield estimation in Southern Africa from AVHRR data: Remote Sensing of Environment, v. 63, p. 219-232.

UN-HABITAT, 2003, Slums of the world: the face of urban poverty in the new millennium?, p. 90.

van Westen, C.J., van Asch, T.W.J., and Soeters, R., 2006, Landslide hazard and risk zonation - why is it still so difficult?: Bulletin of Engineering Geology and the Environment, v. 65, p. 167-184.

Vannucci, G., Pondrelli, S., Argnani, A., Morelli, A., Gasperini, P., and Boschi, E., 2004, An atlas of Mediterranean seismicity: Annals of Geophysics, v. 47, p. 247-306.

Watts, M.J., and Bohle, H.G., 1993, The space of vulnerability - the causal structure of hunger and famine: Progress in Human Geography, v. 17, p. 43-67.

White, G.F., 1945, Human adjustment to floods: a geographical approach to the flood problem in the United States, Research Paper no. 29, Department of Geography, University of Chicago, p. 225.

Wiart, P.A.M., Oppenheimer, C., and Francis, P.W., 2000, Eruptive history of Dubbi volcano, northeast Afar (Eritrea), revealed by optical and SAR image interpretation: International Journal of Remote Sensing, v. 21, p. 911-936.

Wilde, G.J.S., 1994, Target Risk: Toronto, Canada, PDE Publications, 234 p.

Wisner, B., Blaikie, P., Cannon, T., and Davis, I., 2003, At Risk: Natural Hazards, People's Vulnerability and Disasters: London, Routledge, 464 p.

Wooster, M.J., and Roberts, G., 2004, Review of MTG FDHSI mission requirements regarding fire applications, King's College, Environmental Monitoring and Modelling Group, p. 22, http://www.eumetsat.int/en/area4/pps/ExpertMeetings/KCL-MTG%20final%20report.pdf.

Wright, R., Flynn, L.P., Garbeil, H., Harris, A.J.L., and Pilger, E., 2004, MODVOLC: near-real-time thermal monitoring of global volcanism: Journal of Volcanology and Geothermal Research, v. 135, p. 29-49.

Xiao, X.M., Gilbert, M., Slingenbergh, J., Lei, F., and Boles, S., 2007, Remote sensing, ecological variables, and wild bird migration related to outbreaks of highly pathogenic H5N1 avian influenza: Journal of Wildlife Diseases, v. 43, p. S40-S46.