The Value of Geoinformation for Disaster and Risk Management (VALID)

Benefit Analysis and Stakeholder Assessment

International Council
for Science - GeoUnions

Joint Board of Geospatial
Information Societies

United Nations Office
for Outer Space Affairs

International Council for Science - GeoUnions

Joint Board of Geospatial Information Societies

United Nations Office for Outer Space Affairs

The Value of Geoinformation for Disaster and Risk Management (VALID)

Benefit Analysis and Stakeholder Assessment

Editors: Orhan Altan, Robert Backhaus, Piero Boccardo, Fabio Giulio Tonolo, John Trinder, Niels van Manen, Sisi Zlatanova

Book design: Natalie Epler

Published by: Joint Board of Geospatial Information Societies (JB GIS)

Launched at the United Nations Office for Outer Space Affairs (OOSA), Vienna, Austria, on 3 September 2013.

This publication is the result of the collaboration of many scientists who are dedicated to the implementation of geospatial information for Disaster and Risk Management.

Joint Board of Geospatial Information Societies
c/o International Federation of Surveyors (FIG)
Kalvebod Brygge 31–33
DK-1780 Copenhagen / DENMARK

Tel. +45 38 86 10 81 / Fax +45 38 86 02 52
E-mail: FIG@FIG.net

www.fig.net/jbgis

Published in English in Copenhagen, Denmark, ISBN 978-87-90907-88-4

Credits to title photo: Aiguille de Tsa, Dent Blanche nappe, Swiss Alps, by Roland Oberhänsli

Preface by the United Nations Office for Outer Space Affairs

Space-based information can be a very useful resource in disaster management. Satellites provide reliable and rapid observation tools, supporting efforts in emergency response as well as in disaster-risk reduction. But the application of space technology to disaster risk management and emergency response is a wide and complex field. Knowledge and expertise are widely dispersed, and institutions and practitioners need orientation to access and use available data and services. In recognition of these needs the United Nations General Assembly has established the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) as a program of the United Nations Office for Outer Space Affairs (OOSA), with the mandate to "ensure that all countries and regional organizations have access to and develop the capacity to use all types of space-based information to support the full disaster management cycle" (resolution A/RES/61/110 of 14 December 2006). As one of many contributions to fulfill this mandate, OOSA has published, together with the Joint Board of Geospatial Information Societies (JB GIS), the booklet entitled "Geoinformation for Disaster and Risk Management – Examples and Best Practices" (Copenhagen 2010).

Meanwhile, increasing concern about damage and losses caused by disasters triggered by natural hazards has led to comprehensive studies exploring the economic dimension of disasters, highlighting the importance of efficient disaster risk management. In view of this development I highly appreciate the decision of the JB GIS and the UN-SPIDER team to carry out, in collaboration with scientists from the University of Amsterdam and with additional support from the ICSU Geo-Unions, a global interdisciplinary study addressing questions about the economic value and the operational and strategic benefits that can be realized by applying geoinformation in efforts in all phases of the disaster management cycle. The final report of the VALID study provides benefit assessment data as well as scientific background information on the respective geospatial products and services. It is partially based on a global stakeholder survey which was facilitated by the UN-SPIDER contact database, including the network of National Focal Points. Its results clearly show the emphasis given by the participating user community to the application of geoinformation, not just to support of emergency response but also to map and monitor risks, with beneficial effects such as reducing public losses and supporting risk reduction strategies.

The VALID project report provides orientation about the value and impact of disaster-related geoinformation, accentuating the challenging issue of preventive action. As the former Secretary General of the United Nations Kofi Annan stated in 1999: "Building a culture of prevention is not easy. While the costs of prevention have to be paid in the present, their benefits lie in a distant future."

I am convinced that the VALID project results are helpful in supporting programmatic as well as operational decisions and I am confident this final report will enjoy widespread distribution among communities with a role in disaster management all over the world and that concrete applications and actions will benefit from the principles and recommendations of this report.

Mazlan Othman,
Director of the United Nations Office for Outer Space Affairs

Preface by the Joint Board of Geospatial Information Societies and the International Council for Science - GeoUnions

The booklet, Geoinformation for Disaster and Risk Management - Examples and Best Practices, published on July 2nd 2010 by the Joint Board of Geospatial Information Societies (JB GIS) and the United Nations Office for Outer Space Affairs (OOSA), outlined the potential uses of Geoinformation technologies for reducing the impact of natural or manmade disasters and risks. It brought together concise scientific contributions from experts around the world and created a decision support forum based on their knowledge. The articles in the booklet covered natural events such as earthquakes, floods, volcano outbreaks, tsunamis, landslides, dust storms and wildfires, as well as societal issues such as health care, refugee camps, urban sprawl and traffic infrastructure security. Case related regional studies are complemented by presentations of global information systems. This publication aims to raise awareness amongst governments, disaster management professionals and other decision-makers, of the potential uses of Geoinformation technologies to reduce the impact of natural disasters and to assist in support of decision-making in all phases of disaster management, prevention and mitigation, as well as immediate response and recovery.

The second publication of this series, which is being published by the JB GIS, ICSU-GeoUnions (International Council for Science-GeoUnions) and OOSA outlines the potential financial benefit of Geoinformation technologies used to reduce the impact of natural or manmade disasters and risks. It contains examples and case studies of Geoinformation Technologies resulting from different stakeholder assessments.

We believe that this publication will contribute towards harmonious co-existence of human beings and nature by creating awareness of potential natural and man-made hazards and measures that can be taken to manage their impacts.

William Cartwright, Chair, JB GIS

Ron Abler, Chair, ICSU-GeoUnions

Georg Gartner, ICA

Chris Rizos, IUGG –IAG

CheeHai Teo, FIG

David Coleman, GSDI

Tony Milne, IEEE-GRSS

Vladimir Kolossov, IGU

Chen Jun, ISPRS

Roland Oberhänsli, IUGS

Phil Wilkinson, URSI

Orhan Altan, Coordinating Editor

Table of Contents

1. Introduction

Orhan Altan, Robert Backhaus, Piero Boccardo, Niels van Manen, Fabio Giulio Tonolo, John Trinder and Sisi Zlatanova

Major disasters cause massive disruption to societies and overburden national economic systems. Thousands of people are killed and tens of thousands more are displaced from their homes every year by natural disasters triggered by storms, floods, volcanic eruptions and earthquakes. Many thousands more lose their livelihoods and huge damage is caused to property. By windstorms, floods, earthquakes, tsunamis, debris flows and lahars, vital resources are destroyed, infrastructure is damaged, and transport and communication are jeopardized. Enduring periods of drought decrease crop yields, increase wildfire risks, and affect human health.

However, these effects could be minimized and considerable losses of life and property could be avoided through improved risk assessment, early warning, and disaster detection and monitoring. Risk assessment provides information about the combined effect of hazard and vulnerability, allowing improved risk reduction and mitigation. The outcome of early warning is information on the onset of potential disasters, which can improve preparedness in the affected area.

Earth observation can help to provide this information. Technologies for processing, storing, analysing and visualising geospatial data have advanced greatly in recent years enabling building national and global Spatial Data Infrastructures (SDI). These new developments can contribute to improving prediction and monitoring of hazards, risk reduction and emergency response.

However, these technologies are still not fully exploited for Disaster and Risk Management. The successful implementation of geospatial technologies requires a solid base of political support, laws and regulations, institutional responsibility, and trained people. Knowledge should be transferred from geoscience specialists and international bodies to professionals and decision makers working on Disaster and Risk Management with different technological backgrounds.

Many international organizations are tackling this issue, among them the Joint Board of Geospatial Information Societies (JB GIS), and the United Nations Office of Outer Space Affairs (OOSA) which is carrying out the United Nations Platform for Space-based information for Disaster Management and Emergency Response (UN-SPIDER).

To facilitate the process of getting familiar with geospatial technology, JB GIS and OOSA have embarked on a major initiative to demonstrate the potential of geospatial technologies for Disaster and Risk Management to decision takers in governmental and administrative bodies, to disaster management professionals and to other stakeholders.

As early as July 2009, JB GIS and UN-SPIDER jointly invited the global stakeholder community to contribute articles for a collection of case studies, application examples, and best practices. More than 70 responses were received and evaluated, and finally 16 were accepted for publication, due to their exemplary coverage of different regions of the world, types of disasters, and phases of the disaster management cycle.

The resulting booklet entitled: "Geoinformation for Disaster and Risk Management - Examples and Best Practices" was officially launched during the Centenary Celebrations of the International Society for Photogrammetry and Remote Sensing (ISPRS) in Vienna on 2 July 2010.

The booklet is available on-line at: http://www.isprs.org/news/announcements/ and http://www.un-spider.org/about/portfolio/publications/jbgis-unoosa-booklet. It convincingly demonstrates various aspects of geospatial technology and how they can be efficiently integrated into Disaster and Risk Management.

The "Best Practices Booklet", as it was termed unofficially, provides knowledge on "what can be done" – methods, systems, applications, experiences – to support disaster management with appropriate geoinformation. As a next logical step it seemed useful to ask "what is the impact and value of the geoinformation?"

Therefore, a follow-on publication on the evaluation of benefits was prepared, in the framework of an interdisciplinary project named VALID (The Value of Geoinformation for Disaster and Risk Management). This second publication in your hands, which was published by the JB GIS, the International Council for Science-GeoUnions (ICSU-GeoUnions), and OOSA, gives evidence of the economic, operational and strategic benefit which can be realized by applying geoinformation to disaster management.

A two-fold approach was followed in order to ensure a holistic as well as detailed view on the benefits of geoinformation for disaster management and the best possible coverage of the disaster management cycle. In an economic benefit analysis, detailed by a dedicated case study, the monetary aspects were addressed (Chapter 2). In parallel, the knowledge and practical experience of the global stakeholder community was explored by way of a web-based survey (Chapters 3 and 4), the results of which are presented together with information on the assessment of the scientific and technical aspects of the geoinformation products (Chapters 4.1 to 4.5), and on the costs aspects of geoinformation provision (Chapter 4.6). The overall results of the study are summarized and commented in Chapter 5.

The editors are convinced that this publication will shed more light on the specific value and impact of geoinformation when it comes to tackling the increasing challenges of natural and man-made disasters and risks.

2. How to determine the economic value of geoinformation in Disaster and Risk Management?

Niels van Manen, Henk Scholten, Tessa Belinfante and George Cho

Recent studies have highlighted the variety of ways in which geoinformation contributes to Disaster and Risk Management (DRM) practices. Geoinformation and associated technologies also play a central part in new methods for assessing costs and benefits of DRM and of disaster related damages and losses. Determining the economic value of geospatial information in DRM itself, however, remains an understudied topic.

2.1 The economic dimension of disasters and geoinformation

The economic impact of disasters of natural origin is profound and felt, to varying degrees, across the globe. Since 1970, total damages caused by all hazards combined accumulate to over $2,300 billion (in 2008 US dollars), equivalent to 0.23 percent of the cumulative world output. A gradual but clear upward trend can be observed, which is likely to continue into the future due to the impacts of climate change and population growth in areas exposed to natural hazards (The World Bank/ United Nations, 2010).

There is a widely held belief that geospatial information and associated technologies can play a vital role in reversing this trend. This belief is fueled by the increasing amounts of risk-related data available - covering hazard, exposure and vulnerability - and rapid technological developments. Digital maps and related services are powerful tools for scrutinizing and communicating the complexities of natural hazards. Better information can facilitate more effective decisions in disaster response, recovery and reduction practices. The 2007 National Research Council report Successful Response Starts with a Map, published in the wake of 9/11 and hurricane Katrina, made a powerful case for establishing in the USA a systematic geospatial information infrastructure to support disaster management. The joint World Bank/ United Nations report Natural Hazards, Unnecessary Disasters (2010) similarly advocated worldwide investments in early warning systems and other geoinformation services. Other studies highlight the number of services already being deployed to good effect at different stages of DRM (Altan et al., 2010).

In recent years, geospatial technology has indeed become an important component in responding to disasters of natural origin. In the United States, for example, many federal, state and country emergency operations centres are using a combination of remote sensing, global navigation satellite systems (GNSS) and geographic information systems (GIS) to determine the magnitude and impact of disasters of natural origin. Geospatial technologies have been used to allocate resources in both the response and recovery phases of the disaster management cycle, but the experiences have been mixed (Hodgson et al., 2010; 2013).

Furthermore, the successful deployment of geospatial services requires organizational measures and training, often at considerable cost, as the required data is spread across different institutions and the production of useable geoinformation requires expert skills. Therefore new geoinformation products have to compete with other DRM investments and even the continuation of successful existing services is by no means a given. For example, the German BIRD satellite mission was dedicated to wild fire detection and monitoring, but the program has been discontinued. At a time when public finances in most parts of the world are seri-

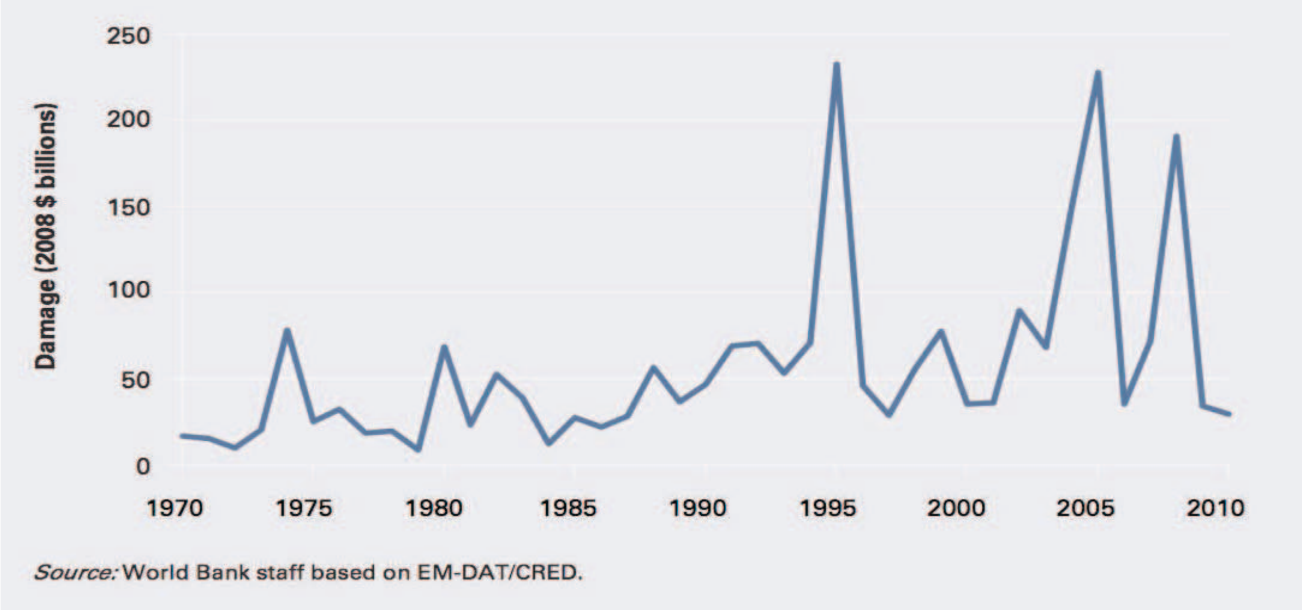


Figure 2.1: Damage on the rise in the last two decades (global damage from hazards, 1970-2010) (The World Bank/ United Nations, 2010)

ously strained, careful assessments must be made of the investment returns of each geoinformation service. Yet, unlike many other aspects of DRM, the economics of geospatial information services are largely unknown.

The Ordnance Survey Report (OS) (Ordnance Survey, 2013) on the value of OS OpenData™ to the economy of Great Britain used a computable general equilibrium (CGE) model to assess the economic value arising from the release of OS OpenData™. The particular CGE model used takes into account trade flows with other countries as well as resource shifts within Great Britain. The model was chosen to overcome problems with simple benefit/multiplier approaches such as allowing for changes in macro-economic aggregates resulting from changes elsewhere. The report acknowledges that CGE models are a recognised way of estimating economic value and has been used by the Bank of England.

However, the OS (2013) study is static snapshot of economic value and does not estimate dynamic impacts. Further, the data fed into a CGE model to estimate the impacts relied on data from interview sources. The model is driven by a series of assumptions and data extrapolations, is not an exact science and the results should be interpreted more qualitatively than quantitatively.

The ACIL Tasman (2008) study of the value of spatial technology to the Australian economy attempted to establish the aggregate economic impact of spatial technology in an economy. The CGE model was used to capture the geospatial industry footprint throughout the Australian economy in terms of its impact on GDP. This methodology offers an empirical model of the economy-wide impacts of geospatial technology focussing on 22 key sectors of the economy.

While the results obtained from the two CGE studies noted above are noteworthy, a drawback of the CGE framework is the huge data requirements necessary for the model to perform effectively. This may prove a heavy constraint in many countries that lack a data infrastructure.

The purpose of this chapter is therefore to evaluate what economic methods can assist in defining cost and benefit assessments that can be more universally applied. This should ultimately contribute to more rational decisions in DRM spending.

Economics of hazards of natural origin and disaster management

The economic valuation of geoinformation in DRM - here defined as cost and loss reduction due to better decisions facilitated by geoinformation - is part of a thriving field of study dealing with the economics of natural hazards and disaster management. Some of the frameworks developed in this wider field can be fruitfully applied to the economic assessment of geoinformation. Based on a systematic literature survey, four approaches have been identified:

- Evaluation of the direct and indirect losses caused by different hazard types in different parts of the world, with the aim to support decisions regarding which hazards to target and where (e.g. Benson and Clay, 2004; The World Bank/ United Nations, 2010; Munich Re NatCatSERVICE Database of losses from natural disasters, 2012);
- Evaluation of the economic costs and returns of risk management and mitigation measures, with the aim to optimize the choice of prevention measures under different circumstances (e.g. Munasinghe and Clarke, 1995; Federal Emergency Management Agency, 1997; Federal Emergency Agency, 1998; Smyth et al., 2002; Multihazard Mitigation Council, 2002; Mechler, 2003; Benson and Twigg, 2004; Vermeiren et al., 2004);
- Assessment of the financial arrangements of DRM activities, with the aim to optimize the regularity, efficiency, effectiveness and transparency of DRM spending (e.g. Comerio and Gordon, 1998; INTOSAI, 2013);
- Assessment of the costs and benefits of knowledge and information in aid of DRM activities, with the aim to prioritize spending on information services with the greatest return (e.g. Stewart, 1997; Williamson et al., 2001; National Oceanic and Atmospheric Administration et al., 2002; Williamson et al., 2003; Ebi et al., 2004).

Our study is closely related to the last of these, but the other approaches also provide valuable insights. The first promotes standardization of post-disaster damage and needs assessments. This helps the economic assessment of geoinformation, because uniform recording of damages (with identical categorization of economic sectors) makes it possible to conduct comparative assessments of the (potential) contribution of geoinformation services to damage reduction per sector. This is indeed an important prerequisite for extending the experimental method applied here to one case to other disaster incidents. The second approach also boosts the potential for economic evaluation of geoinformation, because most geoinformation services are related to a specific stage of DRM, sometimes a specific prevention activity. By scrutinizing the return of investment of different relief, recovery and mitigation practices, this body of works helps to prioritize geoinformation products that contribute to practices with the highest potential returns. This is indeed how, for this chapter, an early warning system was chosen for the Namibian flood case (see section 2.2). The third approach highlights that the financial arrangement and independent auditing of DRM activities have economic impacts, by strengthening or undermining trust in the local market before and after disaster incidents. Since the International Organization of Supreme Audit Institutions is actively promoting the use of geoinformation products in DRM audits (INTOSAI, 2013), this will be an important avenue for future research regarding the economics of geoinformation.

The fourth approach, most closely aligned to our own study, has thus far focused on the economic contributions of forecasting techniques in the context of weather related extreme events (hurricanes, floods, heat waves). These studies helpfully show that economic evaluation of geoinformation products should focus on how these are used in the context of DRM because their use influences the decisions that ultimately affect the economy. These same studies also highlight the challenges of applying a conventional cost and benefit analysis to a geoinformation service. While an intractable problem, at the cost side, it is often hard to determine which part of the costs should be allocated to DRM usage, since most services are also used for other purposes. At the benefit side, the estimated damage reduction or economic growth that would be gained were an effective geoinformation service available, is inevitably modeled on a fuzzy 'what – if' scenario.

Even if a monetary value could be obtained the measure is a relative one and cannot be used in a comparative analysis, as the cost and benefits of producing, deploying and maintaining geoinformation services vary greatly depending on where in the world it is done and at what scale and also between different services. Furthermore, even if CBA were to be applied in DRM activities the data needs can be described as 'data-hungry' – something which is either unavailable or in a poor state to be used for modelling required. Finally, as will be shown in the Namibia case, such modeling requires a simplification of the impact of the geoinformation product – "thanks to this product we would have x hours/ days extra available to conduct evacuation activities" – that is hard to back up with empirical evidence.

Bearing these challenges in mind, it is important to explore how we may tweak the conventional CBA with insights from other economic impact assessments. A number of starting points can be defined. Firstly, economic impact studies employ rigorous conceptual frameworks that evaluate both the direct financial impact as well as the economic externalities that are likely to occur. For example, The World Bank and the Millennium Challenge Corporation (Millennium Challenge Corporation, 2008) have used various models to evaluate potential investments in land administration projects.

Secondly, multilateral development organisations and development banks have combined quantitative *and* qualitative metrics in assessing potential land projects. Some common measures include the use of net present value (NPV) estimations, financial internal rate of return (FIRR), and economic rate of return (ERR). Of these, ERR appears most useful in that rates of returns can be determined and that both the expected positive and negative externalities associated with the project are considered. High ERR values suggest a project will have a substantial economic return. A 10 % ERR or more suggests a project may be worthy of investment.

Thirdly, choice of model is critical but there are no 'silver bullet' solutions as some models should be tailored to resolve particular issues and assessed on a case-by-case basis. Whitehead and Marbell (2013) focussed on the economic rate of return (ERR) calculations as a criterion for the assessment of the economic viability of projects.

The next sections will further examine how the conventional CBA may be revised to make it more suitable for geoinformation services for DRM. Before doing so, it is important to stress that there are downsides to a strictly economic assessment. Economic indicators do not equal human well-being. Therefore, cost-benefit analysis is one method for grasping the available options, but not a road map that dictates what should be done, especially as the impacts are likely to be felt very differently by different communities and individuals and therefore a political process of decision making, in part based on non-economic considerations, must take place (The World Bank/ United Nations, 2010). It is with this philosophy in mind, that the economic evaluation of geospatial information in DRM will be explored further.

Economics of geoinformation

Economic assessment of geoinformation can be conducted at two levels. Either the cost and return of geoinformation services for disaster management as a whole can be evaluated (The Boston Consultancy Group, 2012; Oxera, 2013), or the cost and return of specific services, for specific components of DRM can be assessed. The former can boost the willingness among public and private parties involved in DRM to invest in this kind of information. However, since this general willingness is already strong in the DRM sector, the focus here will be on evaluating specific geoinformation services. This can assist DRM organizations to decide more rationally on which service to invest in with the greatest chance of return. This chapter will deal with the (potential) benefits; more will be said on the costs in chapter 4.6. The focus will be on the economic advantages to DRM activities only; a comprehensive evaluation would require to also consider the economic activities stemming from the production and distribution of the geoinformation services themselves.

Technologies themselves do not result in a reduction in damages and losses; it is the better decisions, facilitated by their use, which can bring this about. The focus is therefore on the economic impact of better decisions facilitated by the use of geoinformation alternatives for current services (Fritz et al., 2008; Krek and Frank, 1999) (Fig. 2.2).

Figure 2.2: Flow chart of (geo)information impact (Fritz et al., 2008)

Studies that analyze the value of information fall broadly into four frameworks: (1) the econometric estimation of output or productivity gains due to information; (2) hedonic pricing studies, assuming the value of information is captured in the prices of goods or services; (3) contingent valuation surveys, which rely on the Willingness to Pay principle (Macauley, 2005); (4) cost avoidance studies, based on an estimation of efficiency gain or loss reduction. The potential of each method for assessing geospatial information in aid of DRM is briefly reviewed.

The first method is particularly useful for estimating the economic benefit of reduced uncertainty. For example, studies regarding the impact of weather forecasting (a geospatial technology) on agricultural output tend to adopt this productivity-gain assessment (Macauley, 2005). Typically in these studies, farm profits under average but uncertain weather patterns are compared with farm profits if rain could be accurately forecasted. A compilation of exemplary studies include the optimization of production levels according to projected temperatures or precipitation rates (Johnson and Holt, 1986). Other weather-related sectors such as energy (Roulston et al., 2003) and aviation safety (Macauley, 2005), can similarly optimize their output or productivity levels. Within the context of DRM, the method is suitable for geospatial technologies related to the forecasting of hydro-meteorological hazards, but not for the full spectrum of technologies and hazards. In the present explorative study that aims to define a comparative methodology suitable for different geoinformation services, the method of estimating economic benefit of reduced uncertainty will not be adopted.

The second framework, based on hedonic pricing analysis, is suited for evaluating whether knowledge about the hazard-proneness of an area affects the prices of land, goods and services. Hedonic pricing models attempt to identify price factors on the premise that price can be determined by the inherent character of the good being sold and the external factors that affect it. A common example is the housing market where the price of a property is determined by all the characteristics of the house including its features, location, age and build quality together with the characteristics of its relative location to schools, shops, transport links. Hedonic pricing models estimate the extent to which each of the factors identified affect the price. An advantage of this model is that it may be used to estimate the approximate values based on actual choices of people and the real estate market gives a good indication of values relative to property sales and other data. Comparative analysis could then be undertaken.

The major limitation to this technique is the fact that there often is no market value available for key assets because, either the nature of the attribute that is impacted by information makes it difficult to put a monetary figure on, for example a nature park, or the impact of information on pricing is difficult to trace back and therefore is difficult to capture. The amount of data required would also be very large. Often it is not feasible to ensure that everyone hvas prior knowledge of both the positive and negative externalities impinging on a particular attribute. The availability of data can affect the amount of time and expense needed to apply such a model. In the final analysis the interpretation of the results from the model can be complex and there is a need for sophisticated statistical knowledge and expertise in its use.

The third method, a contingent valuation survey, makes use of the concept Willingness to Pay (WTP). The amount people are willing to pay for a certain product or service is then translated to the value of this product or service. This is a survey-based technique that attempts to put a value on non-market resources such as the environment, water pollution and the impact of contamination. While there might be utility to be derived from these, some aspects of the environment do not have a market price as they are not sold directly. A scenic vista might not have a market price and contingency valuation techniques might be used to measure these aspects. The difficulty of obtaining accurate economic values through survey methods have been noted by a panel of highly regarded economists led by Nobel Prize laureate Kenneth Arrow and Robert Solow convened under the auspices of the National Oceanic and Atmospheric Administration (NOAA, 2001). The method is widely accepted as a real estate appraisal technique particularly in instances of contaminated sites requiring remediation (Mundy and McLean, 1998). The technique has also been used by many governments to evaluate the cost-benefits of projects impacting positively or negatively on the environment, for example, in Australia where it was used to place a value on the positive and negative impacts of projects within the Kakadu National Park (Carson et al., 1994). As estimates of the values for goods and services that are easily identified and understood by users, the results from these studies are not difficult to analyze and describe.

There are, however, some problems regarding the contingent valuation method as this method has the tendency to produce biased results (Klafft and Meissen, 2011). Such biases include those of a strategic nature where respondents answer questionnaires in order to influence a particular outcome, information bias, where respondents are forced to put a value to an attribute for which they might have little or no experience, and non-response bias where the non-respondents might indeed have different values to those who have responded. Problems encountered are that due to strategic reasons respondents may misrepresent their WTP. This may result in both overstated and understated answers to their WTP. Also, respondents may fail to consider their budget constraints in hypothetical settings, as described by Diamond and Hausman (1994). A common example is where respondents are unfamiliar in placing a dollar value on environmental goods and services. As such these respondents do not really have an adequate basis for stating their true value. In some cases the respondent might be expressing a feeling about the scenario or the valuation exercise itself. Willingness to pay for improved environmental visibility (through reduced pollution) could be interpreted as health risks that the respondent associated with polluted air and the health costs associated with this aspect.

In methodological terms it is important also to distinguish between the Willingness to Pay (WTP) in order to receive an environmental asset as against the Willingness to Accept (WTA) as a compensation for giving up an environmental asset. It could be that the different psychological and personality make-up of respondents may produce different results depending on the way the questions are phrased and asked.

The fourth method, the Cost Avoidance Approach, evaluates the damages and losses that could have been avoided had an information product been used other than the one currently implemented. The avoided damages are then interpreted as the benefits of this product. Other similar names for this approach include the damage cost avoided, replacement cost and substitute cost methods. This fourth approach attempts to estimate the values of ecosystem services based on either the cost of avoiding damages due to lost services, the cost of replacing ecosystem services, or the cost of providing alternative services. Examples of the application of this method include valuing water quality and purification, erosion and run-off, storm mitigation and fish habitats.

A limitation of this method is that it is based on 'what-if' estimation and thus relies on expert judgment of which losses could have been saved rather than an objective evaluation of actual loss-reductions. Implicitly this relies on knowing the actual cost of a loss and how much could be saved. There is also the inherent element of opportunity costs as there needs to be a correct measure of the maximum amount of money or other goods and benefits that a person is willing to forego to have a particular good and service less the actual cost of the good itself. Such a model will work well in cases where the actual damage avoided or the replacement expenditure have already been incurred and the monetary value has already been assessed and obtained. While expenditures to repair damages or to replace services can validly be measurable, costs are not really an accurate estimate of benefits.

An advantage of the Cost Avoidance Approach is its suitability to comparative analysis because (1) the loss-saving impact is something that is relevant to all geospatial technologies and (2) the increasingly standardized methods for damage and loss assessment make it suitable for similarly structured damage reports for different disaster incidents in different parts of the world. The data may provide a rough indicator of economic value given data limitations and the substitutability of similar and related goods. The approaches are less data intensive and are better suited to valuation methods that estimate the Willingness to Pay discussed previously. The results of the study would provide surrogate measures of value that are consistent with concepts of value among peoples and hence a valuable comparative tool under different circumstances.

Given the comparative aims of this report, the Cost Avoidance method will be further developed and deployed in this chapter. To do so, a cost-avoidance analysis will be designed, implemented and evaluated for a specific geospatial information product (an early warning system) in aid of a specific natural disaster (flash floods in Namibia).

2.2 Cost avoidance potential of Early Warning System: A case study on flood in Namibia

Preparedness for disasters caused by hazards of natural origin is a key factor in reducing their negative impacts (Alfieri et al., 2012). The importance of increasing preparedness of society is a major conclusion of the extensive publication Natural Hazards, Unnatural Disasters (The World Bank/ United Nations, 2010). The report identifies early warning systems as one of three key investments desirable for risk reduction (alongside critical infrastructure and environmental buffers). Early warning systems have been furthermore confirmed as an attractive prevention option, because sample studies show that the benefits can significantly exceed the costs of development and maintenance (Rogers and Tsirkunov, 2011; Teisberg and Weiher, 2009). Especially for hydro-meteorological hazards, which can be detected with a sufficient lead time for adequate action, early warning systems can save lives and property in the case of disaster, while providing additional benefits at other times by optimizing economic production in weather sensitive sectors (Hallegatte, 2012). Note however, that care must be taken to not overestimate the impact of an early warning system, as not all property is suitable for protection and/ or removal.

Case selection

The Namibia flooding event in 2009 has been selected as our study case for the following reasons:

- Namibia's geographical location makes the country vulnerable to recurrent hydro-meteorological hazards, including floods.
- Among the sub-Saharan African countries, Namibia is also considered one of the most vulnerable to future climate change (PDNA, 2009). Projections show greater anomalies in rainfall, which increases chances for high intensity rainfalls and subsequent flooding. Optimizing the (future) use of geoinformation would therefore be highly valuable.
- Moreover, there is a high potential for the development of an early warning system due to the nature of (part of) the flooding events, as the headwaters of the main rivers originate far upstream, thereby creating the potential for a high lead time in case of adequate warning.
- There is also potential for developing other geoinformation services, especially satellite based ones, as the

2009 flood covered a large area and the timing and dynamic behaviour was variable among regions (PDNA, 2009) (Figure 2.3). This makes it a suitable case for future comparative research on geoinformation products other than early warning systems. Practical reasons also informed the choice for this use case.

- There is already a history of contact between UN-SPIDER and the Namibia Hydrology Department, which was vital for obtaining context information and for effective distribution of the questionnaire.
- Furthermore, the Post Disaster Needs Assessment (PDNA) for the 2009 flood includes a detailed description of damages and losses as well as medium- and long-term recovery and mitigation strategies. This is vital for evaluating, with the aid of questionnaires, how much of the negative economic effects could have been prevented had an effective early warning system been in place. Since the PDNA was prepared with the aid of the World Bank, the UN and the European Commission, its structure (particularly the categorization of affected economic sectors) follows international standards, making this case study a suitable starting point for future comparative research.

Questionnaire design and dissemination

The questionnaire comprises two parts (see Annex I):

- a quantitative part, attempting to determine the damages and losses that could have been avoided, had an effective early warning system been in place, providing a warning with sufficient lead-time to take protective action;
- and a qualitative part, dealing with the causes of ineffective response to the warning in 2009, improvements implemented since the disaster, and desirable future developments.

The second part was primarily designed to generate helpful suggestions to the authorities in Namibia regarding how to optimize the early warning system in use, thereby returning a favour to the respondents for their participation in the survey. Yet, as this chapter is principally concerned with the Cost Avoidance methodology, the focus is here on the first part of the questionnaire.

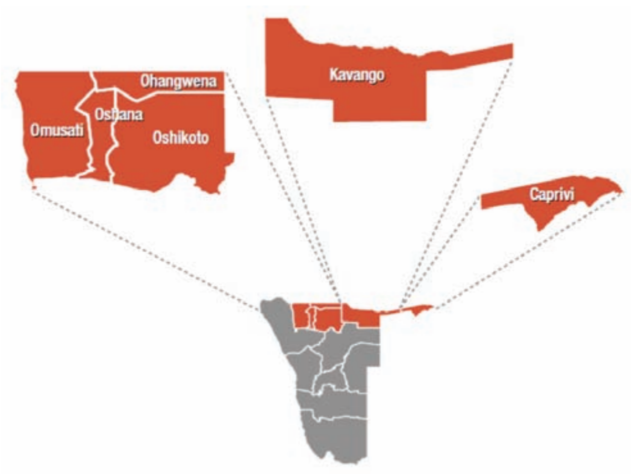
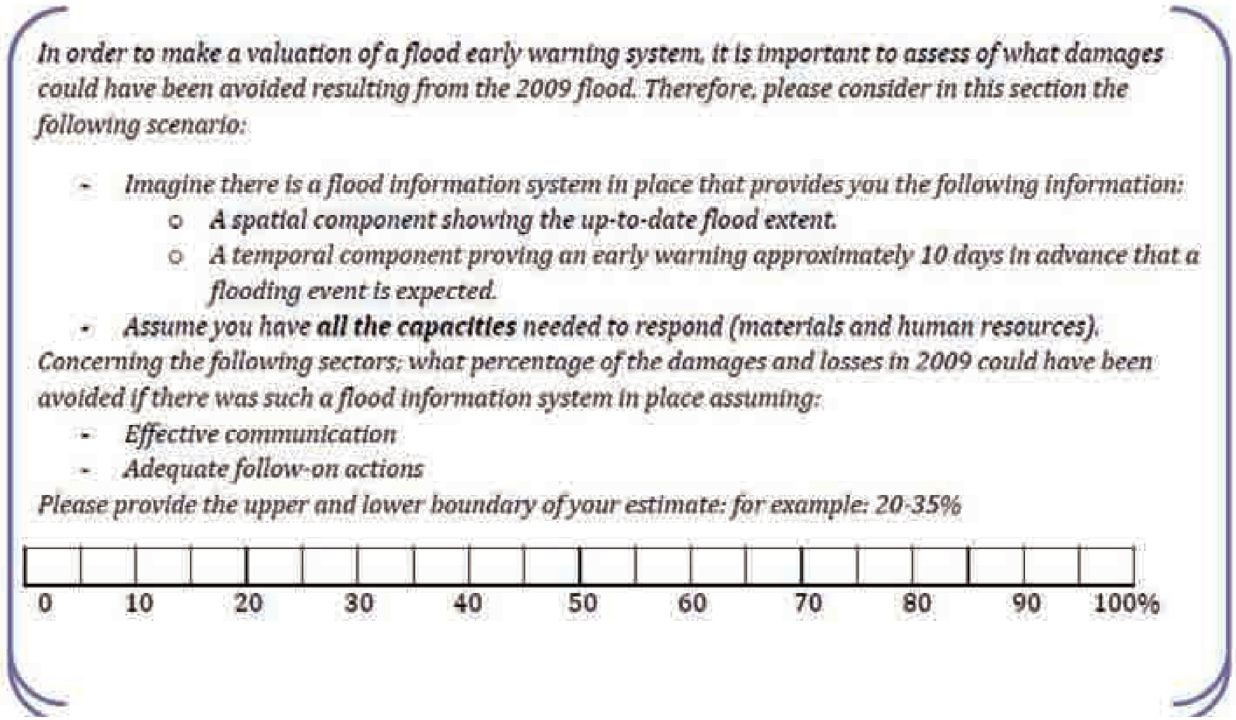


Figure 2.3: Areas impacted by Namibian flood 2009 (PDNA, 2009)


In order to make a valuation of a flood early warning system, it is important to assess of what damages could have been avoided resulting from the 2009 flood. Therefore, please consider in this section the following scenario:

- *Imagine there is a flood information system in place that provides you the following information:*
  - *A spatial component showing the up-to-date flood extent.*
  - *A temporal component proving an early warning approximately 10 days in advance that a flooding event is expected.*
- *Assume you have **all the capacities** needed to respond (materials and human resources).*

Concerning the following sectors; what percentage of the damages and losses in 2009 could have been avoided if there was such a flood information system in place assuming:

- *Effective communication*
- *Adequate follow-on actions*

Please provide the upper and lower boundary of your estimate: for example: 20-35%

0 10 20 30 40 50 60 70 80 90 100%

Figure 2.4: Reference scenario of the case study questionnaire

As an early warning system supported by geospatial information can facilitate earlier actions, it has the potential to reduce damages and losses. Vital input needed for such a cost-reduction analysis are the damage and losses figures resulting from the flood, available in the Post Disaster Needs Assessment (PDNA, 2009). The assessment is divided into four different sectors: infrastructure; productive; social; cross-sectoral. Based on a literature review, it was found that in Namibia it is possible to forecast flooding events resulting from high intensity rainfall events on average, approximately 10 days in advance (De Groeve, 2010). This is only the case when rainfall takes place in the upper basin, not in the case of flash floods in flood plains. Because cost-benefit estimations are known to have a relatively low accuracy level (Klafft and Meissen, 2011), an order-of-magnitude answer structure was used. The participants were asked to indicate on a scale ranging from 0-100 %, what damages and losses could have been avoided, per economic sector, had there been an effective warning 10 days prior to the flood (Figure 2.4). Some assumptions had to be made, including the availability of the means to act. Furthermore, participants were asked what percentage of lives could have been saved, had there been an effective early warning.

Subsequently, the percentages indicated by the respondents were coupled to the damage and losses figures (Figure 2.5), to obtain a monetary indication of the cost and loss reduction potential of an effective warning system.

In the end, these figures should be modified regarding currency standard, the occurrence time of such a severe flooding event, and the costs involved in developing and operating the proposed system, in order to estimate the added value of geo-spatial information. This is however is beyond the scope of this chapter and the focus is on identifying the benefits.

Sector/ Sub-sector	Damage (N$ million)	Losses (N$ million)	Damage (US$ million)	Losses (US$ million)
Infrastructure	**279.7**	**32.2**	**34.3**	**4.9**
Water Supply Sanitation	47.9	28	5.9	3.4
Transport	223.2	2.9	27.4	0.4
Energy	8.6	1.3	1.1	0.2
Productive	**405.1**	**584.4**	**49.7**	**71.7**
Agriculture	38.6	120.9	4.7	14.8
Industry	143.5	162	17.6	19.9
Commerce	209.7	289.7	25.7	35.5
Tourism	13.3	11.8	1.6	1.4
Social	**416.5**	**19.5**	**51.1**	**2.4**
Housing	385.7	13.8	47.3	1.7
Health	0.7	5.7	0.1	0.7
Education	30.1	0	3.7	0.0
Cross-sectoral	**10**	**0.9**	**1.2**	**0.1**
Environment	10	0.9	1.2	0.1
Total	**1,111.30**	**637.1**	**136.4**	**78.2**

Figure 2.5: Summary of damages and losses (PDNA, 2009)

The questionnaire was tested beforehand and the participants were assured that their answers would be treated confidentially and that they would receive a summary of findings. The questionnaire was sent to members of the scientific community related to the Namibian Early Flood Warning SensorWeb project and to the Head of the Namibian Hydrology Department, Guido van Langenhove. Mr. van Langenhove in turn distributed the questionnaire within his department and externally to members of the flood bulletin, which provides regular updates on river levels to local communities (Figures 2.6 and 2.7).

The respondent rate was unfortunately too low for statistical analysis. Nevertheless, the 14 questionnaires that were returned provide important insights regarding the feasibility of this Cost Avoidance Approach and the steps to be taken for further development of this method.

Questionnaire results and discussion

Of the 14 respondents, 8 completed the economic valuation part. Averages and average spans were calculated for each of the four economic sectors (infrastructure; productive; social; cross-sectoral) and for lives lost (Figure 2.8). Note that the number of respondents is small and that outliers are present in a small number of responses.

In total, 102 persons lost their lives due to the flood (PDNA, 2009). The percentage that could have been saved, had an effective early warning system been in place, was estimated to be 56.88 %, with an average range of 33 %. This was the largest range among the different categories. The cross-sectoral category, covering the environment, was estimated at 54.83 %, with an average range of 16.67 %. The social sector has most to gain from an effective early warning system, namely 58.44 %, with an average range of 25 %.

The avoidable damages and losses for the productive sector were estimated at 41.25 %, with an average range of 18 %. The sector infrastructure was estimated to have the lowest potential gains, namely 34.69 %, with an average range of 33 %. Summarizing, the respondents indicate that the social sector would gain the most from an effective early warning system, closely followed by the number of human lives lost. The range provided by participants was largest in the category of the number of lives lost, indicating there is much uncertainty about the potential benefits of an early warning.

The average percentage numbers were subsequently coupled to the monetary damage and losses figures (Figure 2.9), where the currency is from the year 2009. The largest sum that could have been saved, according this approach is in the productive sector (US$ 50.08 million), followed by the social sector (US$ 31.27 million). Damages and losses that could have been avoided in the infrastructure sector are estimated to be US$ 13.60 million. The cross-sectoral savings are said to be at US$ 0.60 million. In total the four sectors add up to a sum of US$ 95.54 million. The number of lives has not been calculated in terms of an economic figure.

Two main problems were encountered when evaluating the questionnaire results: (1) a relatively low response rate and (2) participants indicating they experienced difficulties answering the Cost Avoidance questions. Regarding the low response rate, reasons could be the long distances and thereby the digital distribution of the questionnaires by e-mail. In retrospect, the distribution could not have been done differently. There were no resources available to perform the research in situ, which would have been the most preferable option. Especially because another major flooding event occurred in 2011, that exceeded the impact of the flood in 2009 in terms of deaths, number of affected people and economic damage costs (EM-DAT, 2012), the 2009 flood may have been of less significance in the respondents' minds.

Regarding the second problem of participants experiencing difficulty in answering the Cost Avoidance Approach questions, reasons provided were that participants did not find themselves to be qualified or informed enough to make financial estimations. In addition, the scenario of a ten days advance warning is only a realistic assumption in the case when flooding occurs due to high intensity rainfall events far upstream, as was the case in 2009. Flash floods are not accounted for by this methodology.

The ten days advance notice scenario may be further discussed. In hindsight, this warning time could have been reduced. This would both have lowered the skepticism of the participants towards the representativeness of the scenario as well as increase the reliability of the warning using more up to date data, and lowering the possibility of false alarms which may lead to lower response to future early warnings. In addition, there is a maximum in the amount of damage that can be prevented. This has been shown by Day (1970),

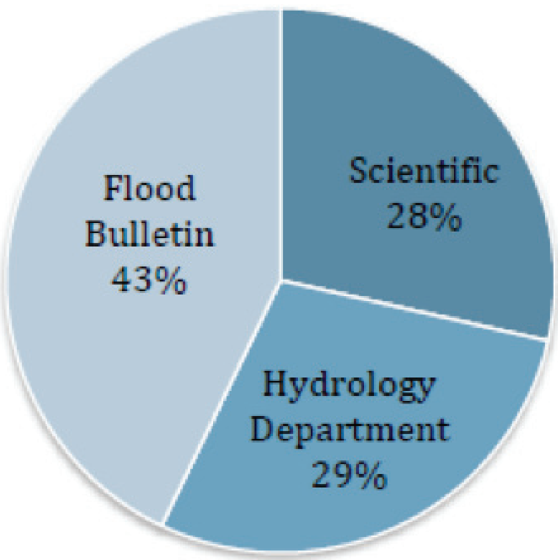


Figure 2.6: Background of respondents

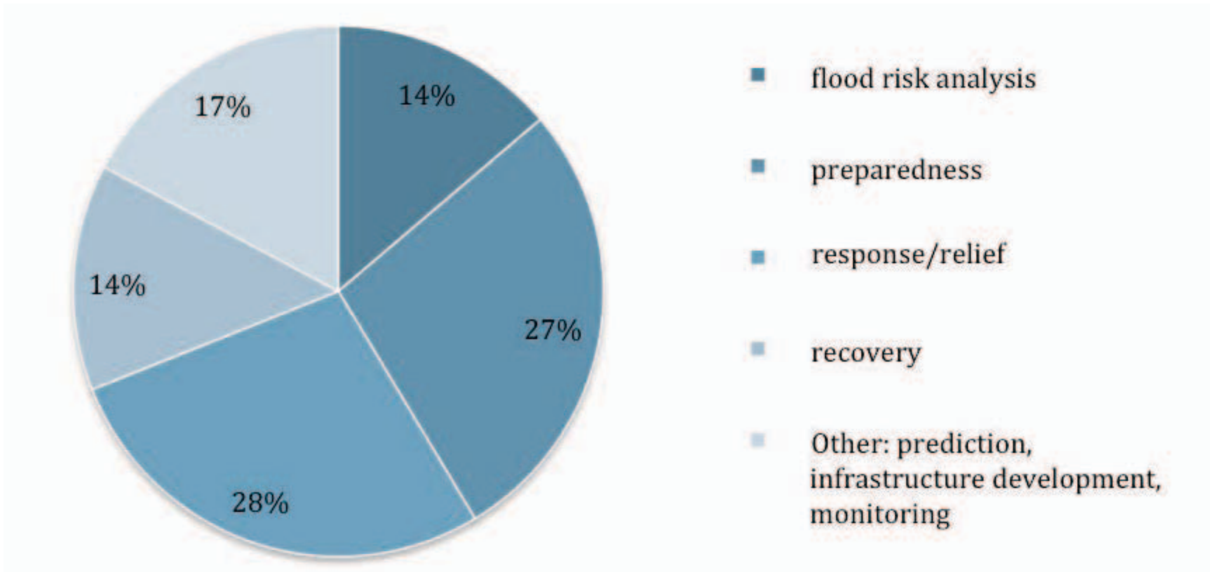


Figure 2.7: Flood related activities of respondents

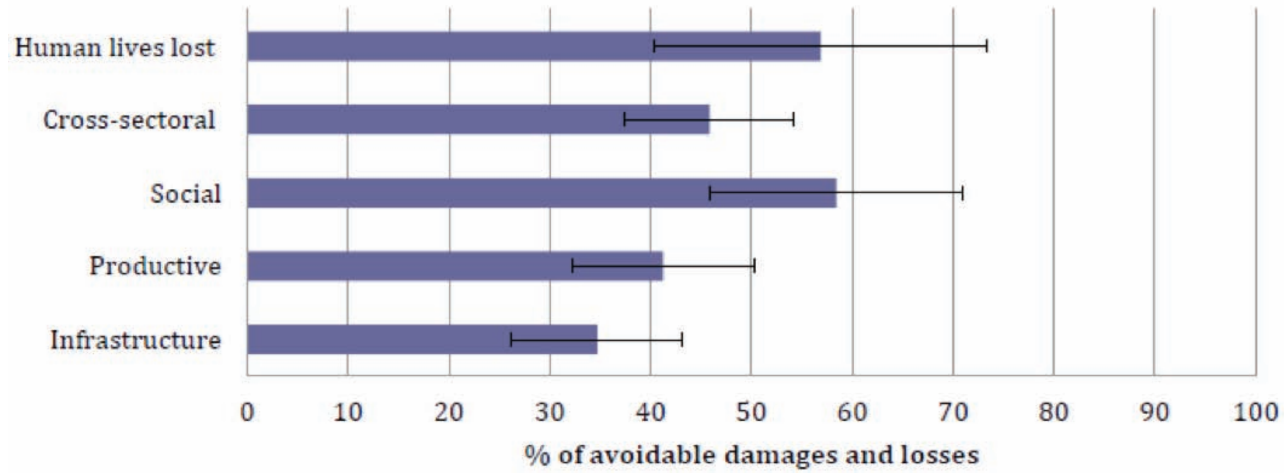
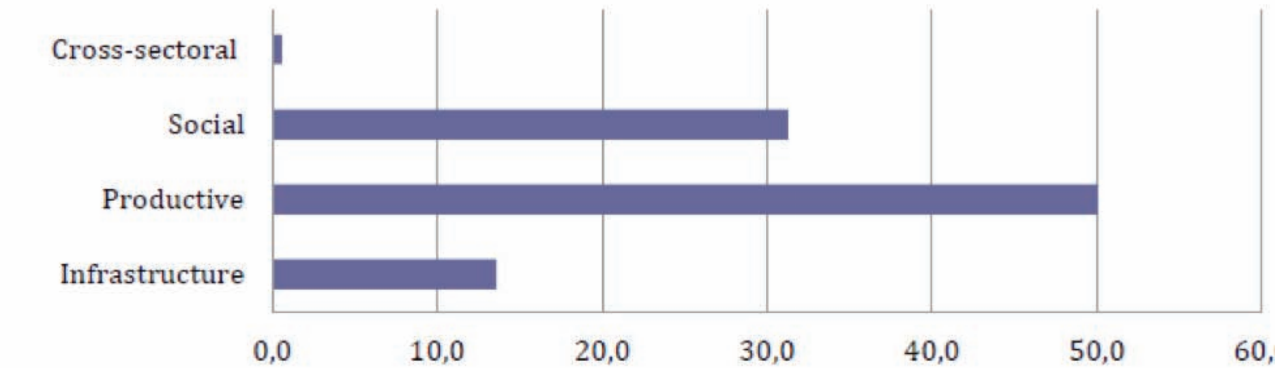


Figure 2.8: Avoidable damage and losses per economic sector (blue bars indicate the average; black lines indicate the average range).



	Infrastructure	Productive	Social	Cross-sectoral
2009 $US Million	13,6	50,1	31,3	0,6

Figure 2.9: Avoidable damage and losses in 2009 US$ million

who described what is now known as the Day curve for flood damages. Note that this only refers to the tangible benefits of the warning system. The Day curve suggests that there is a maximum possible reduction of losses of 35 %, no matter how great the warning time (Carsell et al., 2004).

The trend of the curve towards a maximum is furthermore confirmed by Penning-Rowsell et al. (2003) showing the same trend for different inundations depths (Figure 2.10). Based on these studies it seems advisable to include in the questionnaire a maximum to the percentage that can be saved, in order to eliminate outliers above the percentage that is actually found to be feasible. This maximum amount should however be determined according to local conditions and this study does not recommend a static value of this maximum percentage.

By comparison, a study in the U.S. emphasises that time is of the essence following a disaster. The Hodgson et al. study (2010; 2013) found that in the U.S. more than 50 % of the counties and states expected that satellite imagery and other geospatial information of damage to critical infrastructure must be obtained within three days of the event.

Furthermore, the Cost Avoidance Approach proposed only includes tangible damages and losses, not the intangible ones such as stress, family destruction or health effects on survivors (Carsell et al., 2004). Translating these intangible effects to an economic value and adding them to the tangible damage and losses would likely further increase the value of the EWS considered.

Following the low response encountered during the execution of the questionnaire one may argue that the monetary findings of the value of the EWS based on this Cost Avoidance Approach are not scientifically grounded. Due to this low number of respondents, the results are sensitive to outliers which could distort the true average values. The larger the number of responses, the more stable and significant the answers become. Therefore, this study does not claim to have found a 'final' or 'concluding' monetary figure of the value of geospatial information. Instead, this study aims to provide insight into the proposed methodology and indicates the steps that need to be taken to apply this approach to other case studies.

Another important aspect that influences the outcome of this final figure is the value in economic terms of a life saved. Estimate ranges are large and the number chosen is likely to have a great impact, or even determinative effect, upon the final monetary value of the geospatial product evaluated. This study chooses not to adopt one particular value, but illustrates how large the range of estimates is, showing that the inclusion of this 'value of life' would affect the outcome greatly.

Finally, the major attraction of the Cost Avoidance Approach applied here is its relative ease of use. Only the damage and losses figures and a group of informed participants are required. The downside, however, remains that the results are still estimates that are based on an expert feeling rather than a calculation of facts. Future research on this approach should therefore aim at making the monetary figure on the benefits more precise and based on empirical evidence. Obtaining statistical significance would be the first step towards that goal. The Willingness to Pay approach, which is the other main valuation method for Early Warning Systems, deals with the same difficulties regarding the errors in estimations. Nevertheless, with the Cost Avoidance Approach it is possible to provide a percentage, instead of an exact monetary figure. Therefore, the participants potentially experience less stress as they only have to provide an order of magnitude instead of an exact monetary figure, which is even more difficult to assess. Furthermore, this Cost Avoidance Approach offers a great opportunity for relative comparison between the benefits of several different geoinformation products. When there is a certain amount of money available and a decision maker wants to invest in the geoinformation with highest benefits for DRM, then this Cost Avoidance Approach can be applied to compare the benefits of different geoinformation products for the same case study. The geoinformation product that has the highest benefits can then be prioritized. In this case, the benefits of a certain geoinformation product have a relative meaning instead of representing the absolute final economic figure on the benefits.

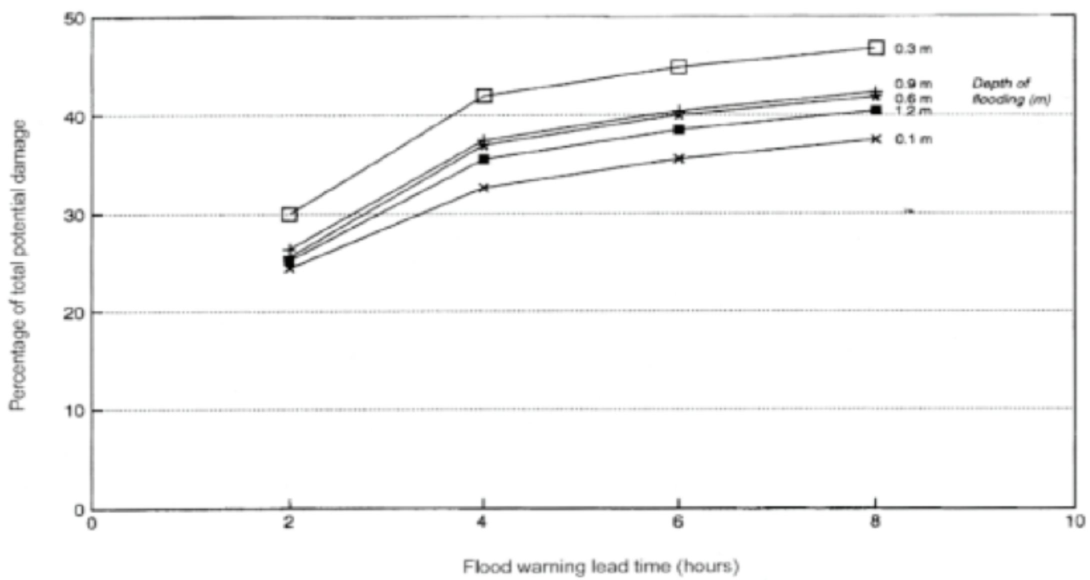


Figure 2.10: Impact of flood warning lead time on flood damage (Penning-Roswell et al, 2003)

3. What are the most important geoinformation products and systems in Disaster and Risk Management?

A global stakeholder assessment

Robert Backhaus, Natalie Epler and Ana Martinez Molina

Assessment by expert stakeholders is an indispensable approach when it comes to valuating the benefits of geospatial information, taking into account the full range of products and services applicable to all the different types of hazard, and all phases of disaster management, including prevention and risk reduction. Given this widespread application potential, and the likely workload of any experts in this field, an approach to collecting expert knowledge from the global community has to be designed in a pragmatic way in order to keep the participants' effort within reasonable limits.

Thus, in a first step a web-based ranking poll was carried out on the UN-SPIDER Knowledge Portal in order to identify a top-ten shortlist of geoinformation products and systems for a more differentiated appraisal to follow (see Chapter 4).

Web-based poll

All stakeholders, i.e. end-users, providers or value adders of geoinformation, were given the opportunity to identify up to 10 geodata products or systems on a longlist containing 51 items, such as hazard-specific risk maps, vulnerability maps, damage assessment maps, and monitoring systems, which they regarded as most important to support Disaster and Risk Management (Table 3.1). Beyond the sheer product names in the list, no further technical specifications were given at this stage.

Hazard Type	Products/Systems
Volcano	• Volcanic Activity Monitoring • Volcanic Topography • Thermal Anomalies Detection for Monitoring Global Volcanism • Sulfur Dioxide Detection • Vegetation Damage Assessment
Severe Storm	• Damage Profile • Detection and Forecast • Forest Damage Assessment Map • Infrastructure Damage Assessment Map • Recovery Progress Map
Pollution	• Dust Storm Monitoring • Oil Spill Detection • Oil Spill Risk Map • Open Water Pollution Map • Nuclear Radiation Map
Mass Movement	• Landslide Hazard Assessment • Landslide Monitoring • Damage Assessment Map
Insects	• Locust Habitat Map • Forest and Crop Change Monitoring
Temperature	• Extreme Heat Risk Map, • Cold Wave Map
Epidemic	• Infectious Diseases Risk Map • Infectious Diseases Spread Map • Epidemic Tracking System

Hazard Type	Products/Systems
Flood	• Inundation Map • Damage Assessment Map • Risk Map • Flood Risk Monitoring System • Recovery Process Map
Drought	• Drought Index Map • Drought Index Map for Soil Moisture Monitoring • Drought Index Map for Vegetation Monitoring • Risk Map • Vulnerability Map
Earthquake	• 3D Damage Visualisation and Animation • Urban Classification for Risk Analysis • Damage Assessment Map • Reconstruction Monitoring
Tsunami	• Damage Assessment Map • Risk Map • Landuse Change • Vulnerability Map • Inundation Map • Hazard Map • Reconstruction Monitoring • Early Warning System
Fire	• Risk Map • Burned Area Detection • Detection and Monitoring • Forest Change Monitoring

Table 3.1: Longlist of applicable geoinformation products and systems

Figure 3.1: Geographic distribution of poll responders

The longlist items were not defined by completing a generic scheme of hazard types and disaster management cycle phases, but were selected by the VALID editors group, based on a review of recent literature, including the content collected in Altan et al. (2010) and in the Space Application Matrix on the UN-SPIDER Knowledge Portal (http://www.un-spider.org/space-application-matrix).

The poll was opened for 1 month during the annual Gi4DM – Geo-information for Disaster Management – conference in Antalya, Turkey, and announced at a special side event on 4 May 2011. In addition, the call for participation was also disseminated via E-mail distribution by several international organizations, such as the United Nations Geographical Information Working Group (UNGIWG), UN-SPIDER, and the Open Geospatial Consortium (OGC).

Poll results

222 participants responded to the call in full detail, 213 of which were attributable to countries or territories, the remaining 9 to regional or global organizations. Figure 3.1 shows the geographic distribution of responders, respectively.

Representation of the different roles in the field of geospatial information was fairly balanced, headed by the group of end-users (39 %), followed by value adders (35 %) and data providers (26 %).

In terms of hazard types addressed, the evaluators' professional role had no major effect on the outcome (Figure 3.2).

In total, on the level of hazard types, Flood scored highest (17 %), followed by Tsunami (13 %), Drought (12 %), Fire (11 %), and Earthquake (11.5 %), with the other disaster types polling below 10 % (Figure 3.3). This clearly indicates that the major concern of the stakeholder community is about hydrometeorological hazards (including Fire) and Earthquake (including Tsunami).

Scaling down from hazard types to specific hazard-related geoinformation items gives a more differentiated picture (Figure 3.4), resulting in Mass Movement hazard (Landslide) also scoring among the Top-10, and Tsunami scoring lower. This differentiation is clearly due to the focus or spread of stakeholders' concern with regard to different specific products or systems addressing the same hazard type, respectively. From the polling, a reference set of geo-

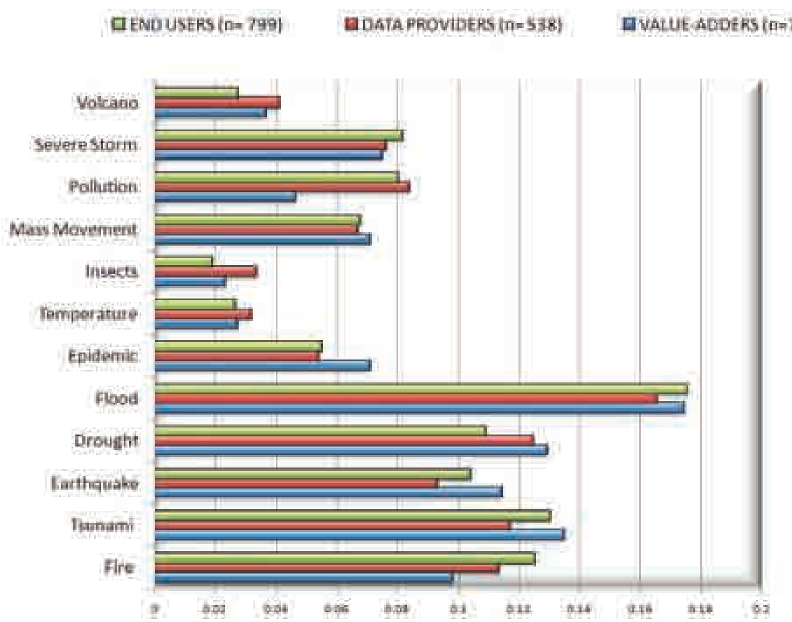


Figure 3.2: Relative distribution of poll results by participants' occupation and hazard type addressed

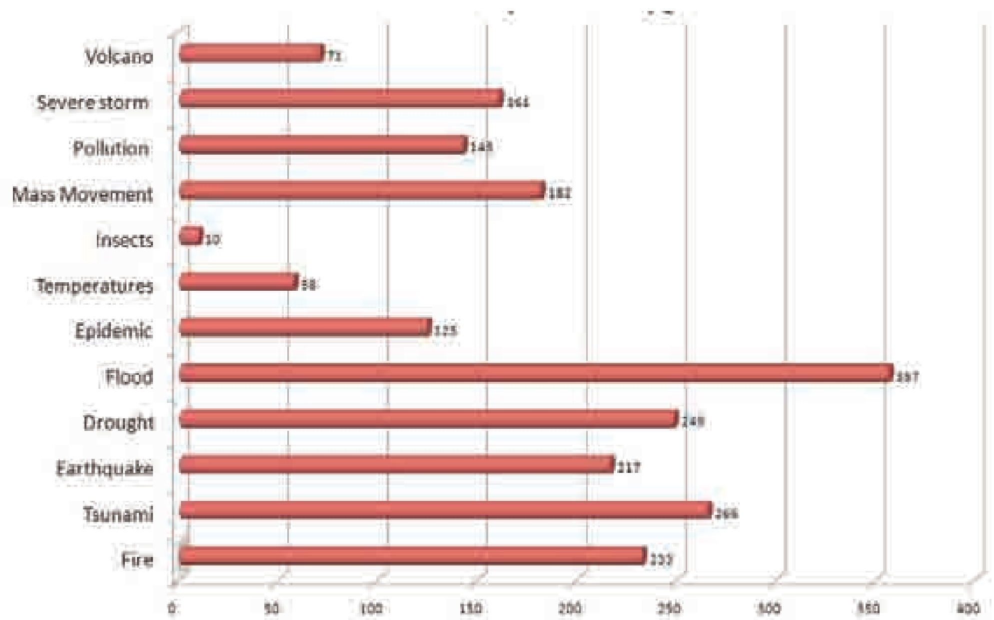


Figure 3.3: Total poll results in counts per type of hazard

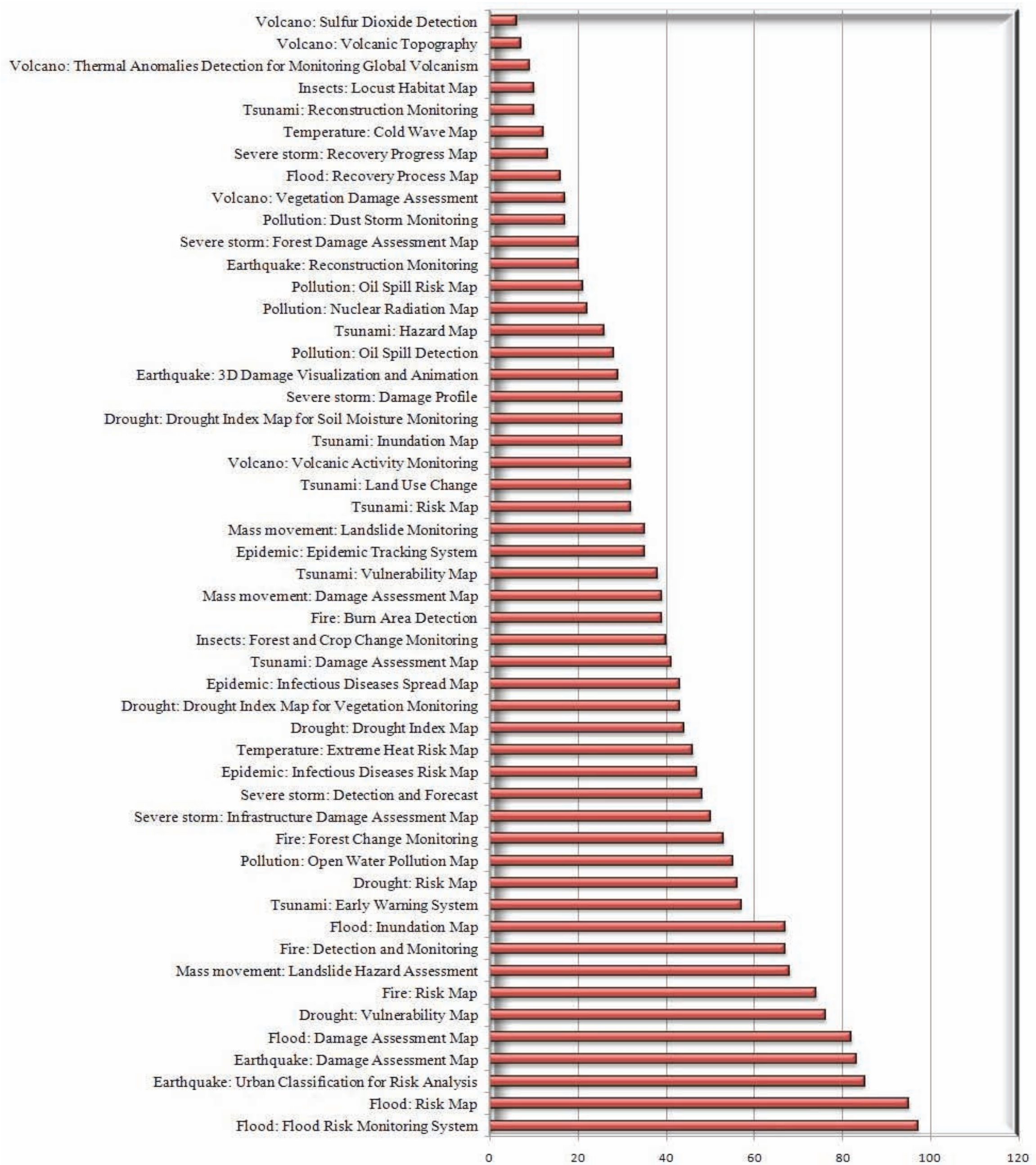


Figure 3.4: Total poll results in counts per geoinformation item

information products and systems was identified for a more detailed survey (Table 3.2). This table highlights the global community's concern about flood, earthquake, drought, fire, and landslide hazards, as well as the importance of risk analysis and monitoring.

Disaster Type	Product/System	Counts
Flood	Flood Risk Monitoring System	97
	Flood Risk Map	95
	Damage Assessment Map	82
	Inundation Map	67
Earthquake	Urban Classification for Risk Analysis	85
	Damage Assessment Map	83
Drought	Vulnerability Map	76
Fire	Risk Map	74
	Detection and Monitoring	67
Landslide	Landslide Hazard Assessment	68

Table 3.2: Top 10 reference set of geoinformation items

4. What are the operational and strategic benefits of geoinformation in disaster and risk management?

An appraisal from the end-users' and non-end-users' point of view

Robert Backhaus, Jula Heide and Anne Knauer

Following the definition of a reference set of geoinformation items (see Chapter 3, Table 3.2), these items were to be appraised as to their likely beneficial impact on specific operational as well as strategic issues in Disaster and Risk Management, combined with an assessment of the criticality of their technical quality for ensuring the respective benefits. In order to approximate the logic of a classical Cost-Benefit-Analysis approach as far as possible, cost aspects should also be addressed (see Chapter 4.6). This approach, based on an appraisal of reference information products through expert stakeholders, has been demonstrated before in the framework of a national study on behalf of the German Federal Ministry for Environment and Nuclear Safety (Backhaus and Beule, 2005).

As a first step, the reference items had to be characterized in more technical detail. The resulting technical feature profiles should be distributed to a global group of potential or actual users (practitioners as well as planners and decision-makers, affiliated to public disaster management bodies, international organizations and NGOs), together with a template for product appraisal. This template should specify a list of criteria related to various aspects of benefit. Based on a normalized rating schedule, the experts were to evaluate the reference items according to the beneficial impact which they would attribute to their application. Likewise, the technical features of each item were to be assessed as to their criticality for the benefit evaluation.

Technical description of reference products

A very detailed and differentiated technical description of each item, taking into account the variety of modifications either implemented already in an operational environment, or advocated by research projects and exemplary demonstrations in the course of case studies, would have resulted, together with the catalogue of evaluation criteria, in an impractical amount of effort expected from any responder to the appraisal call. Therefore, a more pragmatic approach was followed.

For each reference item, the editors group jointly created a Technical Profile, comprising compact information on the major user-relevant features and meta-data, viz.:

- Topic addressed (objective of the information product)
- Thematic content (available thematic information and underlying data layers)
- Access (e.g. via Internet)
- Scale (where applicable)
- Accuracy (in terms of cartographic representation or model validity)
- Areal coverage (local, regional or global)
- Spatial resolution
- Timeliness (post-disaster delivery time for rapid mapping products)
- Update frequency (for monitoring information)
- Data format.

The Technical Profiles were completed with reference to a review of the respective literature. The intention was not to depict any specific operational product or system, but to describe, in condensed form, the state of the art, showing what is feasible given the present state of science and technology, notwithstanding if it is in operational use or not. Draft versions were distributed to the JB GIS member organizations for review and scientific endorsement, resulting in just minor changes and edits. For the final Technical Profiles, as presented to the survey participants, and the referenced literature, see Chapters 4.1 to 4.5, respectively.

Web-based survey for benefit appraisal

The invitation to participate was disseminated via the UN-SPIDER Knowledge Portal and the UN-SPIDER E-Mail distribution list containing about 18,000 addressees. In addition, the UN-SPIDER National Focal Points (http://www.un-spider.org/network/national-focal-points) were requested by a personal letter from the director of OOSA to further disseminate the call within their countries.

The call was open from 11 March until 12 April 2013, providing end-users of geospatial information in the field of Disaster and Risk Management, the opportunity to express their views and needs online by way of a standardized appraisal form on a dedicated section on the UN-SPIDER Knowledge Portal. All section content was presented in English, French, and Spanish. Participants were requested to identify themselves as end-user or non non-end-user. The appraisal criteria given in the appraisal form had been iterated before with an international group of experts at the Gi4DM – Geo-information for Disaster Management – conference in Antalya, Turkey, on 4 May 2011. These criteria are schematically outlined in Table 4.1.

Survey response

In comparison to the foregoing longlist poll (see Chapter 3), the response was markedly lower this time, which was to be expected taking into account the higher effort needed for completing the far more elaborate response form. In total, there were 70 responders, 51 of which had identified themselves as end-users, and 19 as non-end-users (e.g. from

Technical profiles of 10 reference geoinformation items to be evaluated with respect to:		
Operational issues	*Strategic issues*	*Criticality of features*
• Humanitarian aid • Health care • Critical infrastructure • Security	• Efficiency of plans and policies • Public acceptance of plans and policies • Support of superregional consistency and cooperation • Reducing losses in public economy • Support of preventive strategies	• Thematic content • Access • Scale • Accuracy • Areal coverage • Spatial resolution • Timeliness • Update frequency • Data format
Appraisal key: high - medium - low		

Table 4.1: Schematic content outline of the appraisal form

Figure 4.1: Geographic distribution of survey participants (end-users/non-end-users)

research organisations). However, there was a more or less similar global spread of responses (Figure 4.1).

Not all 10 reference items were evaluated by all responders. There was some difference in this regard between end-users and non-end-users (Figures 4.2 and 4.3), which might be explained by the end-users' more pronounced engagement in specific regional hazard situations. Both groups showed a relatively high interest in all four flood-related items.

Survey results by appraisal criteria

In the following, survey results on operational and strategic benefits of the 10 reference geoinformation items are presented with respect to the several evaluation criteria as listed in Table 4.1, separately for end-users and non-end-users. The results are also presented and further discussed with reference to each single geoinformation item in Chapters 4.1 to 4.5, respectively, together with the results on the criticality of technical features.

Operational benefits would take effect in the immediate context of emergency response, but also in support of disaster preparedness following an early warning or in the course of a slow-onset disaster.

Humanitarian aid, e.g. logistical assistance in deploying supply goods, or assisting refugees, is a paramount requirement in emergency response. Here, the benefit of all items was appraised as high by >50 % of the end-users, with emphasis on Earthquake Damage Assessment (93 %). Even Fire Risk Mapping as a more prevention-related item scored 52 % (Figure 4.4). All items scored lower in the appraisal by non-end-users (Figure 4.5).

Health care, e.g. emergency medical assistance or disaster preparedness in hospitals organization, is a highly crucial and time-critical issue in humanitarian support. In the end-users' appraisal, most items were evaluated as highly ben-

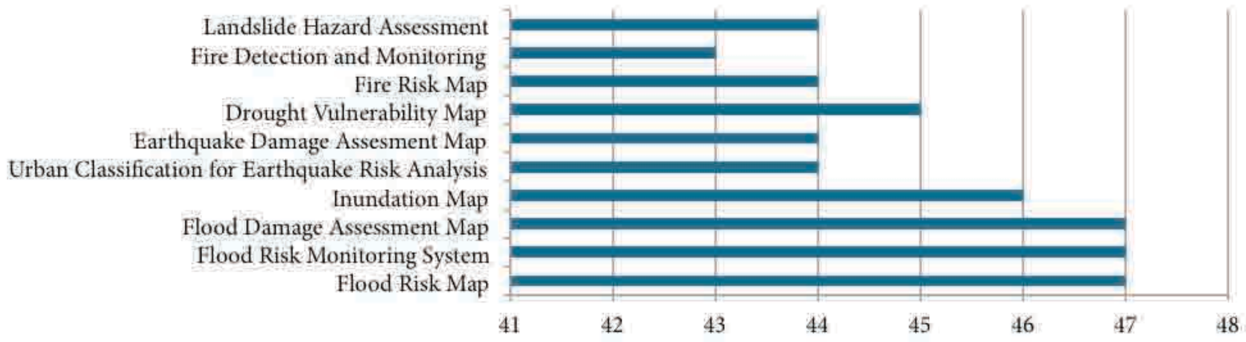


Figure 4.2: Number of reference items evaluated by end-users (n = 51)

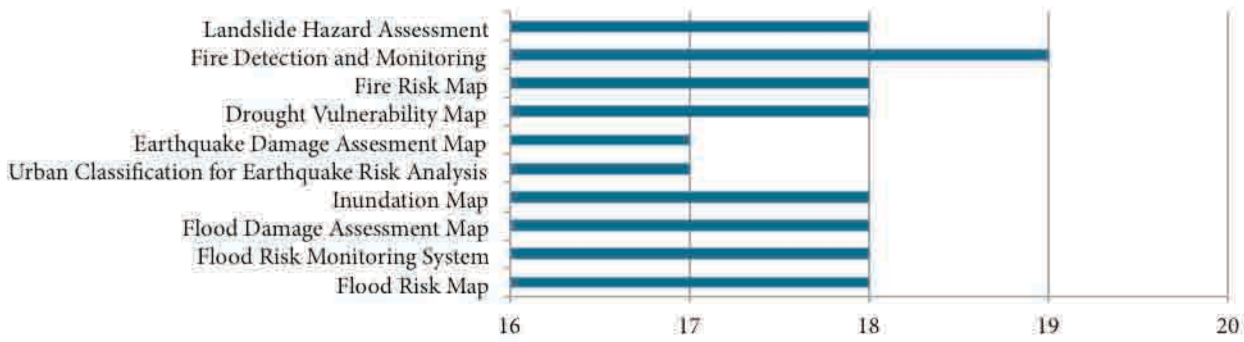


Figure 4.3: Number of reference items evaluated by non-end-users (n = 19)

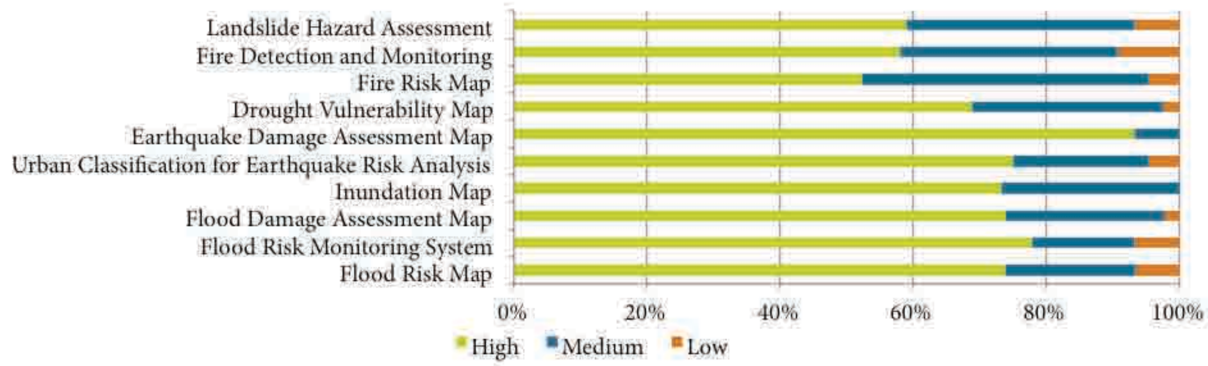


Figure 4.4: Benefit for *humanitarian aid* (end-users)

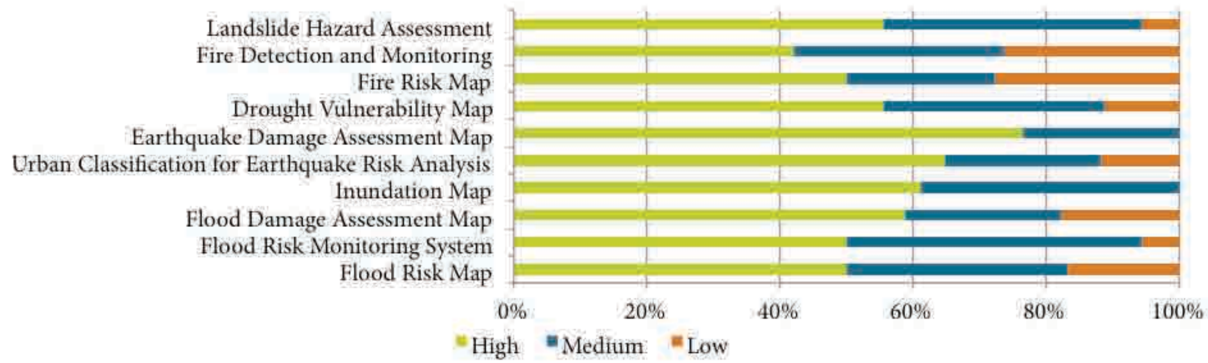


Figure 4.5: Benefit for *humanitarian aid* (non-end-users)

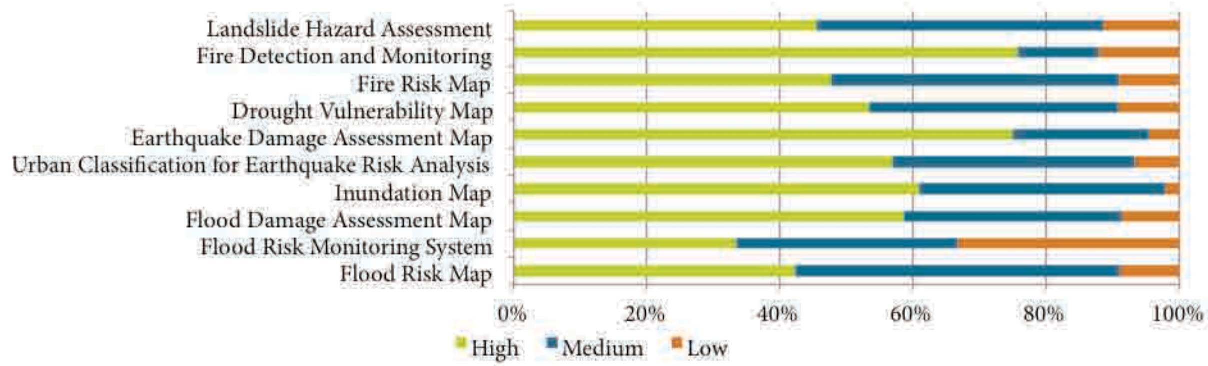


Figure 4.6: Benefit for *health care* (end-users)

eficial by >50 %, except for Landslide Hazard Assessment, Fire Risk Mapping, Flood Risk Monitoring and Flood Risk Mapping. Emphasis was given to Earthquake Damage Assessment (75 %) and Fire Detection and Monitoring (>75 %) (Figure 4.6). Apparently, emphasis is given to the needs of immediate medical aid in emergency situations, resulting in distinctly higher benefit scores of disaster detection and damage assessment versus risk and hazard mapping. All items scored lower in the appraisal by non-end-users (Figure 4.7).

Critical infrastructure encompasses transportation, energy supply, communication links and food production. More than 70 % of the end-users evaluated all items except Drought Vulnerability Mapping as highly beneficial (Figure 4.8). Although drought vulnerability is a critical issue regarding food production, apparently the major concern was about technical infrastructure which is not directly affected by drought. Scores >90 % were reached for Earthquake Damage Assessment Mapping, Urban Classification for Earthquake Risk Analysis and Flood Risk Mapping. The appraisal by non-end-users followed a similar pattern, with most high benefit evaluations being lower, except Landslide Hazard Assessment, Fire Risk Mapping and Flood Risk Mapping (Figure 4.9).

Security means e.g. control over vulnerable structures in emergency situations as well as preparedness of the population and resilience of infrastructure in the pre-disaster phase. In the end-users' appraisal, all items but Drought Vulnerability Mapping scored >50 % for highly beneficial, with scores >60 % for Earthquake Damage Assessment Mapping and Urban Classification for Earthquake Risk Analysis (Figure 4.10). With the exception of Earthquake Damage Assessment Mapping, all items scored distinctly lower in the non-end-users' appraisal (Figure 4.11).

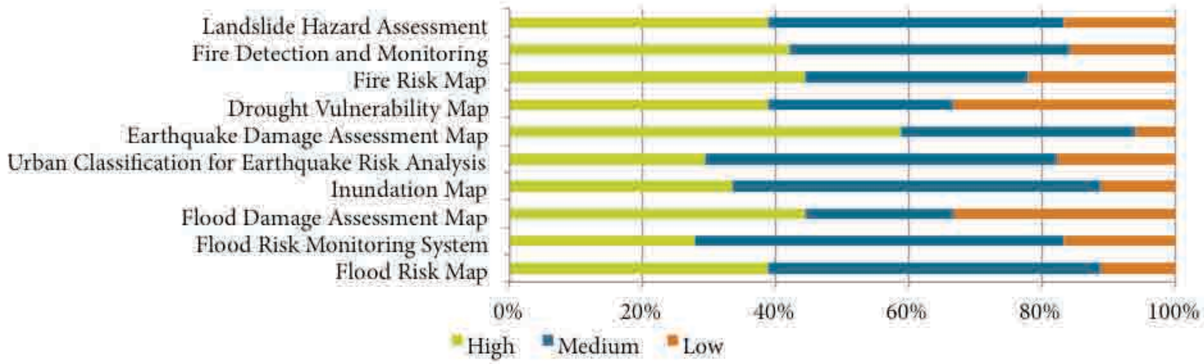


Figure 4.7: Benefit for *health care* (non-end-users)

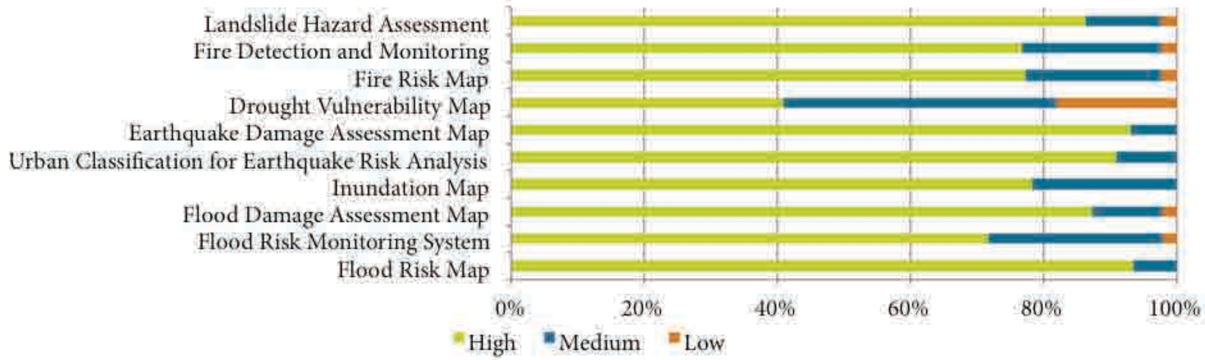


Figure 4.8: Benefit for *critical infrastructure* (end-users)

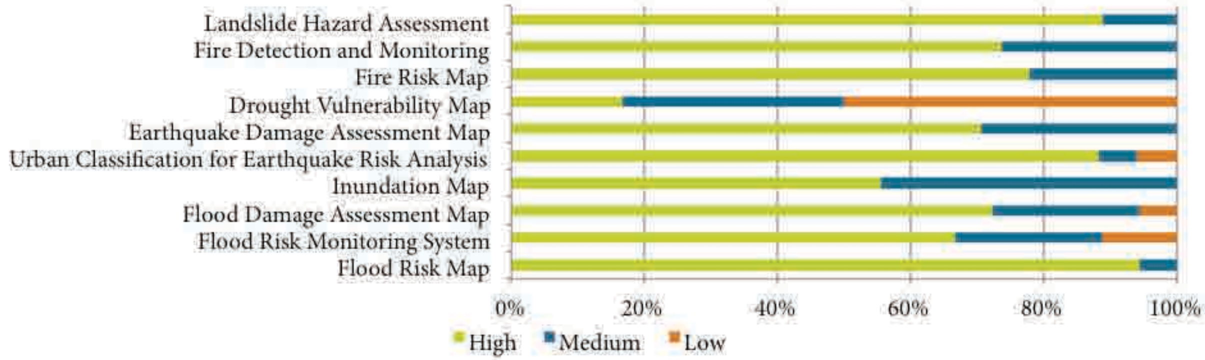


Figure 4.9: Benefit for *critical infrastructure* (non-end-users)

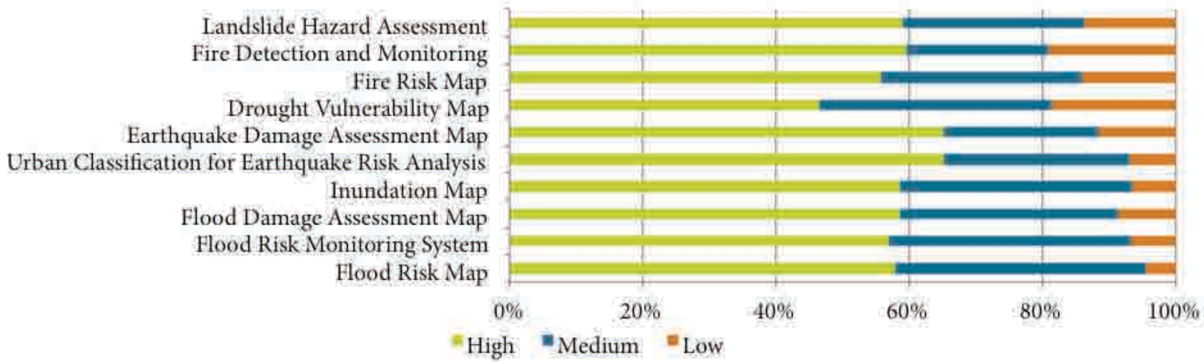


Figure 4.10: Benefit for *security* (end-users)

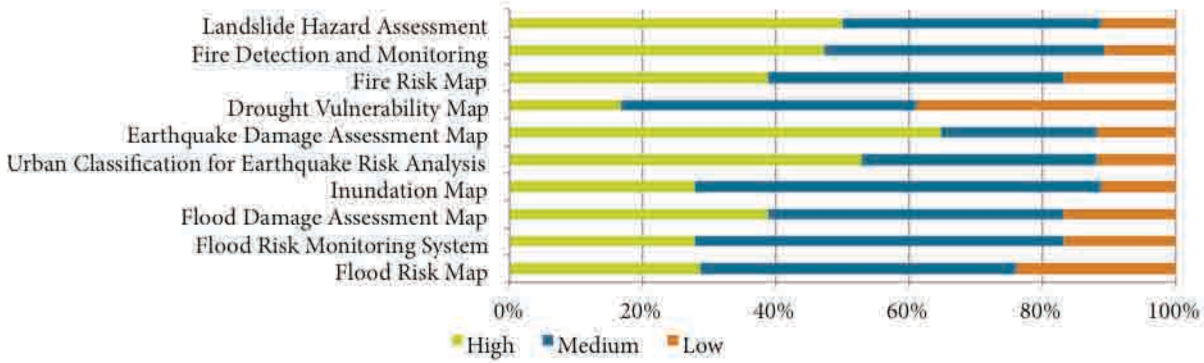


Figure 4.11: Benefit for *security* (non-end-users)

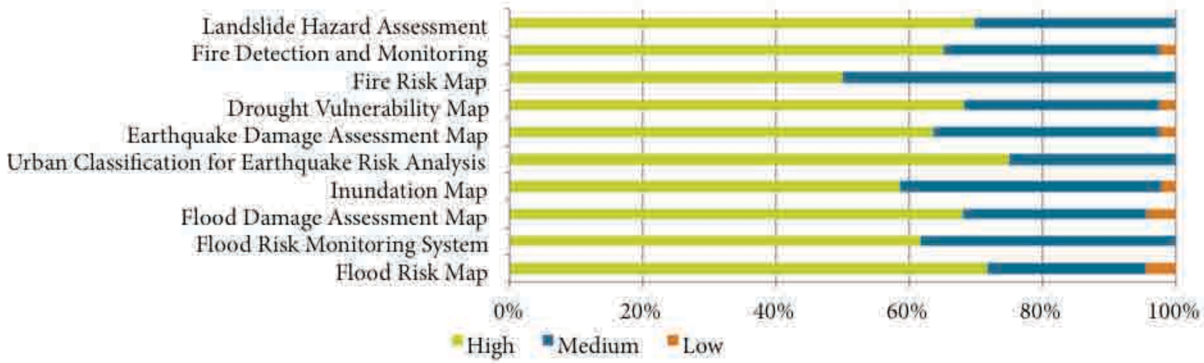


Figure 4.12: Benefit for *efficiency of plans and policies* (end-users)

Strategic benefits can be expected mostly on the level of pre-disaster planning for risk reduction, but also in the aftermath of a disaster when it comes to coping with economical losses and reconstruction.

Efficiency of plans and policies in Disaster and Risk Management may benefit from integrating the geospatial dimension into the information base for strategic decision support, which is complementary to merely statistical data. Except for Fire Risk Mapping, all geoinformation items were evaluated by >50 % of the end-users group as highly beneficial, with the highest scores for Urban Earthquake Risk Analysis (75 %) and Flood Risk Mapping (>70 %) (Figure 4.12). The appraisal by non-end-users followed a similar pattern with some slightly lower high benefit scores, but giving more emphasis, however, to Fire Risk Mapping (>60 %) (Figure 4.13).

Public acceptance of plans and policies may be increased especially by the visual representation of damage, vulnerabilities and risks, as provided by suitable geoinformation products. Under this aspect, however, the overall evaluation as highly beneficial was lower by end-users (Figure 4.14), with just Flood Damage Assessment Mapping scoring well above 50 %. In comparison, non-end-users gave distinctly more emphasis to Fire Risk Map, Drought Vulnerability Map, Urban Earthquake Risk Analysis and Flood Risk Map, all scoring with >60 % for high benefit (Figure 4.15). In general, the responders assess the benefits of geospatial information as moderate when aiming to increase public acceptance of plans and policies.

Support of superregional consistency and cooperation, e.g. by sharing uniform geospatial reference information, is a critical strategic issue in all cases where a spatially extended trans-boundary hazard has to be coped with, where a global strategy shall be implemented, or where Disaster and Risk Management is carried out in a federal administrative system. Here, >50 % highly beneficial appraisals from end-users were given to Fire Detection and Monitoring,

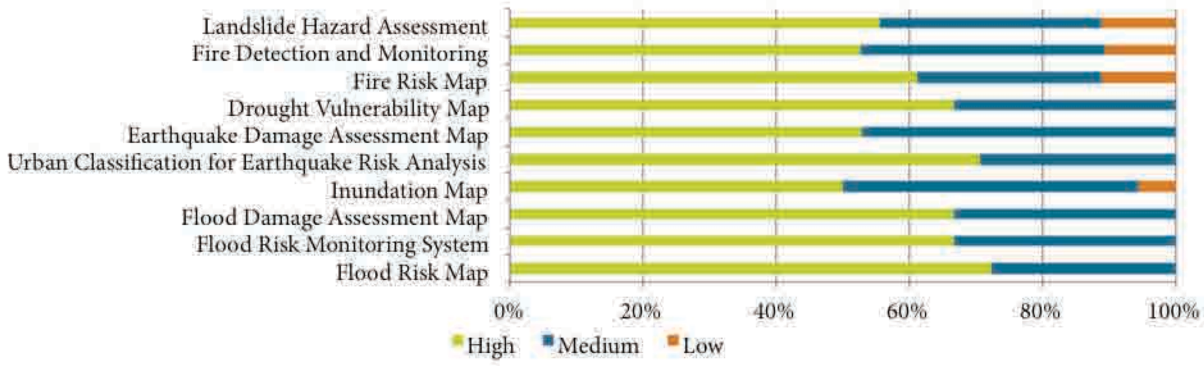


Figure 4.13: Benefit for *efficiency of plans and policies* (non-end-users)

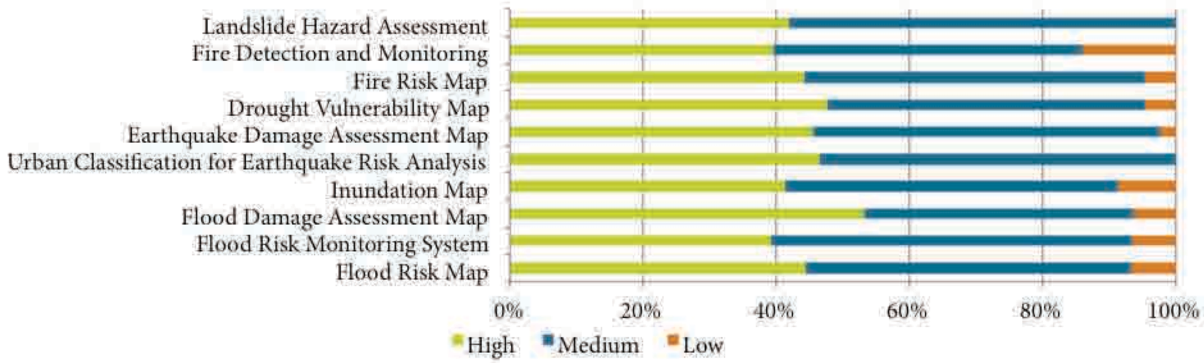


Figure 4.14: Benefit for *public acceptance of plans and policies* (end-users)

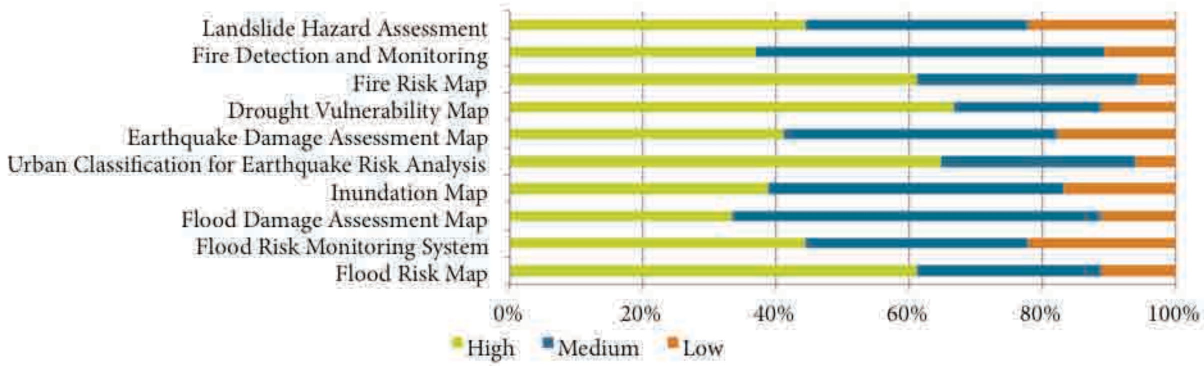


Figure 4.15: Benefit for *public acceptance of plans and policies* (non-end-users)

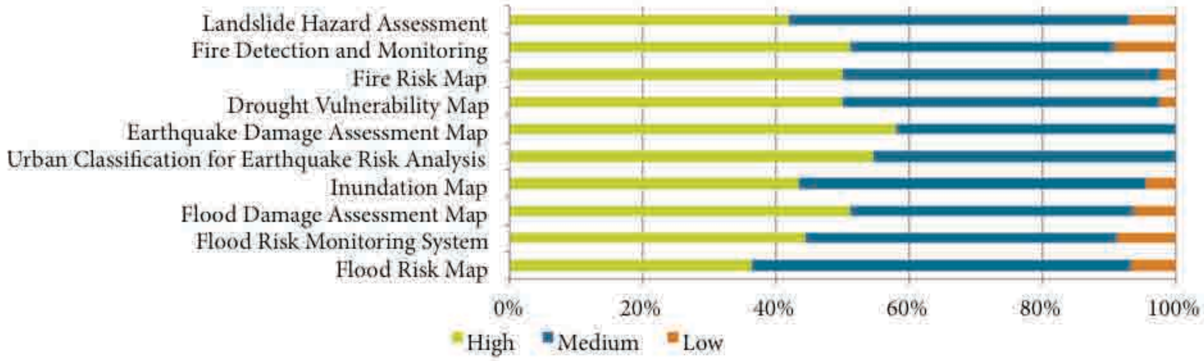


Figure 4.16: Benefit for *support of superregional consistency and cooperation* (end-users)

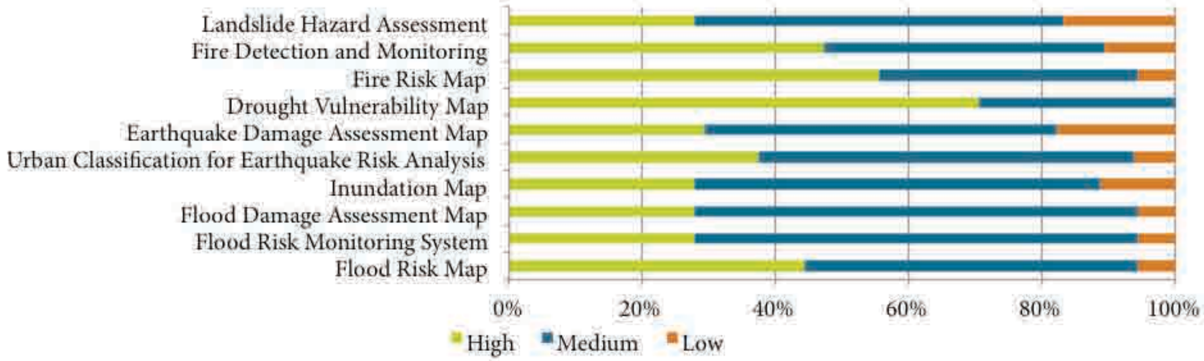


Figure 4.17: Benefit for *support of superregional consistency and cooperation* (non-end-users)

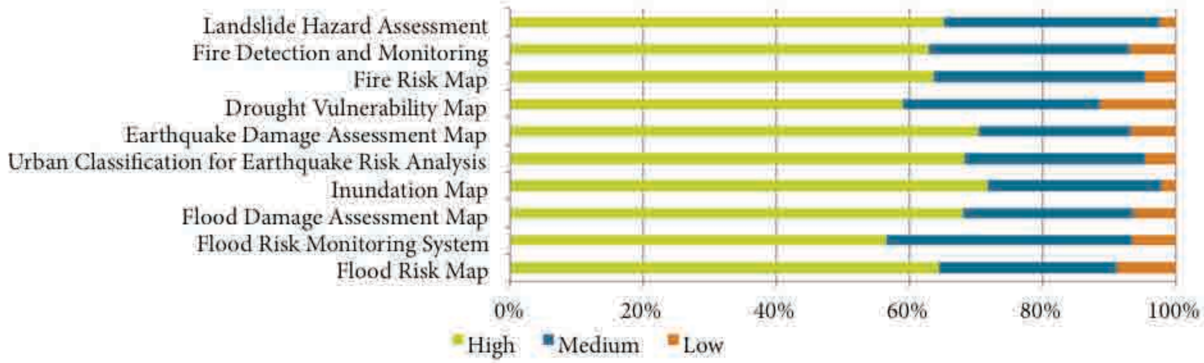


Figure 4.18: Benefit for *reducing losses in public economy* (end-users)

Earthquake Damage Assessment Mapping (>55 %), Urban Earthquake Risk Analysis (55 %), and Flood Damage Assessment Mapping (Figure 4.16). All items scored lower in the non-end-users' appraisal, with the exception of Fire Risk Mapping (>55 %) and Drought Vulnerability Mapping (>70 %) (Figure 4.17).

Reducing losses in the public economy, e.g. by risk reduction or more efficient emergency response, is addressed in more detail in Chapter 2. In the global appraisal results presented here, >60 % of the end-users group evaluated most items as highly beneficial, with only minor differences (Figure 4.18), and with Drought Vulnerability Mapping and Flood Risk Monitoring (both >55 %) coming just short of this score. All items were evaluated lower in the appraisal by non-end-users (Figure 4.19).

Support of preventive strategies has been proven as a highly efficient approach to disaster management (see Chapter 2) and may benefit from geoinformation e.g. in the way of identifying, assessing and locating disaster risks. Accordingly, in the end-user appraisal of highly beneficial all items except Flood Damage Assessment (55 %) scored distinctly >60 % (Figure 4.20). From the non-end-users point of view, the results for highly beneficial appraisal are more varied, but with most items well above 50 %, and with Urban Earthquake Risk Analysis (>80 %) and Flood Risk Mapping (>75 %) scoring even higher for high benefit in comparison with end-users (Figure 4.21).

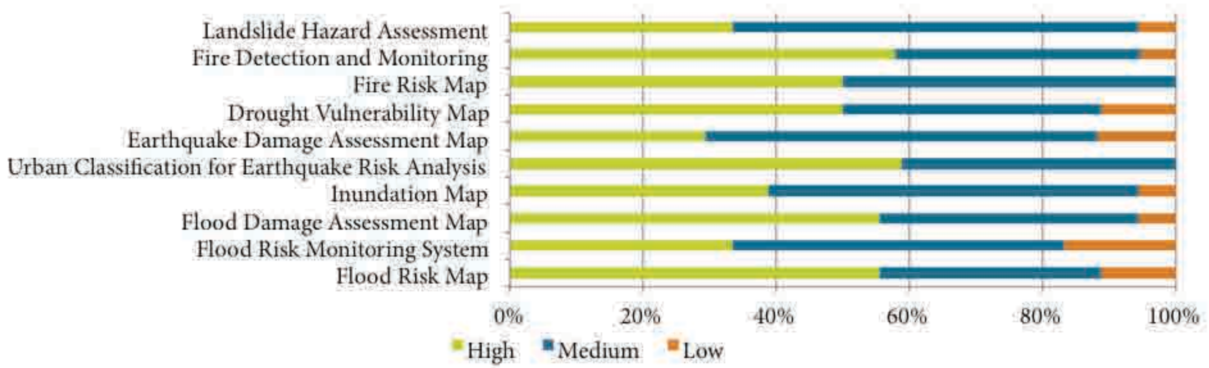


Figure 4.19: Benefit for *reducing losses in public economy* (non-end-users)

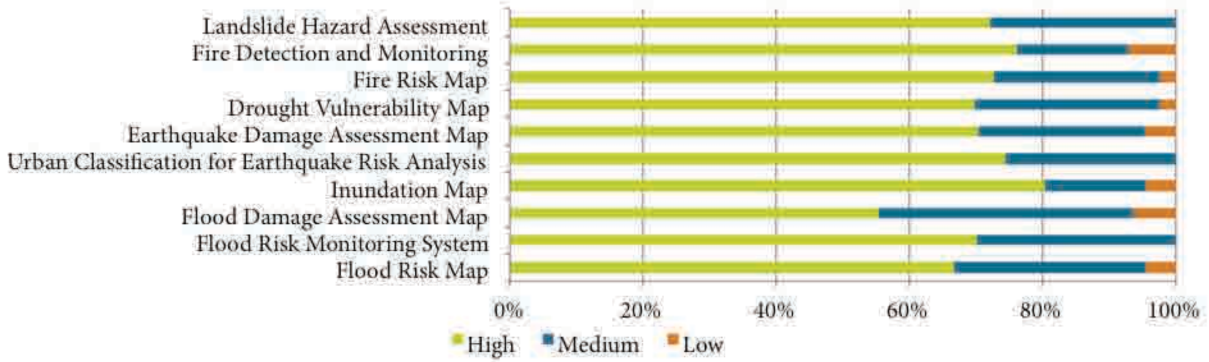


Figure 4.20: Benefit for *support of preventive strategies* (end-users)

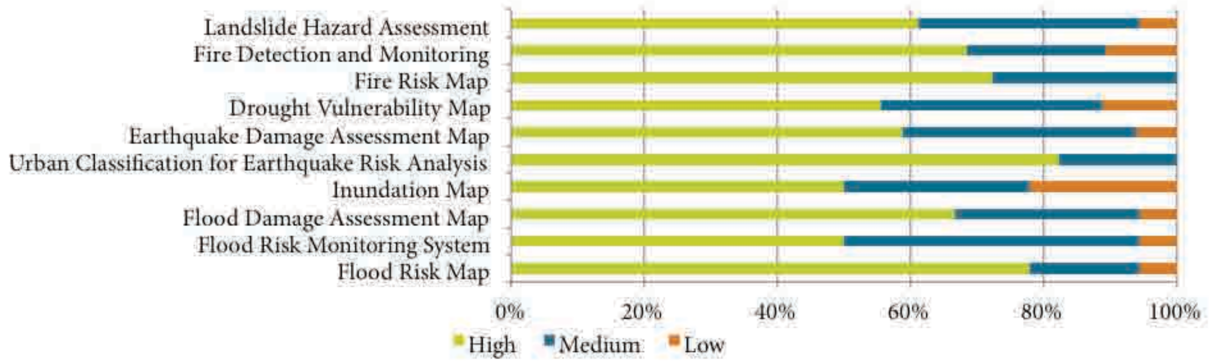


Figure 4.21: Benefit for *support of preventive strategies* (non-end-users)

4.1 Flood and flood risk: Mapping, monitoring and damage assessment

Sisi Zlatanova

Floods are among the most frequent disasters and are ranked as number three world-wide in frequency. Europe, America, Asia, and Australia have recently witnessed a severe growth in the scale and frequency of flood events. Figure 4.1.1 clearly shows that storms and floods are the most extreme and frequent disasters.

For example, the Elbe floods in 2002 caused a total of € 8 billion of economic damage in Germany, Austria and the Czech Republic. The economic losses contributed to reductions in these countries' 2002 GDP of 0.54 %, 1.4 % and 3.75 % respectively (CEA, 2007). 91 % of the most severe catastrophes in the world have been weather related: 300 storms, 310 floods, storm surges and mass movements caused by heavy rain (Munich Re, 2012). According to statistics the impact of flood events on societies and economies worldwide is likely to increase, since population densities and economic activities along rivers, sea shores and deltas have increased and will increase further in the future. Furthermore, the frequency and magnitude of floods are expected to grow due to the impacts of climate change (Thieken et al., 2006; Taubenböck et al., 2011; Shamaoma et al., 2006; CEA, 2007; Munich Re, 2012). The annual maximum peak discharges of major rivers are also expected to rise by 3–19 % by 2050 (Middelkoop et al., 2001). For example, te Linde et al. (2011) estimate an increase in the flood hazard (e.g. extreme 1/1250 per year flood events) by a factor of three in the Lower Rhine delta by 2050.

These trends require special attention to flood early warning as well as flood and flood risk management protection.

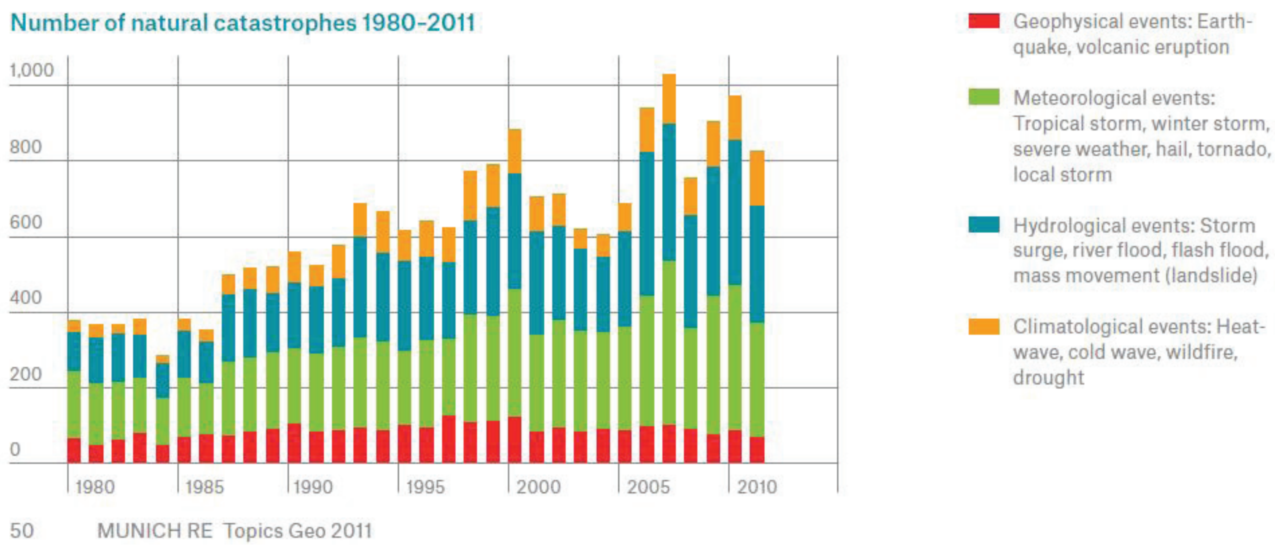


Figure 4.1.1: Catastrophes statistics published by Munich Re, 2012

According to Article 2 of the European Directive on the Assessment and Management of Flood Risks (EU, 2007):

"Flood" means the temporary covering by water of land not normally covered by water. This shall include floods from rivers, mountain torrents, Mediterranean ephemeral water courses, and floods from the sea in coastal areas, and may exclude floods from sewerage systems;

"flood risk" means the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event.

Generally, flooding is a natural and recurring event for a river or stream. It is caused in most cases by heavy or continuous rainfall, which exceeds the absorption capacity of soil and the flow capacity of rivers. Such rains may originate from storms, tornadoes, etc. However floods can be caused also by rapid melting of snow caps due to temperature peaks or the regular spring thaw, by earthquakes and consequent tsunami, and by dam and dyke bursts due to natural events or human failure. All these events cause watercourses to overflow their banks or dykes and inundate the surrounding lands. These flooded areas, usually referred to as floodplains, are the most flood-prone. Volcanic eruptions on glaciers or snow-covered volcanic peaks can also result in a sudden flood or fast-moving mudflows, which may create streams that are outside the normal riverbeds, causing even more damage and loss of life.

Frequency is one of the most critical characteristics of a flood event. The flood may be described as a 1 in 5-year, 20-year, 50-year, 100-year, or even 500-year flood event. For example a 100-year flood means that an area is subject to a 1 % probability of a certain size of flood in a given year, i.e. the chance of the flood is 1% every year. That does not mean that a certain size flood will occur once every 100 years. The boundary of the 100-year flood is an important measure and commonly used in all kinds of mitigation programs to identify areas of significant flooding hazard (OAS, 1991).

Scientific and technical background

Given the complexity of and the reason for the occurrence of floods, it is almost impossible to create a complete and accurate picture of flood potential. Similarly, it is difficult to precisely estimate flooded areas and damage that might be caused. The most common approach is to delineate the floodplains or flood-prone areas and consider them as risk areas. The major and very valuable contribution of remote sensing is that it provide rapid methods of mapping and monitoring flooded areas and predicting possible extensions of the flood. Various 2D and 3D products can be prepared to assess the extent of the floodplains and actual flooded areas. In this chapter we have considered four types of products: Flood Risk Map, Flood Risk Monitoring System, Flood Inundation Map and Flood Damage Assessment Map.

The purpose of a Flood Risk Map is to delineate the areas prone to flooding. Generally such maps should be available in advance of a flood event and should not only consider the threat of flooding but also flood mitigation and its impact on urban development. Flood Risk Monitoring Systems should be able to detect critical spatial changes in flood hazard and vulnerability over time. A Flood Inundation Map is prepared most commonly immediately after a flood event has taken place and aims to delineate the actual flooded areas including the water depths. The fourth product is the Flood Damage Assessment Map which aims to present details of socio-economic damage.

The preparation of maps for flood risk management, monitoring and damage assessments has always been seen as an important activity to ensure information is shared and the community is informed about the event. The Technical Profiles in Tables 4.1.1 to 4.1.4 specify the information that must be included in these products.

Some of the data in these tables is already available in GIS layers (land cover, administrative units, population density, urban fabrics, etc.), while other data (such as water depth,

Topic	Areas prone to flood damage
Thematic content	4 risk classes, based on • topographic base map, • inundation areas as reference scenario • water depth • population density • landuse • urban fabric • location of vulnerable objects (as schools, hospitals) • location of critical infrastructure (pipe lines, gas stations, factories)
Access	Upon registration via internet
Scale	1:2,000 - 1:10,000
Accuracy	0.5 m - 1 m geometric accuracy according to thematic class
Areal coverage	Regional
Spatial resolution	1 m – 5 m
Timeliness	Not relevant for risk assessment
Update frequency	5 years
Data format	Raster or vector (OGC standards should be used)

Table 4.1.1: Technical Profile of Flood Risk Map

Topic	Spatial changes in flood hazard and vulnerability over time
Thematic content	• Topographic base map • Change detection maps on • landuse and vegetation • water bodies • urban fabric • population density • asset values • total precipitation
Access	Upon registration via internet
Scale	1:25,000 – 1:3,000,000
Accuracy	5 m - 500 m geometric accuracy according to thematic class
Areal coverage	Regional
Spatial resolution	10 m - 1,000 m according to thematic class
Timeliness	Not relevant for risk assessment
Update frequency	5 years; < 1 week for precipitation data
Data format	Raster or vector (OGC standard-based)

Table 4.1.2: Technical Profile of Flood Risk Monitoring System

inundation extent, total precipitation) have to be obtained from in situ sensors. In many cases, the availability of the map products is highly dependent on dynamic measurements: i.e. the sensors and the platforms that could be used to collect data. For example, floods are frequently accompanied by dense cloud cover, which may require either an active radar sensor that can penetrate clouds, or an optical imaging system that would fly beneath cloud level (Zwenzner and Voigt 2009, Zhang and Kerle 2008). However, radar-based inundation maps require additional processing, leading to higher costs and delays in information availability. Radar intensity images are most commonly used to delineate inundation, as the water appears black after the image is processed (Figure 4.1.2). Jiang and Cao (1994) reported one of the first operational airborne radar flood management systems in China, where data were obtained real-time from a satellite.

Airborne sensors typically have higher spatial resolutions (centimetres to a few metres) than most satellite sensors (metres to kilometres), although the spatial resolutions of panchromatic images on some optical imaging satellites can also achieve close to 0.5 m. This means that for large scale flooding a resolution of 100-500 m may be sufficient for a general overview inundation map, while for more localized views and informing citizens, especially in urban areas, sub-metre detail would be more appropriate (Thompson et al. 2011). Furthermore, the existence of a pre-event Digital Terrain Model (DTM) or Digital Elevation Model (DEM) is recommended for more accurate computation of inundation levels. Many countries have at their disposal national DTMs, but their quality varies greatly. Integrating 2D with 3D information extends the options to perform more complex analysis of flood behaviour. Inundation extent outlines merged with 3D building data allow the estimation of which floors in buildings might be secure from floods (Figure 4.1.3). Given frequently repeated data acquisition cycles, changes over time can also be estimated. An interesting application reflecting the changes in the flood over time was

Topic	Flooded areas
Thematic content	• Topographic base map • Contours of flooded areas • Water depth
Access	Upon registration via internet
Scale	1:1,000 - 1:1,000,000
Accuracy	1 m - 100 m
Areal coverage	Regional
Spatial resolution	0.5 m - 250 m
Timeliness	few hours after an emergency
Update frequency	Several hours to 1-2 days
Data format	Raster Maps and vector datasets (OGC standard)

Table 4.1.3: Technical Profile of Inundation Map

Topic	Spatial distribution of economic damage due to flooding
Thematic content	Aggregated monetary losses in • residential content • industrial structure • agricultural crop based on • landcover/landuse • administrative units • socioeconomic statistics • inundation extent and duration • water depth
Access	Upon registration via internet
Scale	1:1,000 – 1:60,000
Accuracy	15 m geometric accuracy
Areal coverage	Regional
Spatial resolution	30 m
Timeliness	1 - 2 days after an emergency
Update frequency	1 - 2 days for actual flood monitoring
Data format	Raster or vector (OGC standard)

Table 4.1.4: Technical Profile of Flood Damage Assessment Map

displayed by ABC News (Australian Broadcasting Corporation) to observe and compare areas 'before and after' the flood events (Figure 4.1.4).

The cost of acquiring the map product should also be considered. For example in a cloudy situation, while radar data might be recommended for inundation mapping, it is unlikely that such data will be available and it will in any case be expensive. A non-calibrated optical photograph, acquired by a camera on a kite might cost a few dollars, while the acquisition and processing, depending on the provider, of an interferometric radar product might exceed US$ 1000 (Kerle et al 2008). Hence a situation-specific compromise must apply.

There are several systems that resemble the data content and functionality as specified in the Technical Profiles in Tables 4.1.1.to 4.1.4. A good example of a Flood Risk Map maintained over the internet is the Dutch 'risicokaart' (www.risicokaart.nl). The web site was developed in response to Act 12 of Directive Seweso II (http://ec.europa.eu/environment/seveso/), which obliges companies and providers to indicate any dangerous installations on their sites, which store or use chemicals, petrochemicals and metal refining sectors in large qualities. The Dutch authorities have included floodplains in these maps. The web site is publicly available, maintained by the Dutch provinces and provides topographic base map, flood prone areas, with water depth indicated by colours, location of vulnerable establishments (such as schools, hospitals) and location of critical infrastructure (pipe lines, gas stations, factories) (Figure 4.1.5). The iso-areas are given only for dangerous establishments. Furthermore, the information provided is rather limited. Iso-areas represent the individual risk at the given location, which is defined as the statistical probability that a person who is permanently present at a certain location in the vicinity of a hazardous activity, will be killed as a consequence of an accident within that activity (Zlatanova and Fabbri, 2009).

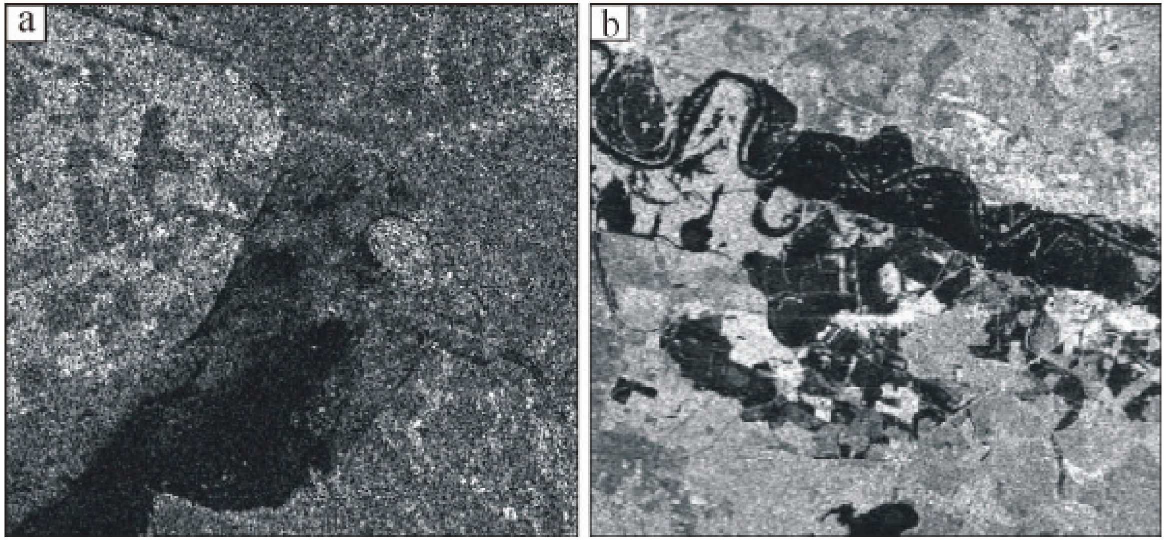


Figure 4.1.2: Radar images: a) original intensity image, and b) flooded area after processing (Kerle et al. 2008)

Figure 4.1.3: 3D visualization of flood Queensland, Australia (courtesy 3VI)

In recent years many systems have been developed for inundation mapping. An example is provided by VIKING (http://www.programmaviking.nl/), with the cooperation of two provinces in the Netherlands and Germany. The system has many of the functionalities of a traditional GIS and allows many layers to be overlaid and analyzed. The graphic user interface is based on maps and aerial photographs. Inundation areas are interactively shown on the screen with prediction animation. Several modules have been developed which allow for inundation warning information or for training and simulations. Delft-FEWS (Flood Early Warning System) (http://www.wldelft.nl/soft/fews/int/index.html) is another example of an inundation mapping system. The system is basically a combination of dynamic hydrological models and highly-functional-real-time-simulation software. It provides essential generic GIS functionality for handling real-time data, data assimilation and managing forecast runs. OSIRIS (Erlich, 2007) is yet another inundation mapping system. The emphasis in this system is on an interface which can help citizens understand official forecasts. The system also allows for integration of various data such as risk maps, flood prevention plans and rescue organizational charts.

Several systems have been developed as web portals to provide early warning and on-going information on the extent of inundation. The goal of these systems is primarily to inform on inundation rather than specifically monitor inundation extent, but still many are able to produce maps showing inundation extents and depths. These maps then can be re-used when needed. For example the JRC Floods Portal (Figure 4.1.6) provides information about ongoing inundation, flood disasters, economics of flood risk, run-off simulation models, climate impact changes, etc.

Besides the real-time information, several maps also exhibit flood damage probabilities or flood disasters over the past 50 years.

Figure 4.1.4: High resolution optical images, Queensland floods, Australia (courtesy ABC News)

Figure 4.1.5: Integrated risk map representing flood risk areas, dangerous establishments according to the Sewezo directive and vulnerable objects (http://www.risicokaart.nl)

Thompson et al. (2011) have investigated the inundation map prepared by Dartmouth Flood Observatory, which covers the entire world (http://floodobservatory.colorado.edu/). It is not based on continuous mapping and is triggered by press reports of flood events from around the world. The Dartmouth metadata is limited. The actual time and date of the raw data is not immediately available to users and needs to be communicated more clearly. Research has revealed that the Dartmouth flood product consists of an accumulation of six MODIS images (36 spectral bands) acquired over three day periods. The spatial resolution is 250 m (bands 1-2), 500m (bands 3-7) and 1 km (other bands).

Several developments have been reported on Flood Damage Maps. Herath (2003) presented an example of a Flood Damage Assessment Map based on stage-damage functions which are better estimates than only interviews. Stage-damage functions are derived from analytical indicators for flood inundation and duration. The study elaborated on the Japanese damage estimation method, which uses seven damage classes indicating monetary losses due to damage to residential content, industrial structures and agricultural crops. To determine the estimates a grid flood damage map is prepared consisting of topographic map, landuse map, administrative units, inundation extent, water depth and duration and socio-economic statistics. Another example of a Flood Damage Map is presented by Venkatachary et al. (2001). The monetary losses due to crop damage were estimated with the help of a Flood Damage Map composed of landuse/landcover, administrative boundaries, agricultural statistics and inundation extent and duration layers. Similar approaches are reported by Thieken et al. (2006) and Srivastava et al. (2000).

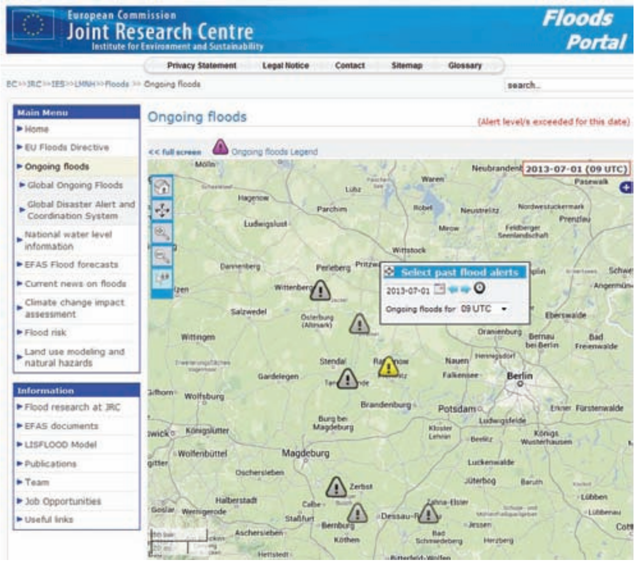


Figure 4.1.6: JRC Floods Portal exhibiting information about current floods.

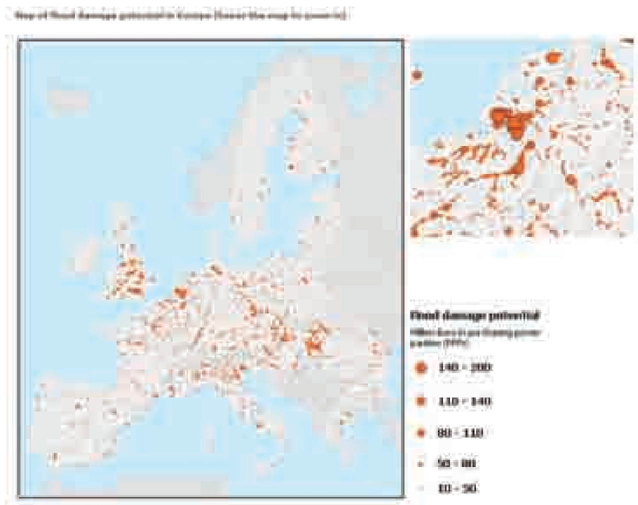


Figure 4.1.7: Flood damage potential (available at Floods Portal)

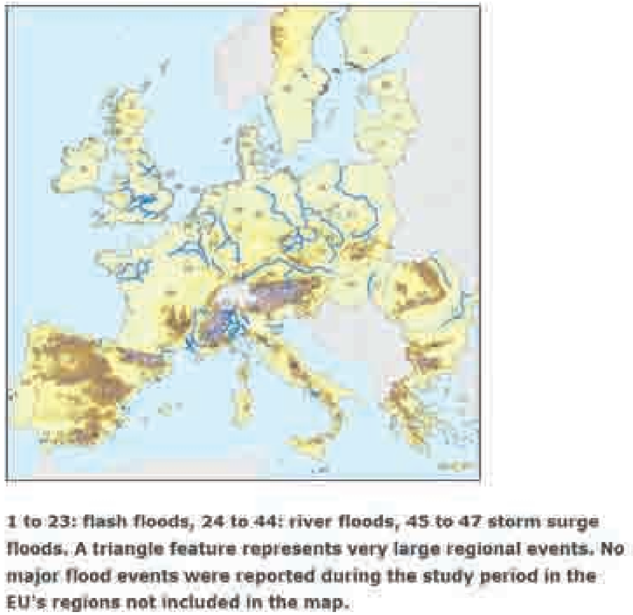


Figure 4.1.8: Major flood disasters in Europe, 1950-2005 (available at Floods Portal)

Figure 4.1.9: The Dartmouth Flood Observatory portal

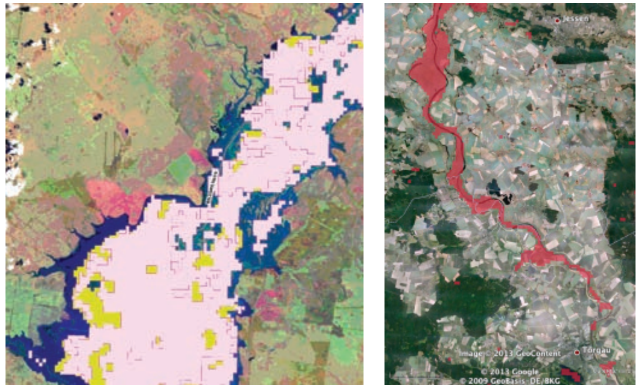


Figure 4.1.10: Examples of flood maps: a) Queensland floods, Darthmouth flood superimposed on Landsat 5 (Thompson et al., 2011), b): Floods in Germany 2013, product provided on the Dartmouth portal

Appraisal results

Less than 10 % of the end-users have rated the products as of low benefit. Non-end-users generally have given slightly lower ratings especially for **operational benefit**. The **strategic benefits** of all flood products have been estimated as highly relevant by the vast majority of end-users.

Flood Risk Map

Considering the **operational benefits**, more than 90 % of end-users and non-end-users alike have attributed a high benefit of this product with regard to the *critical infrastructure*, which is indeed most affected by floods (Figures 4.1.11; 4.1.12). More than 70 % of the end-users evaluated Flood Risk Maps as highly beneficial also for *humanitarian aid*. Apart from critical infrastructure, benefits to other operational issues scored distinctly lower in the appraisal by non-end-users.

Regarding **strategic benefits**, the end-users found Flood Risk Mapping to be highly beneficial to increase the efficiency of plans and policies (>70 %), to *support preventive strategies* and to *reduce losses in public economy* (>60 %, respectively) (Figure 4.1.13). Here, the appraisal by non-end-users followed a similar pattern (Figure 4.1.14).

Regarding the **criticality of specific product features** (Figure 4.1.15), end-users have indicated *thematic content* and *spatial resolution* as the most critical features. This is not surprising as the *thematic content* reflects the quality of risk information, and *spatial resolution* the spatial precision of Flood Risk Maps. In comparison, non-end-users assigned a higher importance to *areal coverage and access* (Figure 4.1.16).

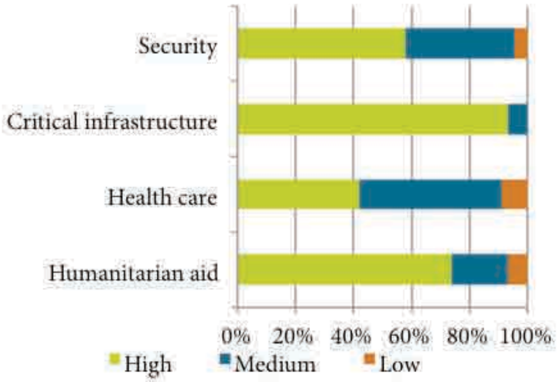


Figure 4.1.11: Operational Benefits of Flood Risk Map (end-user appraisal)

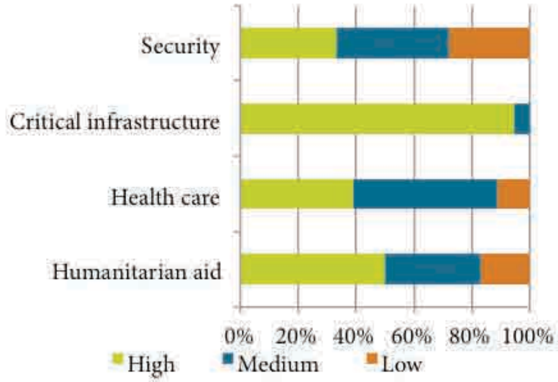


Figure 4.1.12: Operational Benefits of Flood Risk Map (non- end-user appraisal)

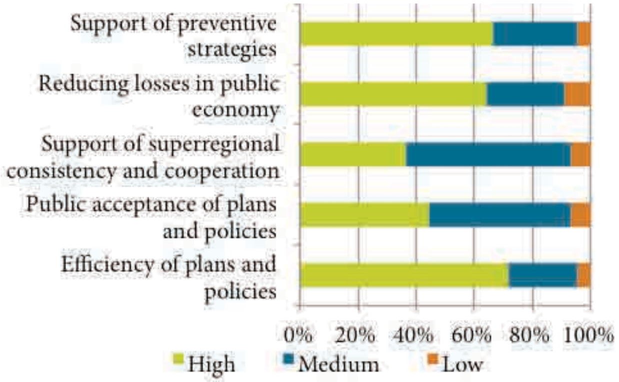


Figure 4.1.13: Strategic Benefits of Flood Risk Map (end-user appraisal)

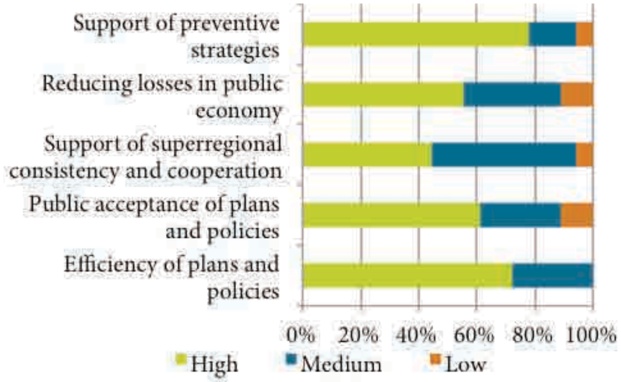


Figure 4.1.14: Strategic Benefits of Flood Risk Map (non-end-user appraisal)

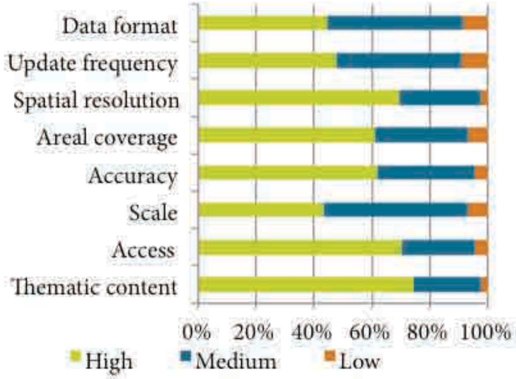


Figure 4.1.15: Criticality of specific features of Flood Risk Map (end-user appraisal)

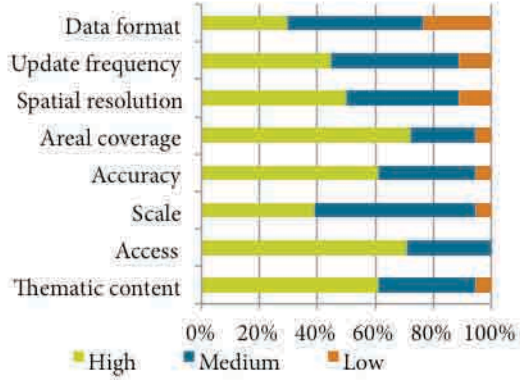


Figure 4.1.16: Criticality of specific features of Flood Risk Map (non-end-user appraisal)

Flood Risk Monitoring System

Among the **operational benefits**, end-users evaluated Flood Risk Monitoring as highly beneficial again for *critical infrastructure* (>70 %), but even more so for *humanitarian aid* (nearly 80 %), probably reflecting the importance of up-to-date risk information for the logistics of humanitarian support (Figure 4.1.17). The pattern of the non-end-user appraisal was similar, with a general trend to distinctly lower scores (Figure 4.1.18).

Regarding **strategic benefits**, it is not surprising that end-users acknowledged the high benefit of up-to-date risk information for the *support of preventive strategies* (>70 %), for the *efficiency of plans and policies* (>60 %), and for *reducing losses in public economy* (>50 %) (Figure 4.1.19). Again, the non-end-users' appraisal follows a similar pattern, with a trend to lower scores (Figure 4.1.20).

The end-user results for the **criticality of specific product features** give emphasis to *access, accuracy, areal coverage, thematic content*, and *update frequency* as highly critical features (>60 %) (Figure 4.1.21), whereas the non-end-users focus on *accuracy, update frequency, access* and *areal coverage* (>60 %) (Figure 4.1.22). Differing from the Flood Risk Map results, both groups saw a higher criticality of *update frequency* which is to be expected for a monitoring system.

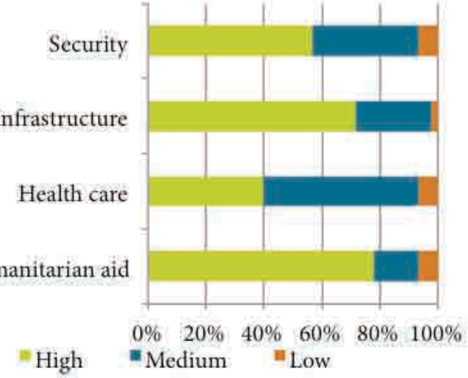


Figure 4.1.17: Operational Benefits of Flood Risk Monitoring System (end-users)

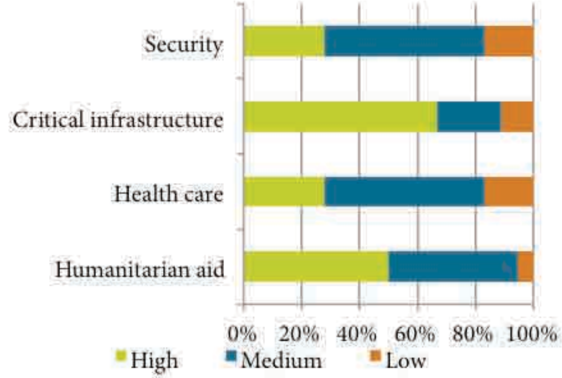


Figure 4.1.18: Operational Benefits of Flood Risk Monitoring System (non-end-users)

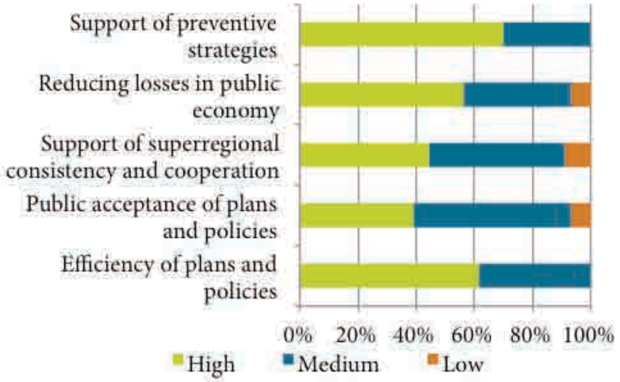


Figure 4.1.19: Strategic Benefits of Flood Risk Monitoring System (end-users)

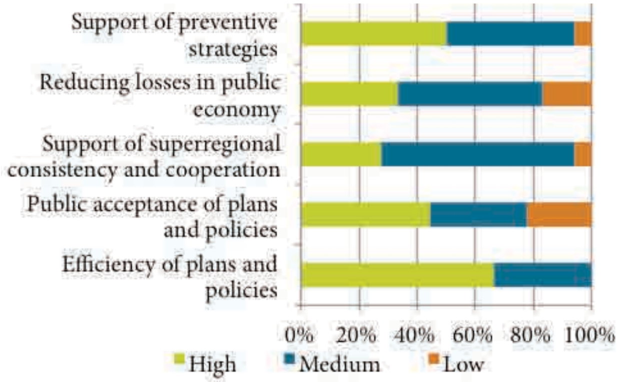


Figure 4.1.20: Strategic Benefits of Flood Risk Monitoring System (non-end-users)

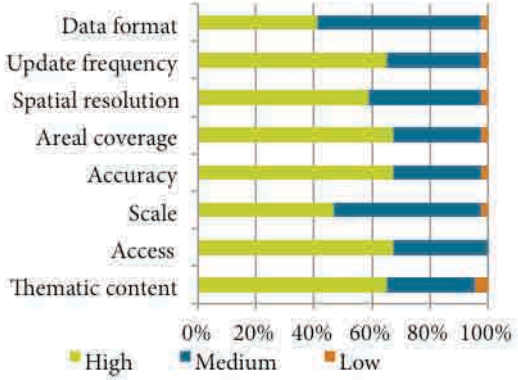


Figure 4.1.21: Criticality of specific features of Flood Risk Monitoring System (end-users)

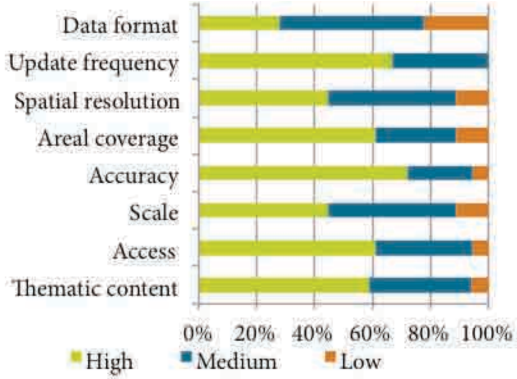


Figure 4.1.22: Criticality of specific features of Flood Risk Monitoring System (non-end-users)

Inundation Map

Similar to the results for Flood Risk Mapping and Monitoring, end-users attributed a high **operational benefit** of Inundation Maps to *critical infrastructure* (nearly 80 %) and *humanitarian aid* (>70 %) (Figure 4.1.23). The non-end-users confirmed this evaluation, again with a trend to lower scores (Figure 4.1.24). In contrast to the non-end-users' evaluation, the end-users gave more emphasis to the benefit for *security* (nearly 60 %), probably due to their closer involvement in emergency situations.

In the end-user appraisal of **strategic benefits**, Inundation Maps scored as highly beneficial especially for *support of preventive strategies* (slightly above 80 %) and *reducing losses in public economy* (>70 %) (Figure 4.1.25). It can be assumed that the high value attributed to Inundation Maps for the *support of preventive strategies*, i.e. outside an actual emergency situation, is due to the information that these maps can provide also in the post-emergency phase, e.g. for the validation of flood simulation models. This asset was not confirmed by the non-end-users who gave generally lower appraisal results (Figure 4.1.26).

Regarding the **criticality of specific product features**, the major concern of end-users was about *thematic content* (80 % for highly critical), followed by *accuracy* and *areal coverage* (both >70 %) (Figure 4.1.27). The priority given to *thematic content* probably refers to the completeness of information shown in the respective Technical Profiles (Table 4.1.3) which includes a topographic base map and indication of water depth. Similar to the end-users, the non-end-users (Figure 4.1.28) assessed *timeliness* of the product as highly critical (>60 %), which is to be expected for use in an immediate emergency situation, but non-end-users gave a distinctly lower assessment for the criticality of *data format*, apparently not taking into account the operational needs for data exchange.

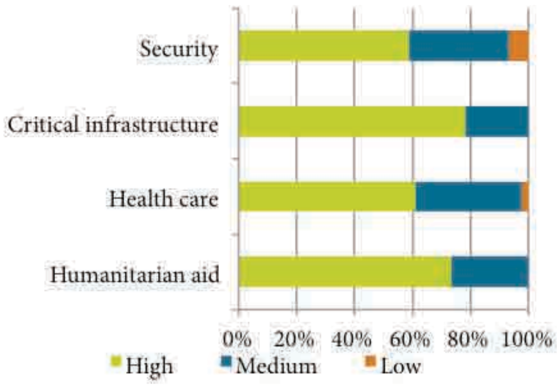


Figure 4.1.23: Operational Benefits of Inundation Map (end-user appraisal)

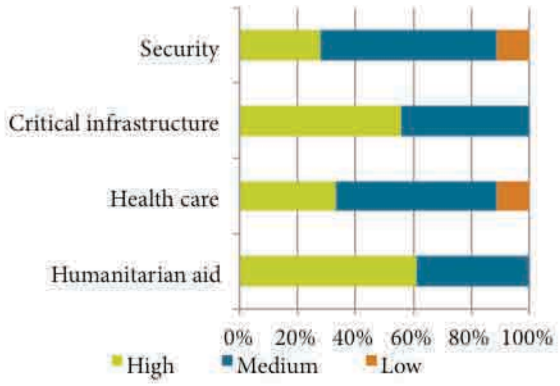


Figure 4.1.24: Operational Benefits of Inundation Map (non-end-user appraisal)

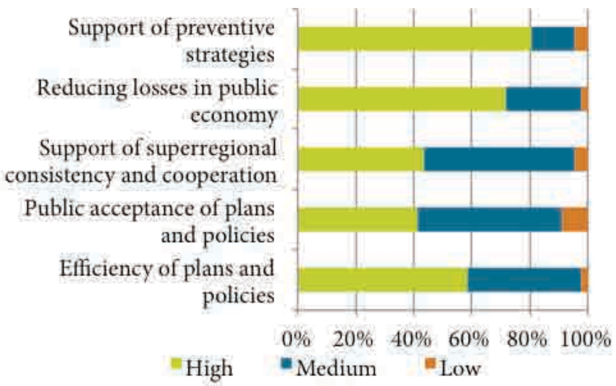


Figure 4.1.25: Strategic Benefits of Inundation Map (end-user appraisal)

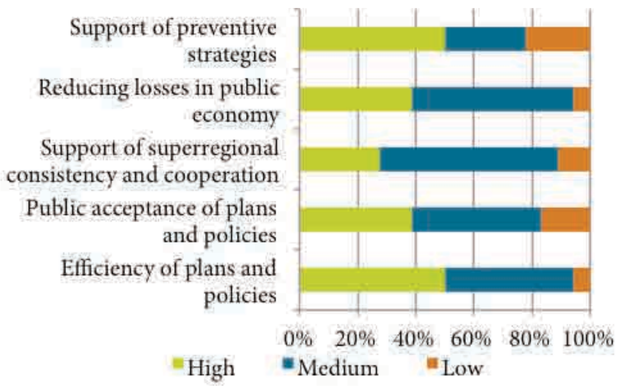


Figure 4.1.26: Strategic Benefits of Inundation Map (non-end-user appraisal)

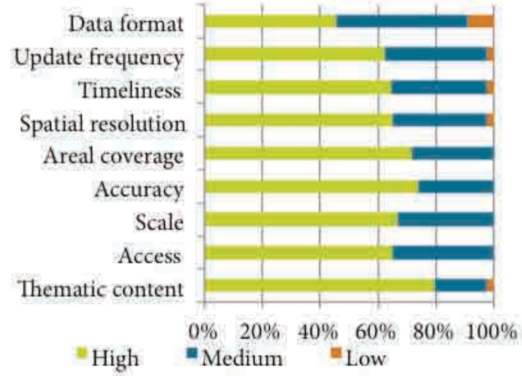


Figure 4.1.27: Criticality of specific features of Inundation Map (end-user appraisal)

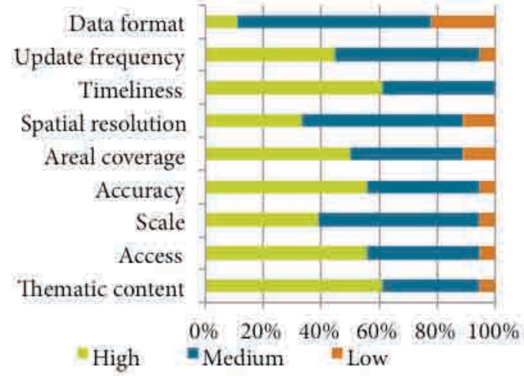


Figure 4.1.28: Criticality of specific features of Inundation Map (non-end-user appraisal)

Flood Damage Assessment Map

With regard to **operational benefits**, end-users evaluated the product as highly beneficial mainly for *critical infrastructure* (>80 %), and also for *humanitarian aid* (>70 %) and *health care* (nearly 60 %) (Figure 4.1.29). The relatively high score for *health care* could reflect the usefulness of information on the distribution of damage for more efficient organization of medical assistance during and after a flooding emergency. These priorities were confirmed by the non-end-users with generally lower scores (Figure 4.1.30).

As to the **strategic benefits** of the product, the end-users' appraisal gave high benefit scores especially for *efficiency of plans and policies* and *reducing losses in public economy* (both >60 %) (Figure 4.1.31). In addition, the non-end-users also highlighted the *support of preventive strategies* (Figure 4.1.32), probably assuming a higher potential of damage information from previous disasters for optimizing preventive measures for the future.

Areal coverage and *thematic content* were identified as highly **critical features** by the end users (both >70 %) (Figure 4.1.33), followed by *access, spatial resolution, timeliness* and *accuracy* (>60 %). High criticality of *thematic content* scored even higher in the appraisal by non-end-users (nearly 80 %) (Figure 4.1.34), who are perhaps even more aware of the methodical problems in deriving damage information from available spatial data in an emergency situation.

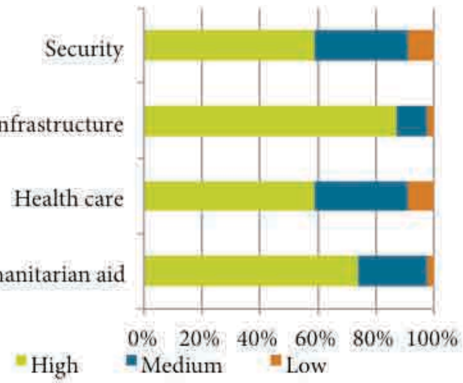


Figure 4.1.29: Operational Benefits of Flood Damage Assessment Map (end-users)

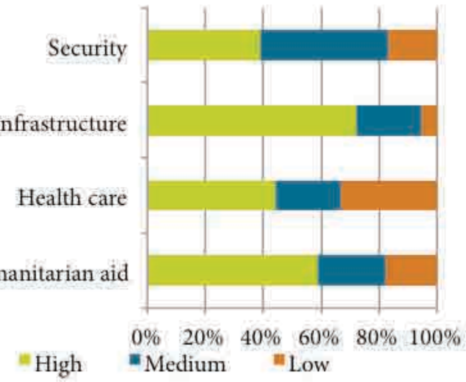


Figure 4.1.30: Operational Benefits of Flood Damage Assessment Map (non-end-users)

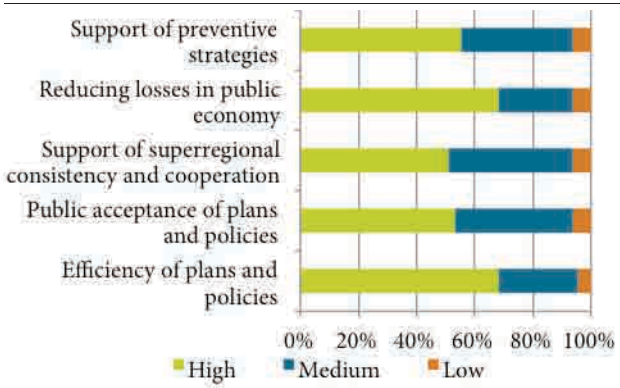


Figure 4.1.31: Strategic Benefits of Flood Damage Assessment Map (end-users)

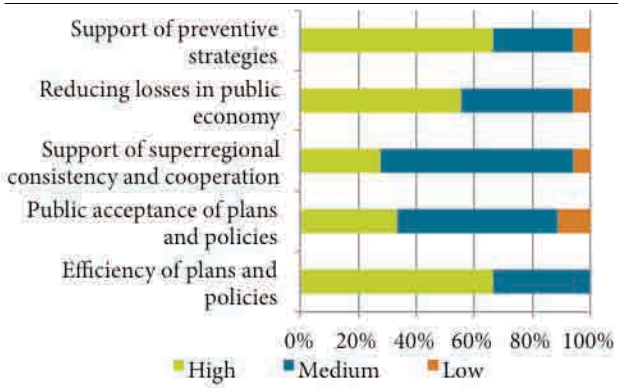


Figure 4.1.32: Strategic Benefits of Flood Damage Assessment Map (non-end-users)

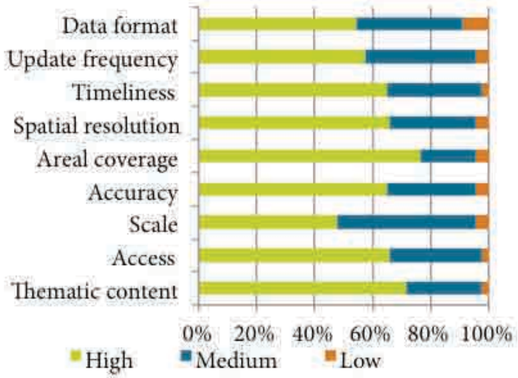


Figure 4.1.33: Criticality of specific features of Flood Damage Assessment Map (end-users)

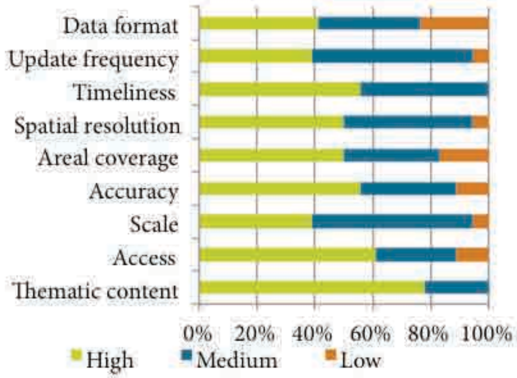


Figure 4.1.34: Criticality of specific features of Flood Damage Assessment Map (non-end-users)

4.2 Earthquake risk analysis and damage assessment

Alessandro Demarchi and Anna Facello

Seismic phenomena do not always trigger disasters; for example a powerful earthquake in an unpopulated area is not a disaster, while a weak earthquake which hits an urban area with buildings not constructed to withstand earthquakes, can cause great misery (Schwieger et al., 2006).

The United States Federal Emergency Management Agency (FEMA) defines seismic risk as "the harm or losses that are likely to result from exposure to seismic hazards. They are usually measured in terms of expected casualties (fatalities and injuries), direct economic losses (repair and replacement costs), and indirect economic losses (income lost during downtime resulting from damage to private property or public infrastructure)". According to Reiter (1991), a seismic hazard is the probable or possible occurrence of earthquake-related natural phenomena such as ground-shaking, fault rupture or soil liquefaction (Figure 4.2.1), while according to UNISDR (2009a), vulnerability is understood as "the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard". Moreover, as reported in the ENSURE Project (2010a), "the vulnerability of a system relates to its capacity to be harmed by a threat. Vulnerability can be seen as an internal property of a system". In addition, vulnerability could be understood as a "…whole which has several facets. Each facet is intrinsically related to every other facet" (ENSURE Project, 2010b). Among the most important components of vulnerability are physical vulnerability, socio-demographic vulnerability, economic vulnerability and the political/institutional/cultural vulnerability.

Geoinformation tools are mostly employed in physical aspects of vulnerability, which as Kundak (2010) states, is the susceptibility of all kinds of human-made structures such as buildings, roads, infrastructures, and which can be listed in more detail in sub-categories such as:

- *Urban fabric vulnerability*: seismic risk in an urban area is closely related to the structure, material and dimensions of buildings and their spatial distribution; thus a building inventory is the primary tool to assess this component of vulnerability. A building inventory can be obtained by a field survey, but a large amount of time and effort is required whereas satellite remote sensing, which can easily monitor a large area, can provide effective information on the urban fabric (Yamazaki et al., 2003).
- *Infrastructure vulnerability* includes all crucial infrastructures such as gas stations, power plants, factories, utility lifelines (those systems commonly used to transport water, oil, natural gas and other material). Damage to some of these installations may also lead to *Natural Hazard Triggering Technological Disasters (Natech)* which occur in relation to natural hazards and disasters and have in the past resulted in the release of hazardous substances leading to fatalities, injuries, environmental pollution and economic losses (Theilen-Willige et al., 2011). In addition, one of the principal problems of most Natech accidents is the simultaneous occurrence of a natural disaster and a technological accident, both of which require simultaneous response efforts in a situation in which lifelines needed for disaster mitigation are likely to be unavailable (Theilen-Willige et al., 2011).
- *Functional vulnerability* addresses the vulnerability of strategic urban functions, such as hospitals, fire stations, police stations, which may be located in inappropriate areas, prone to earthquake hazard, and thus cannot operate appropriately in the case of a disaster.

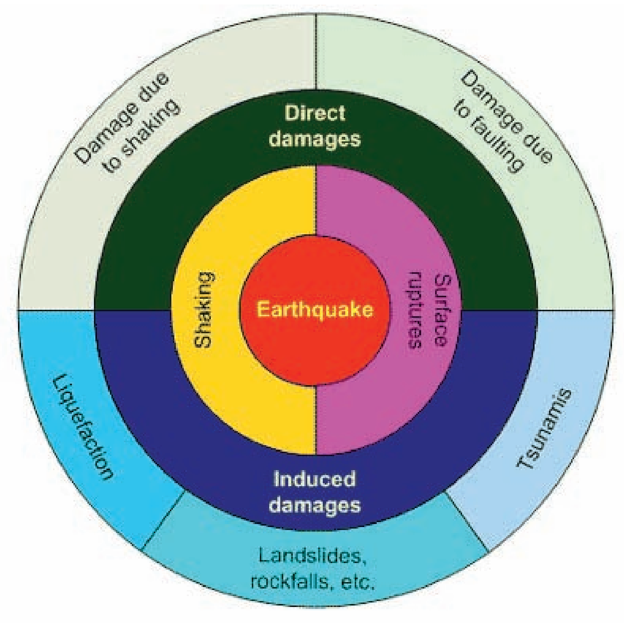


Figure 4.2.1: Relations between earthquakes and possible triggered hazards (Turk and Gumusay, 2008)

4.2.1 Seismic risk assessment

Scientific and technical background

In the assessment of seismic risk, one of the first steps is the realization of an earthquake hazards zonation, which identifies sites more susceptible to earthquake damage and related secondary effects due to local site conditions (Theilen-Willige et al., 2011). In particular, GIS integrated with remote sensing data and geodata analysis can be used to visualize factors that are related to the occurrence of higher earthquake shock and/or earthquake induced secondary effects (Theilen-Willige at al., 2011). Moreover, GISs play a fundamental role in the hazard evaluation process inasmuch they allow the realization of referenced geo-databases containing maps, information and spatial data layers derived from satellite data and various other sources (e.g. topographic, soil, geologic, hydrogeologic and land use maps) (Theilen-Willige et al., 2011).

In general, common datasets used in seismic hazard assessment are:

- *Seismic hazard zonation*: as stated above, the seismic hazard could be assessed by evaluating possible earthquake-related natural phenomena such as ground-shaking, fault rupture, and soil liquefaction. The most relevant of these is ground-shaking which predominantly depends on factors such as the magnitude of the earthquake, properties of the fault plane, and the distance between the fault and local geologic structures (Theilen-Willige et al., 2011). Ground-shaking is measured using the Peak Ground Acceleration (PGA), which indicates the magnitude of the shaking after an earthquake, or the Spectral Acceleration (SA), which indicates the maximum acceleration on an object during an earthquake.
- *Morphologic map*: the steepest slopes, areas with the highest curvature and depressions can be identified by parameterizing Digital Elevation Models (DEM) of the location, which may be combined with lithologic and seisomotectonic information in an exhaustive referenced database (Theilen-Willige et al., 2011).

Furthermore, remote sensing tools can support geologists in detecting stress in the rocks and hence forecasting areas that might be subject to an earthquake. Interferometric Synthetic Aperture Radar (InSAR) techniques based on satellite radar data can monitor even very small changes in the terrain surface that might indicate pressure in the geological structures. Other sensors, such as hyper-spectral space-based or airborne scanners, can assist to detect anomalies in the environment, e.g. thermal emissions, gas or other indicators that point to ongoing underground activity (Altan and Kemper, 2008).

Besides hazard assessment, geoinformation tools also have a fundamental role in the assessment of physical and functional vulnerability. Common datasets used in the evaluation process are:

- *Macroscopic classification*: multi-spectral characteristics of satellite images reveal different reflectances of materials on the earth's surface (Yamazaki et al., 2003). For instance, urban areas in Metro Manila were classified into six land cover classes (congested, non-congested, vegetation, bare ground, water, and cloud cover) based on the commonly used Normalized Differential Vegetation Index (NDVI) acquired from Landsat satellite data with ground resolutions of 30 m (Yamazaki et al., 2003; Yamazaki and Matsuoka, 2006; see Figure 4.2.2). Moreover, using a time series of satellite images, the urban areas can be further classified according to the age of buildings (Figure 4.2.3), and thus their compliance with the seismic building codes in force at the time of their construction (Yamazaki and Matsuoka, 2006).
- *Microscopic urban classification*: besides a general land-cover classification, high resolution satellite images allow more detailed analysis. For instance, from IKONOS II satellite acquisitions (ground resolution 1m) the built environment in Old Manila was classified using two indexes: NDVI and the uniformity of image texture in a local area (Yamazaki et al., 2003). Specific classification results are shown in Figure 4.2.4.
- *Location of vulnerable objects*: according to (Theilen-Willige et al., 2011), geoinformation tools also allow the integration of disaster response institutions such as fire stations, police stations, hospitals and disaster management centres. In particular, a strategic database con-

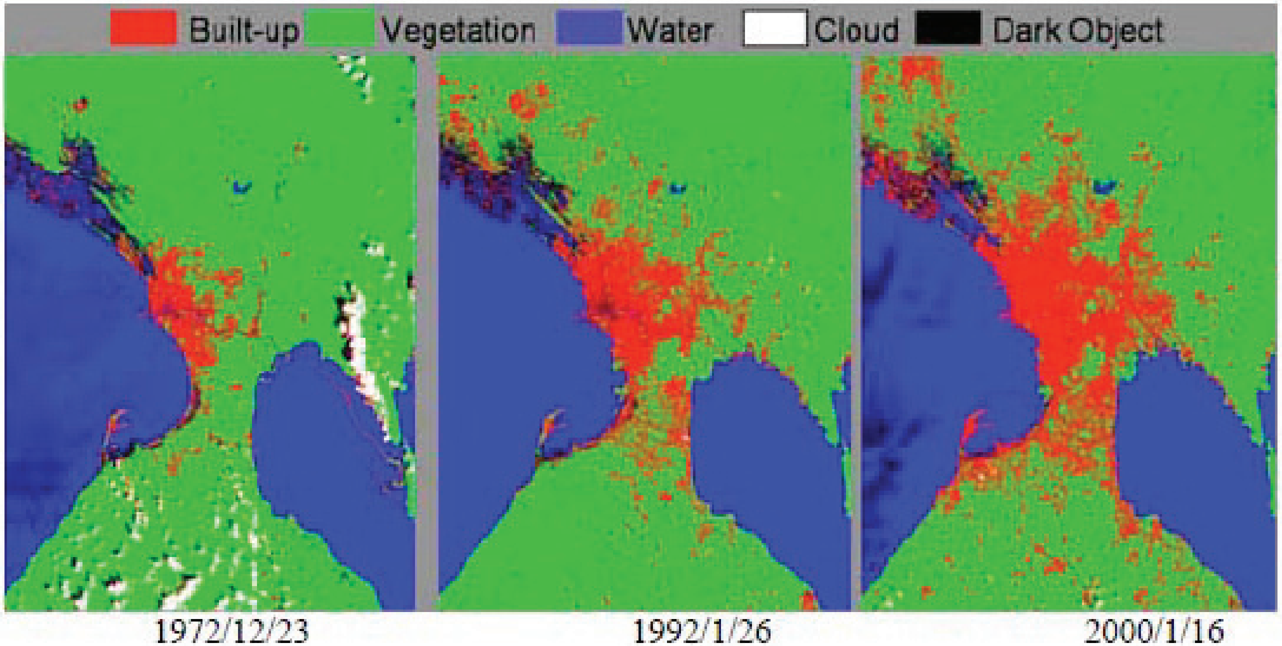


Figure 4.2.2: Earth surface classification for Metro Manila estimated from Landsat images in 1972, 1992 and 2000 (Yamazaki and Matsuoka, 2006)

taining information about the capacities of hospitals, fire stations and police stations (e.g. in terms of staff, beds, equipment, etc.), may be included in the process of risk assessment (Theilen-Willige et al., 2011).

- *Location of critical infrastructure*: a dataset containing information on industrial buildings, gas stations, infrastructure etc. may be included in the process of risk assessment through its integration in the specific Geoinformation System. Another important aspect for emergency preparedness and damage loss estimation is the actual inventory of land use and infrastructure of industrial facilities, settlements and cities, including age, structure, type and functions of buildings (Theilen-Willige et al., 2011).

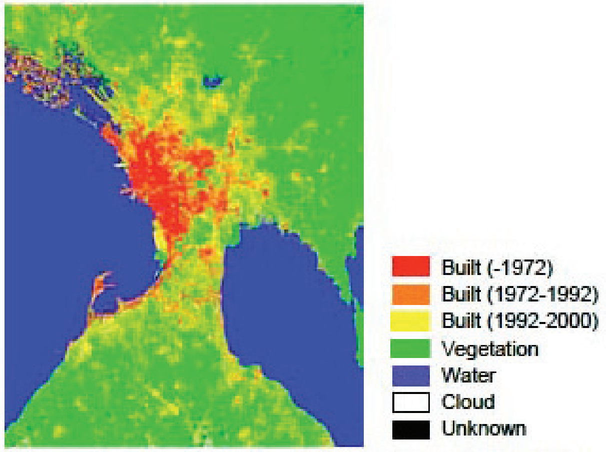


Figure 4.2.3: Distribution of estimated building ages for Metro Manila by time-series analysis (source: Yamazaki and Matsuoka, 2006)

All these datasets used in the hazard and vulnerability assessment are integrated in the Technical Profile for an Urban Classification for Earthquake Risk Analysis shown in Table 4.2.1.

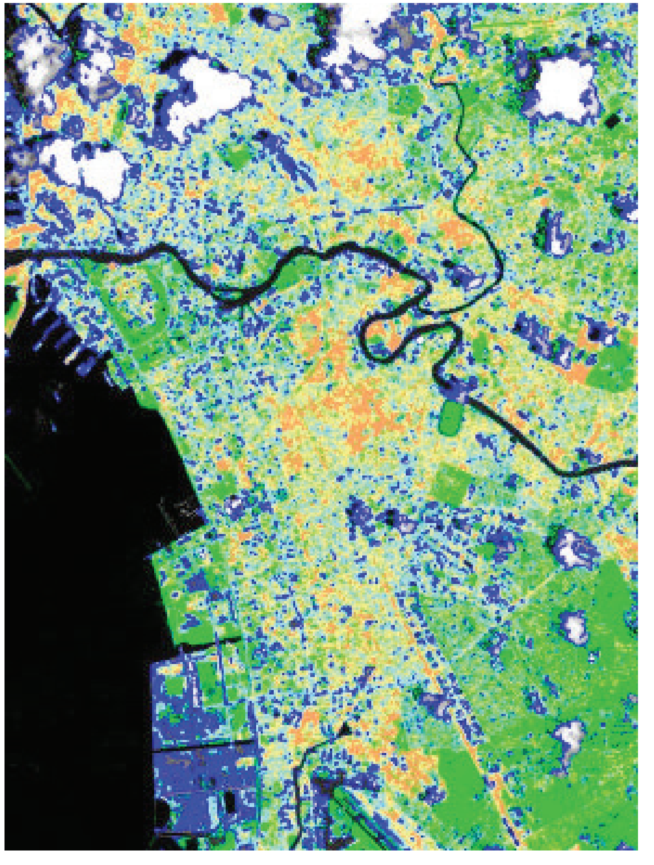


Figure 4.2.4: Result of microscopic classification in Old Manila using pan-sharpened IKONOS II image. Orange and yellow: dense areas with low-rise buildings, light blue: mid-height buildings (mainly commercial areas); blue: areas with large buildings and others; green: vegetation areas (source: Yamazaki et al., 2003)

Topic	Regional vulnerability to economic, environmental, or social impacts of drought
Thematic content	8 drought vulnerability classes based on • socio-economic data (such as gross domestic product per capita, dependence on agriculture for income and employment, total and rural population) and • biophysical data (such as land cover, annual precipitation and river discharge, soil depth, soil degradation)
Access	Upon registration via internet
Scale	Not applicable
Accuracy	Not applicable
Areal coverage	Global/Regional
Spatial resolution	• 0.5° x 0.5° (average) for global raster datasets used for drought vulnerability indicators • national aggregation level for socioeconomic data
Timeliness	Not relevant for vulnerability assessment
Update frequency	2 - 10 years
Data format	Raster Maps and vector datasets (OGC standard)

Table 4.2.1: Technical Profile for Urban Classification for Earthquake Risk Analysis

Appraisal results

Operational benefits of an Urban Classification were generally assessed as high by more than 55 % of the end-users (Figure 4.2.5), with a score of 90 % for the management of *critical infrastructure*, and the other 10 % with a medium benefit score. Indeed, damage to critical infrastructure may lead to other accidents (so-called Natech accidents) in the aftermath of seismic waves. Therefore, knowing their location and the composition of the surrounding urban environment are fundamental to the assessment of risk and its reduction. Also for *humanitarian aid* and *security*, sectors most involved in case of a disaster, the product was evaluated as highly beneficial by >70 % and >60 % of end-users and non-end-users, respectively.

Comparing Figures 4.2.5 and 4.2.6, it is noticeable that non-end-users rated the operational benefits as less than end-users. This is particularly true for *health care*. Benefits for *critical infrastructure*, however were also rated as high by nearly 90 % of non-end-users, probably due to the same reasons as stated above.

Apparently, end-users and non-end-users alike ascribe a high benefit of risk analysis in advance of an actual earthquake disaster in an urban environment to the maintenance of *critical infrastructure* in the course of emergency response activities.

End-users considered the **strategic benefits** as highly significant (Figure 4.2.7), in particular for *efficiency of plans and policies* and *support of preventive strategies* (both with >70 %), followed by *reducing losses in public economy* (nearly

70 %). *Support of superregional consistency and cooperation* registered with just above 50 %: earthquakes are phenomena that generally afflict restricted areas and consequently an Urban Classification may not be beneficial for large scale activities. The lower value for high benefit to *public acceptance of plans and policies* (<50 %) is probably due to the fact that an urban classification represents the base on which to develop appropriate information products for the public. Therefore, this technical product as such may not improve public awareness of risks and vulnerabilities without dedicated visualization products for public dissemination.

The vast majority of the non-end-users generally confirmed the strategic benefits appraisal by end-users, with lower high benefit scores except for support of preventive strategies (>80 %) and public acceptance of plans and policies (>60 %) (Figure 4.2.8). Whereas the high value of an urban database for earthquake risk analysis seems self-evident with regard to prevention support, the non-end-users' comparatively high benefit score for public acceptance of plans and policies may reflect a less critical view on the needs for dedicated public awareness raising.

Regarding the **criticality of specific product features** (Figure 4.2.9), *access* (which is upon registration via internet) is ranked as highly critical by more than 60 % of end-users, followed by *spatial resolution, areal coverage, accuracy* (which refers to geometric accuracy) and *thematic content* with about 5 % lower score. By contrast, *scale* and *data format* were considered as less critical.

Data format and *update frequency* were evaluated as of very low criticality by the non-end-users, with only around 20 % of respondents rating them as highly critical (Figure 4.2.10). *Thematic content* and *access* were assessed by end-users as the most critical features. Nevertheless, some respondents commented that more specific vulnerability parameters of built-up areas (e.g. materials used, number of floors, and technical code values on earthquake resistance) should also be included. *Accuracy* and *areal coverage*, which are important issues for thematic maps, were considered by the majority of respondents as highly critical, while the response was less significant for *spatial resolution* and *scale*. In particular, some non-end-users also commented that a spatial resolution of 5 m is not sufficient for evacuation routing and for identifying access to open space.

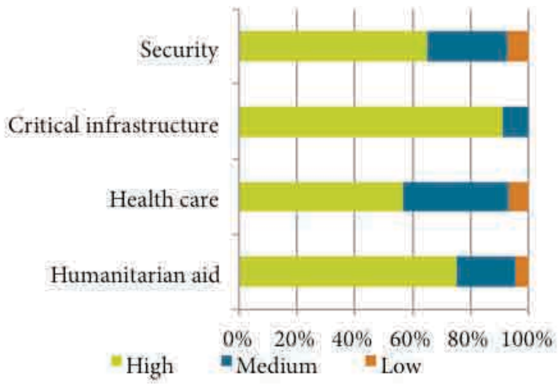


Figure 4.2.5: Operational Benefits of Urban Classification for Earthquake Risk Analysis (end-users appraisal)

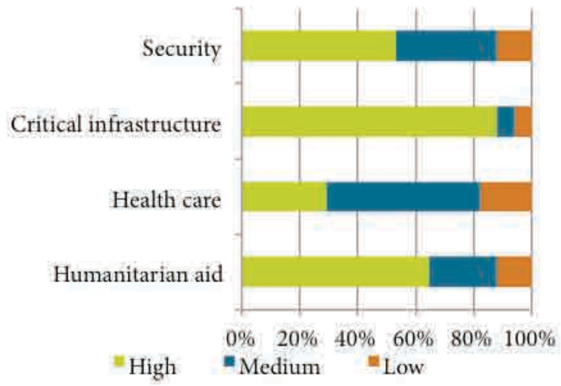


Figure 4.2.6: Operational Benefits of Urban Classification for Earthquake Risk Analysis (non-end-users appraisal)

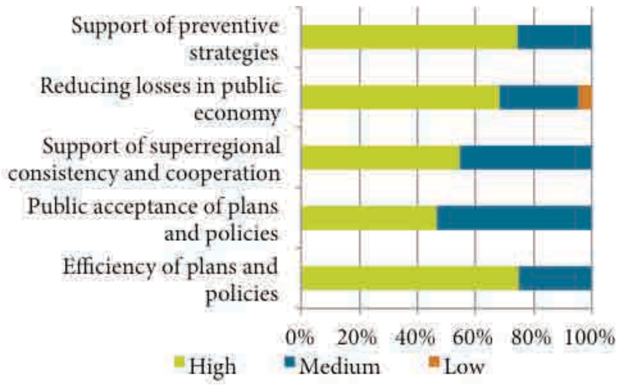


Figure 4.2.7: Strategic Benefits of Urban Classification for Earthquake Risk Analysis (end-users appraisal)

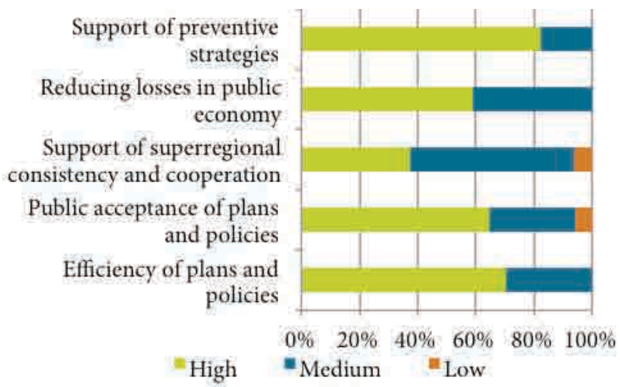


Figure 4.2.8: Strategic Benefits of Urban Classification for Earthquake Risk Analysis (non-end-users appraisal)

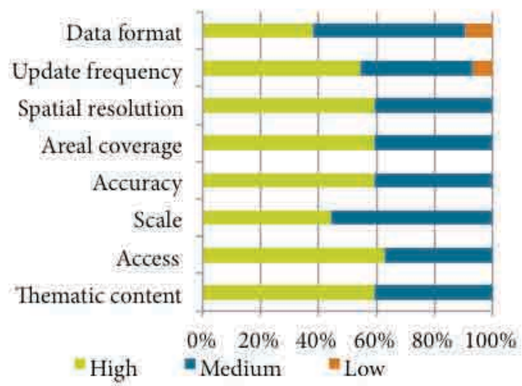


Figure 4.2.9: Criticality of specific features of Urban Classification for Earthquake Risk Analysis (end-users appraisal)

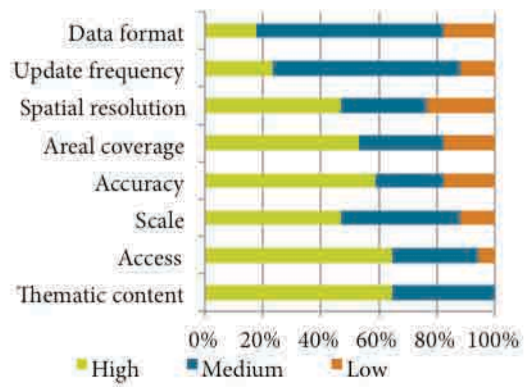


Figure 4.2.10: Criticality of specific features of Urban Classification for Earthquake Risk Analysis (non-end-users appraisal)

4.2.2 Earthquake Damage Assessment

Scientific and technical background

Damage assessment involves determining the extent of damage to life, property and the environment resulting from a disaster. Earthquakes can cause severe damage to buildings and infrastructure and massive loss of human life. For this reason, it is important for emergency management and recovery work to capture the damage distribution immediately after the disaster event in order to prioritize relief efforts. In recent years, remote sensing technology has increasingly been recognized as a valuable post-earthquake damage assessment tool. Recent studies performed by research teams in the United States, Japan and Europe have demonstrated that building damage sustained in urban environments can be readily evaluated through the analysis of optical and Synthetic Aperture Radar (SAR) imagery (Adams et al., 2004).

A Damage Assessment Map generated in this way will display and highlight the damage to buildings and infrastructure and allow the definition of road accessibility. One of the first steps is the identification of the spatial distribution of structural damage by comparison with the situation before the event (Figure 4.2.11). Usually, the damage assessment process divides the affected area into different classes depending upon the nature and intensity of damage (slight, heavy, collapsed). There are several methods available for identifying and evaluating damaged areas, the most frequently used are as follows.

A common approach is based on high spatial resolution optical satellite data e.g. from commercial satellites with a spatial resolution of the order of 0.5 m, that can acquire images in a few hours after the event. Post-disaster imagery is used to assess the impact of the earthquake by detecting and enumerating the collapsed buildings and identifying other affected infrastructure, such as damaged roads or features of interest (i.e. temporary shelters). In an operational context, a

Figure 4.2.11: Example of earthquake damage assessment in Boumerdes, Algeria (Adams, 2004)

visual interpretation approach is generally adopted to ensure that results are as reliable as possible. A simple damage assessment classification is conducted based on the European Macroseismic Scale (EMS-98), to display buildings subject to different grades of damage by comparing the pre- and post-event images (Yamazaki et al., 2005).

In the case of the 2003 Bam Earthquake a Damage Assessment Map was created by visual interpretation using the high-resolution satellite images acquired from the QuickBird satellite before and after the event, and subsequently a damaged building survey was carried out. Comparing pre and post-event pan-sharpened images, buildings surrounded by debris, partially collapsed buildings and totally collapsed buildings were identified and categorized as *slightly damaged, heavily damaged* and *collapsed* (Yamazaki et al., 2005) (Figure 4.2.12).

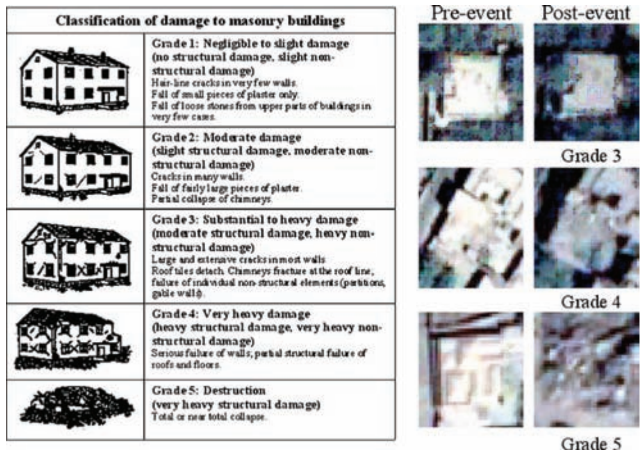
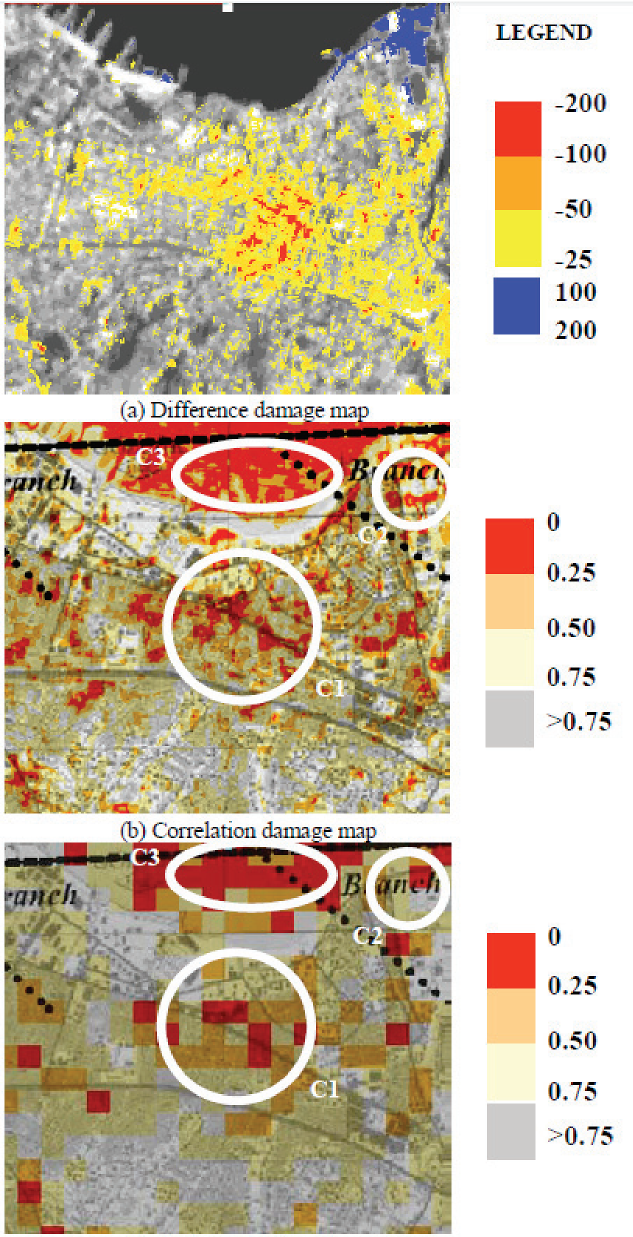


Figure 4.2.12: Classification of damaged buildings (EMS1998) and pre and post visual interpretation (Yamazaki et al., 2005)

An innovative approach is a damage detection algorithm, which allows the determination of the location and severity of post-earthquake building damage. It is based on the comparative analysis of a multi-temporal sequence of optical or SAR images, acquired before and after an earthquake event. A pair of 'before' and 'after' images are pre-processed to remove geometric errors inherent in the data, and all scenes are registered in a common coordinate system. Depending on the sensor resolution, an additional image processing step involving edge detection and texture analysis may then be performed to highlight features of interest (i.e. non-damaged and collapsed buildings). Changes between the scenes are then computed using a simple arithmetic operator, such as the *Difference, Correlation* or *Block Correlation*. Damage severity is established through building damage profiles, which demonstrate the general correlation between temporal changes in the remote sensing imagery and the extent of building collapse, as determined by field survey (Adams, 2004).



(a) Difference damage map

(b) Correlation damage map

(c) Block correlation damage map

Figure 4.2.13: Damage maps of Golcuk city center derived from SPOT satellite images (source: Adams, 2004)

Topic	Spatial distribution of structural damage due to earthquake
Thematic content	• Topographic base map • Damage to buildings disaggregated by 3 classes (slight, heavy, collapsed) • Damage to critical infrastructures • Road accessibility
Access	Upon registration via internet
Scale	1:500 - 1:10,000
Accuracy	0.2 m - 2 m
Areal coverage	Regional
Spatial resolution	0.5 m - 5 m
Timeliness	few hours after an emergency
Update frequency	Not applicable
Data format	Raster Maps and vector datasets (OGC standard)

Table 4.2.2: Technical Profile of Earthquake Damage Assessment Map

As described above, all the methods include a comparison between pre-and post-event images. Therefore, it is important to have a geographic information system that stores information and spatial data (e.g. topographic data, geologic and hydrogeologic data, land use/land cover data, settlements etc.) as reference data in order to evaluate subsequent damage (Adams et al., 2004; Teimouri et al., 2008).

All this thematic content used to evaluate the spatial distribution of structural damage is part of the Technical Profile for an Earthquake Damage Assessment Map. The specific features of this product are shown in Table 4.2.2.

Appraisal results

Concerning **operational benefits** (Figure 4.2.14), end-users attributed high benefit (>90 %) to Damage Assessment Mapping for *humanitarian aid* and *critical infrastructure protection,* sectors which are most impacted by an earthquake. A high benefit rating was also given with regard to *security* (>60 %) and *health care* (>70 %).

Also non-end-users evaluated the *benefits for humanitarian aid* and *critical infrastructure* as highest, but with lower scores for all aspects in comparison with end-users (Figure 4.2.15). End-users and non-end-users alike gave no low-benefit ratings to the product with regard to *humanitarian aid* and *critical infrastructure*.

Also the **strategic benefits** are considered highly relevant by the vast majority of the end-users (Figure 4.2.16), apparently in recognition of the full information potential of an emergency product which can serve to minimize losses in the actual emergency situation, as well as to support preventive reconstruction and mitigation plans in the follow-on. Indeed, around 70 % of end-users assigned a high benefit to the product with regard to *support of preventive strategies* and *reducing losses in public economy,* and more than 60 % did so for *efficiency of plans and policies*. A slightly lesser rating was assigned with respect to *support of superregional consistency* and *cooperation and the public acceptance of plans and policies*, where the latter was evaluated of medium benefit by more than half of the end-users.

In general, non-end-users considered the strategic benefits of Damage Assessment Maps less important than end-users. In particular, the benefits for *reducing losses in public economy* and *support of superregional consistency and cooperation* were evaluated as less significant, with an increase in medium and low benefit scores (Figure 4.2.17). *Efficiency of plans and policies* and *support of preventive strategies* obtained the highest benefit rating (almost 50 % of high benefit scores). However, also in these cases, there was an increase in the medium benefit assessments.

Concerning the **criticality of specific product features** (Figure 4.2.18), the responses of more than 70 % of end-users rated *spatial resolution* and *accuracy* as the features of greatest importance, followed by *scale, areal coverage* (both >60 % high criticality), *access* (i.e. via internet), *timeliness* and t*hematic content* (>50 %). *Data format* was considered of secondary importance.

The non-end-users gave a substantially different response to the level of criticalities compared with end-users (Figure 4.2.19). The features considered of highest importance were *thematic content* and *timeliness*, with nearly 80 % of non-end-users evaluating them as highly critical. *Access* to the product was the third most critical feature (>60 %). A lower percentage of high criticality scores, were attributed to *accuracy* (nearly 60%) and *scale* (>50 %). High criticality of *spatial resolution* and *areal coverage* scored even lower with <50 %, although in particular *spatial resolution* is a relevant aspect for the cartographic output and often may influence the quality of the map products and the typology of *thematic content*. *Data format* was the feature with the least importance also to non-end-users.

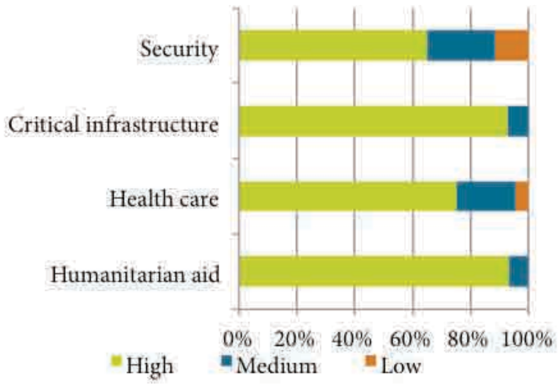


Figure 4.2.14: Operational Benefits of Earthquake Damage Assessment Map (end-users appraisal)

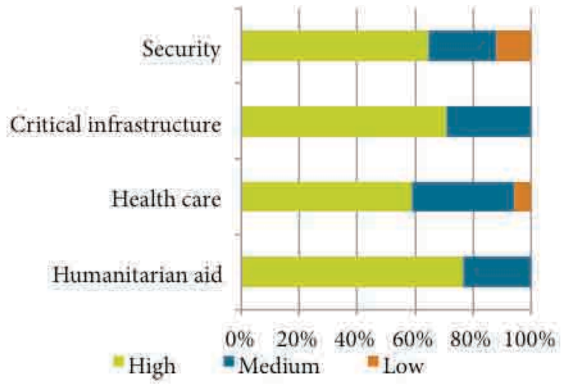


Figure 4.2.15: Operational Benefits of Earthquake Damage Assessment Map (non-end-users appraisal)

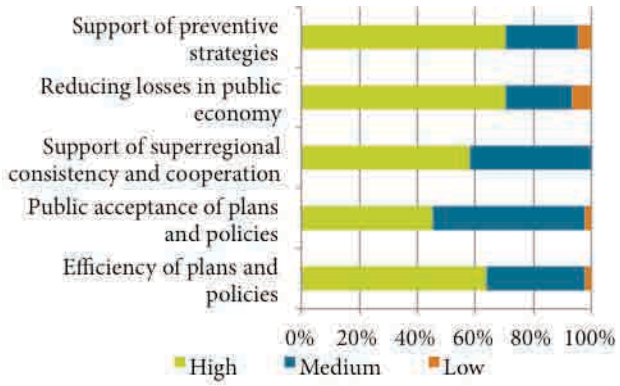


Figure 4.2.16: Strategic Benefits of Earthquake Damage Assessment Map (end-users appraisal)

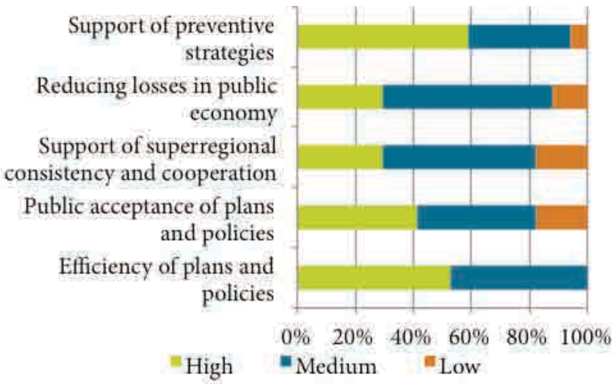


Figure 4.2.17: Strategic Benefits of Earthquake Damage Assessment Map (non-end-users appraisal)

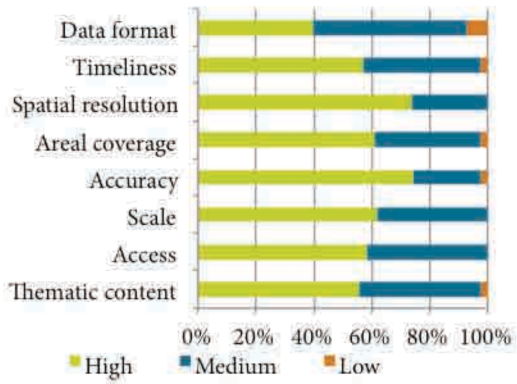


Figure 4.2.18: Criticality of specific features of Earthquake Damage Assessment Map (end-users appraisal)

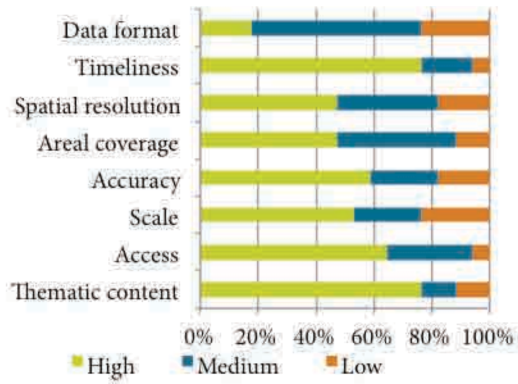


Figure 4.2.19: Criticality of specific features of Earthquake Damage Assessment Map (non-end-users appraisal)

4.3 Drought hazard assessment and vulnerability mapping

Irene Angeluccetti and Francesca Perez

Article 1 of the United Nations Convention to Combat Desertification(UNCCD)[1] defines drought as "the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems".

Beyond this general definition, there are more specific ways of understanding drought. For example, a classification of droughts from a discipline perspective also exists. Thus, in terms of typologies, droughts are commonly classified as meteorological, agricultural, hydrological, and socio-economic inter-related events (see Figure 4.3.1).

In general, the potential disaster losses in terms of lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period, are defined as *disaster risk* (UNISDR, 2009b). The risk associated with a disaster for any region or group is a product of the *exposure* to the natural hazard and the *vulnerability* of the society to the event. Therefore, *drought risk* is based on a combination of the frequency, severity, and spatial extent of drought events (the physical nature of the considered hazard) and the degree to which a population or activity is vulnerable to the effects of drought (UNISDR, 2009b). The degree of vulnerability of a region depends on the environmental and social characteristics of the region and is measured by the inhabitants' ability to anticipate, cope with, resist, and recover from drought.

In the following, some considerations regarding indicators and indices developed to identify, assess and map drought hazards and vulnerability are presented.

Scientific and technical background

The frequency of drought events at various levels of intensity and duration defines the *drought hazard* for the nations and regions considered. Because of the complex definition of the observed phenomena, several indices have been developed to characterize the meteorological, soil moisture and hydrological aspects of the hazard in order to analyze the historical frequency, severity and extent of drought events. Starting from the investigation of the historical occurrence of drought in a country, the most drought-prone and chronically drought-affected areas can then be classified.

Commonly used drought hazard indicators/indices include (IPCC, 2012):

- those based only on precipitation data, e.g. the Standard Precipitation Index (SPI) (McKee et al., 1993; Lloyd-Hughes and Saunders, 2002) and the Consecutive Dry Days (CDD) index (Frich et al., 2002; Alexander et al., 2006);
- those that reflect both precipitation and estimates of actual or potential evapotranspiration, e.g. the Palmer Drought Severity Index, PDSI, (Palmer, 1965), the Precipitation Potential Evaporation Anomaly, PPEA, (Burke and Brown, 2008) and the Standardized Precipitation Evapotranspiration Index, SPEI (Vicente-Serrano et al., 2010);
- soil moisture anomalies (Dai, 2011; Orlowsky and Seneviratne, 2011; Zribi et al., 2012) and vegetation-derived monitoring indices, e.g. the Normalized Difference Vegetation Index, NDVI, (Bai, 2008; Townshend and Justice, 1986; Reed et al., 1994; Justice et al., 1996) which were specifically conceived for the assessment of agricultural drought.

It should be noted that most of these indicators/indices may be derived from satellite-based data, frequently available globally and free-of-charge, thus allowing proper drought hazard mapping activities.

People's *vulnerability to drought* is complex. The United Nations Secretariat of the International Strategy for Disaster Reduction (UNISDR) defines vulnerability as "the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard"[2].

Drought effects are substantial in both developing and developed countries, but the characteristics of these effects differ considerably. The ability to cope with drought also varies considerably from country to country and from one region, community, or group to another. The coping capacity is defined as "the ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters"[3]. In this framework, vulnerability is described by assessment of conditions of people derived from the historical and prevailing cultural, social, environmental, political and economic contexts. Vulnerable groups are not only at risk because they are exposed to a hazard but are also subject to the marginality of everyday patterns of social interaction and organization, and access to resources (Cardona et al., 2012).

According to the report in the United Nations Development Programme (UNDP, 2004) Visions of Risk: A Review of International Indicators of Disaster Risk and its Management, prepared by the Working Group on Risk, Vulnerability and Disaster Impact Assessment of the Inter-Agency Task Force of the International Strategy for Disaster Reduction (ISDR), at present the assessment and mapping of human vulnerability are less developed than the assessment of hazards.

---

1 http://www.unccd.int/en/about-the-convention/Pages/Text-Part-I.aspx

2 http://www.unisdr.org/eng/terminology/UNISDR-Terminology-English.pdf

3 http://www.unisdr.org/we/inform/terminology

Vulnerability assessments vary in the balance between considerations of social, economic and political characteristics and the extent to which environmental and ecological assets are included. For this reason, and because of the dynamic nature of human vulnerability, the implementation of a comprehensive vulnerability assessment has proven difficult (UNDP, 2004).

A general approach proposed by the UNISDR to assess vulnerability, is based on drought impact assessment activities. Each drought produces a unique set of impacts, depending not only on the drought severity, duration and spatial extent, but also on the ever changing social conditions. For practical purposes, drought impacts can be classified as economic, environmental, or social, even though several of the impacts may actually span more than one sector and are linked closely to each other (see Tables 4.3.1, 4.3.2 and 4.3.3). These impacts are symptoms of underlying vulnerabilities. Identification and prioritization of drought impacts will raise an important question: why have these significant impacts occurred or why might they occur? Mapping the cause/effect relationships of such impacts helps to understand where the triggering factors are, how these underlying factors interact with each other at both micro and macro levels, and how these dynamics create vulnerability within a society. Therefore, impact assessments are a good starting point in helping to highlight sectors, populations, or activities that are vulnerable to drought (UNISDR, 2009b).

In general, an impact assessment is carried out by reviewing the past or current drought records and it is included in a more general risk assessment procedure, comprising:

- the analysis of the historical frequency, severity and extent of drought,
- the identification and ranking of drought-related impacts, and
- a vulnerability analysis to investigate why the impacts occur.

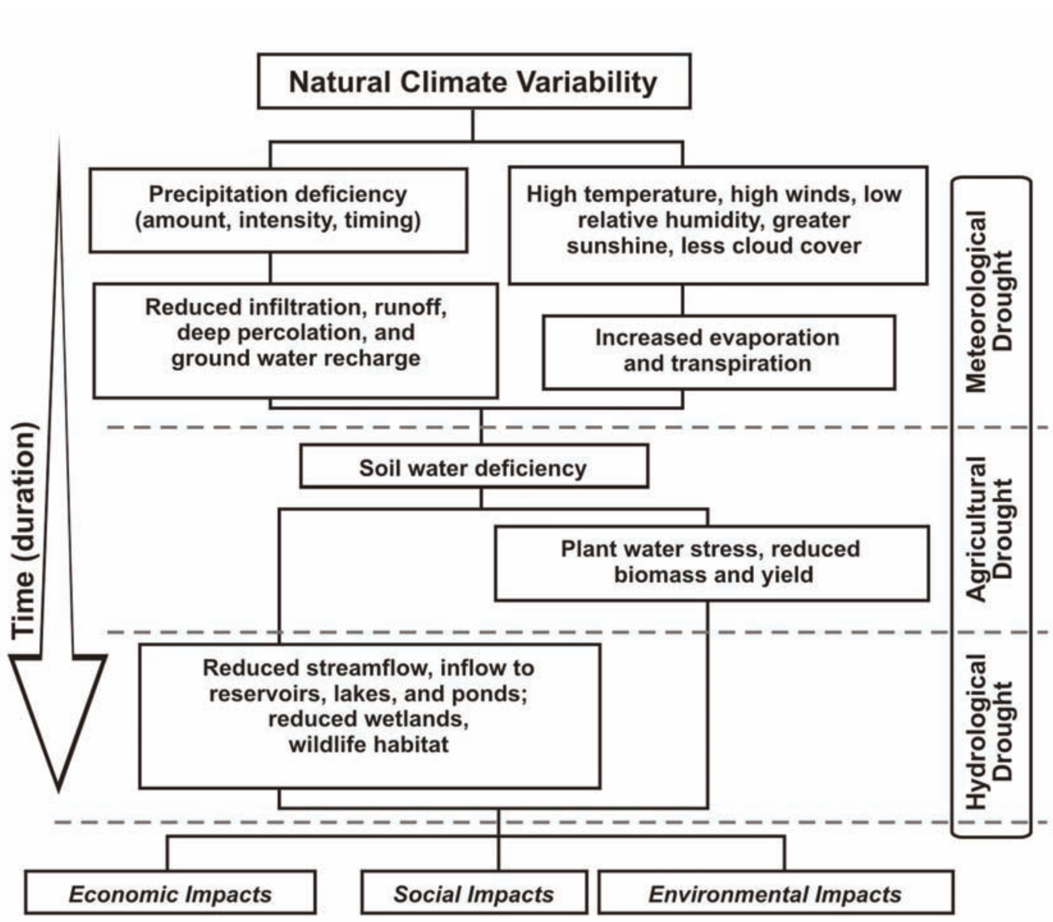


Figure 4.3.1: Relationship between meteorological, agricultural, hydrological and socio-economic drought (National Drought Mitigation Center, University of Nebraska-Lincoln, USA)

	Direct Impacts	*Indirect Impacts*
Costs and losses to agricultural producers	• Annual and perennial crop losses • Damage to crop quality • Reduced productivity of cropland, e.g., wind erosion • Insect infestations • Plant diseases • Wildlife damage to crops	• Income loss to farmers because of reduced crop yields • Increased irrigation costs • Cost of new or supplemental water resource development, e.g., wells, dams and pipelines • Long-term loss of organic matter • Loss to industries directly dependent on agricultural production, e.g., food processors • Increased commodity prices
Costs and losses to livestock producers	• Reduced productivity of range land, animal carrying capacity • Increased travel time for grazing • Decreased stock weights and reduced milk production • Increased livestock diseases • Closure/limitation of public lands to grazing • Range fires	• Forced reduction of foundation stock (seeds) • High cost/unavailability of feed or water for livestock • Reductions in livestock market prices • Increased feed transportation costs • Disruption of reproduction cycles (delayed breeding, more miscarriages) • Increased predation and pouching
Costs and losses to industry and urban activities	• Higher cost of water and sanitation • Decrease in public water supplies • Impacts on transportation • Higher cost/lower availability of hydro-electric power	• Higher cost or unavailability of water for horticulture, agro-food processing and value added manufacturing • Impaired productivity of forest land and reduced timber production • Increased pollution, e.g., dust • Increased diseases • Reduction in tourism revenue, e.g., wildlife • Strain on financial institutions, e.g., greater credit risks

Table 4.3.1: Economic impacts of drought (UNDP, 2011)

	Direct Impacts	*Indirect Impacts*
Hydrological	• Lower water levels in reservoirs, lakes and ponds • Reduced stream flow • Loss of wetlands • Increased groundwater depletion and land subsidence	• Increased time and cost for water collection and transfer • Lower water quality, e.g., salinization and temperature increase • Waterborne diseases • Wind and water erosion on soils
Biological	• Loss of trees and vegetation • Loss of animal species diversity	• Fragmentation and destruction of wildlife habitats • Migration, concentration and increased predation • Loss of biodiversity

Table 4.3.2: Environmental impacts of drought (UNDP, 2011)

	Direct Impacts	*Indirect Impacts*
Reduced quality of life	• Increased workload for women in collecting fuel-wood and water • Reduced levels and variety of food sources • Increased government expenditure on relief	• Increased poverty • Migrations (rural to urban areas, cross border) • Reduction or modification of recreational activities • Disruption of cultural practices and belief/value system • Loss of cultural sites and aesthetic values
Increased conflicts		• Water user conflicts • Political conflicts • Management conflicts • Other social conflicts, e.g., scientific and media-based
Health	• Physical and emotional stress, e.g., anxiety, depression and loss of security	• Health-related low-flow problems, e.g., cross-connection contamination, diminished sewage flows, increased pollutant concentrations and reduced firefighting capability • Reductions in nutrition • Loss of human life • Public safety from forest and range fires • Increased respiratory ailments • Increased disease caused by wildlife concentrations

Table 4.3.3: Social impacts of drought (UNDP, 2011)

Starting from investigating drought impacts, some indicators have been developed to characterize *drought vulnerability*, considering the economic, environmental, or social nature of these impacts, and are specifically used for mapping vulnerability on a global scale. Generally, these indicators are based on global socio-economic databases available on a national aggregation level (or even a sub-national level, but in this case, they are unlikely to be of global coverage) or geospatial datasets with a very coarse resolution, some of which are derived from satellite acquisitions. It should be noted that this issue constitutes a major limitation of the attainable spatial resolution of the final vulnerability maps.

Common examples of base datasets used for the definition of drought vulnerability indicators, considering socio-economic as well as natural components of coping capacity and related references, are summarized in Table 4.3.4. In this table, particular attention has been paid to the datasets used for the production of global risk indices. In particular, the Disaster Risk Index (DRI) developed by the United Nations Development Programme (UNDP) (Peduzzi et al., 2009; BCPR-UNDP, 2004) and the World Risk Index (WRI) (Birkmann and Mucke, 2011) have been taken into consideration.

Figures 4.3.2 and 4.3.3 give two examples of maps showing reported components of drought vulnerability.

Furthermore, it should be noted that many complex drought vulnerability indicators can be found in literature, based on more specific datasets, but seldom have these methodologies proven to be applicable globally, mainly because of their lack of geospatial reference data. Therefore, these indicators have not been considered in order to define the Technical Profile as shown in Table 4.3.5.

Components	*Dataset*	*Reference*
Socio-economic capacity	GDP per capita	Birkmann and Mucke, 2011; Eriygama et al., 2009
	Agriculture, value added (% of GDP)	Eriygama et al., 2009
	Employment in agriculture (% of total employment), unemployment rate	Eriygama et al., 2009; Birkmann and Mucke, 2011
	Population and rural population figures	Birkmann and Mucke, 2011; Peduzzi et al., 2009; Eriygama et al., 2009
Natural capital	Arable/irrigated land area	Peduzzi et al., 2009
	Cropland area and land cover	Peduzzi et al., 2009
	Annual Precipitation and River Discharge	Birkmann and Mucke, 2011; Eriygama et al., 2009
	Depth of soil and human induced soil degradation (GLASOD)	Eriygama et al., 2009; Peduzzi et al., 2003

Table 4.3.4: Common base datasets used for vulnerability indicators development

Topic	Regional vulnerability to economic, environmental, or social impacts of drought
Thematic content	8 drought vulnerability classes based on • socio-economic data (such as gross domestic product per capita, dependence on agriculture for income and employment, total and rural population) and • biophysical data (such as land cover, annual precipitation and river discharge, soil depth, soil degradation)
Access	Upon registration via internet
Scale	Not applicable
Accuracy	Not applicable
Areal coverage	Global/Regional
Spatial resolution	0.5° x 0.5° (average) for global raster datasets used for drought vulnerability indicators national aggregation level for socioeconomic data
Timeliness	2 - 10 years
Update frequency	Depth of soil and human induced soil degradation (GLASOD)
Data format	Raster Maps and vector datasets (OGC standard)

Table 4.3.5: Technical profile for Drought Vulnerability Map

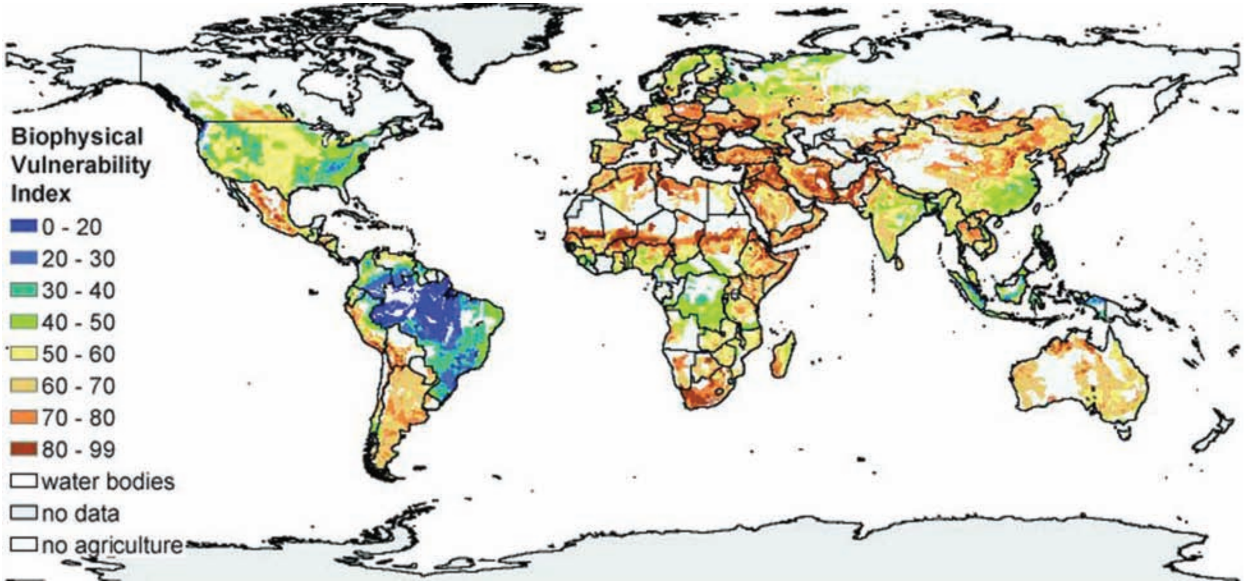


Figure 4.3.2: Biophysical Vulnerability Index based on mean annual surface runoff, mean annual groundwater recharge, soil depth and soil degradation severity within 0.50 grid cell. (Eriygama et al., 2009)

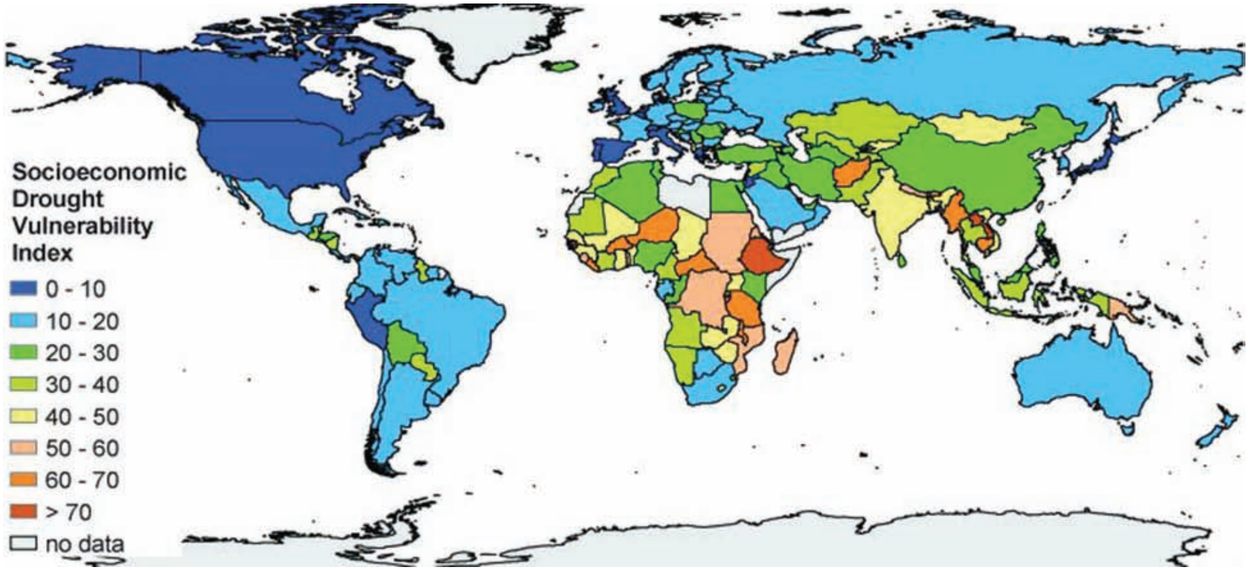


Figure 4.3.3: Socioeconomic Drought Vulnerability Index based on the crop diversity of individual countries and their dependence on agriculture for income and employment generation (Eriygama et al., 2009)

Appraisal Results

Considering the **operational benefits** of a Drought Vulnerability Map (Figure 4.3.4), *humanitarian aid* scored highest in the appraisal by end-users with a >65 % high benefit rating, followed by *health care* with >50 %. Indeed a Drought Vulnerability Map could provide useful information on areas and people most affected by such a crisis and could be helpful in the provision of support to those subjected to a famine, which is one of the indirect consequences of drought. The appraisal results from non-end-users followed a similar pattern, but with a lower score for all operational aspects, especially so for *critical infrastructure* and *security* (Figure 4.3.5).

For the **strategic benefits**, a high benefit was attributed to *support of preventive strategies* and to *efficiency of plans and policies* by more than 60 % of the end-users (Figure 4.3.6), which is plausible with regard to a distinctly prevention-oriented product such as a vulnerability map. A slightly lower rating was given to the benefit for *reducing economic losses*, which could be due to the fact that this kind of map was understood as representing a status quo ante and not an actual emergency situation. Likewise, the benefit to *efficiency of plans and policies* was also rated as high by more than 60 % of the non-end-users (Figure 4.3.7). In contrast to the end-users group, however, non-end-users gave similar high ratings to the benefits for *support of superregional consistency and cooperation* and *public acceptance of plans and policies.* This result apparently reflects the nature of droughts which often affect large areas requiring a coordinated supranational approach and public awareness of vulnerabilities and risks.

From the end-users' point of view, *thematic content* and *areal coverage* were the most **critical product features**, followed by *spatial resolution* (Figure 4.3.8). *Spatial resolution* is also a matter of concern for this cartographic product since it strongly influences the thematic content that can be included in the map.

Non-end-users also identified the *thematic content* most critical (Figure 4.3.9), but assessed the majority of the specific product features as less critical. However, non-end-users considered *access* as far more important, which is obviously a critical issue in many less developed countries affected by drought.

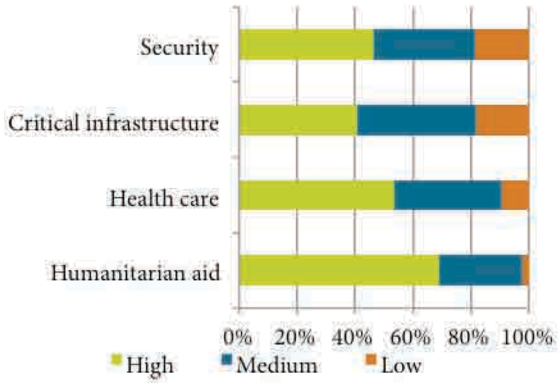


Figure 4.3.4: Operational Benefits of Drought Vulnerability Map (end-user appraisal)

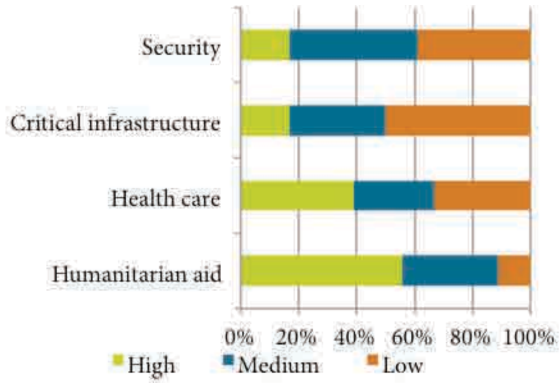


Figure 4.3.5: Operational Benefits of Drought Vulnerability Map (non-end-user appraisal)

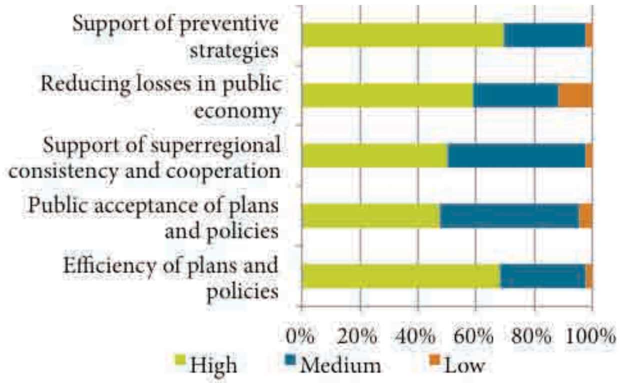


Figure 4.3.6: Strategic Benefits of Drought Vulnerability Map (end-user appraisal)

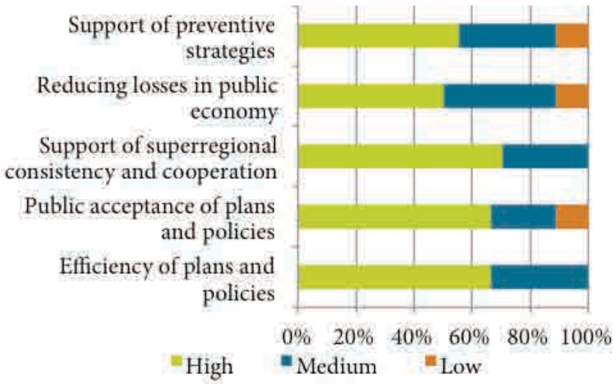


Figure 4.3.7: Strategic Benefits of Drought Vulnerability Map (non-end-user appraisal)

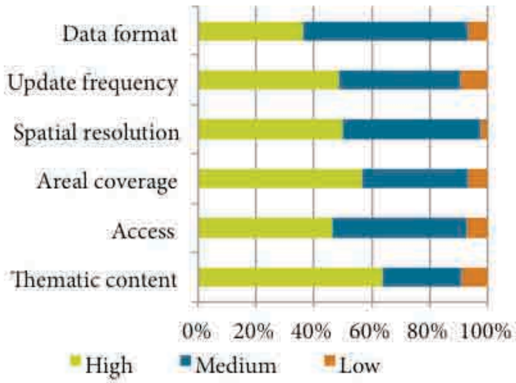


Figure 4.3.8: Criticality of specific features of Drought Vulnerability Map (end-user appraisal)

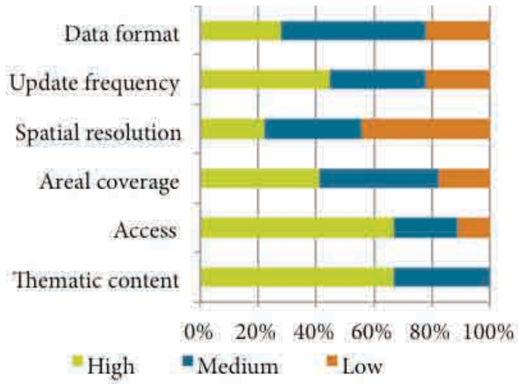


Figure 4.3.9: Criticality of specific features of Drought Vulnerability Map (non-end-user appraisal)

4.4 Fire risk mapping and fire detection and monitoring

Walther Camaro, Sara Steffenino and Rossella Vigna

Fires have far reaching impacts and can damage highways, utilities, bridges, reservoirs and watersheds, agri-business, ranching, timber operations, and community buildings. The economic and social impacts of damage from fires include job losses, destroyed natural resources, burdensome rebuilding costs, and limited transportation options. Furthermore fires can result in loss of life (Aragoneses and Rábade, 2008). For example, in Spain in 1994, 41 victims lost their lives due to forest fires, 20 of whom died in a single fire (Millares, 25,930 hectares) and 15 in three fires (Montemayor, St. Mateu de Bages and Alicante, 45.000 hectares), while in 2003 fires caused the death of seven people. Available literature on epidemiology, economics and wildfires provide essential information on evaluating health costs associated with fire events. The key health outcomes related to wildfires are mortality, restricted activity days (including work days lost), hospital admissions, respiratory symptoms, and ad hoc self-treatment by individuals. Inconsistent results are shown also between conventional and wildfire-related PM epidemiology studies (Kochi et al., 2009).

Climate change impact

Fire has been identified by the international community as an important variable for the Global Climate Observing System and an essential climate variable for the Framework Convention on Climate Change. Fire is an important process within most terrestrial biomes, and the release of gases and particulate matter during biomass burning is an important contributor to the chemical reactions and physical processes taking place in the atmosphere. Fire is a significant and continuous factor in the ecology of savannas, boreal forests and tundra, and plays a central role in deforestation in tropical and sub-tropical regions. In addition, on a periodic basis, extensive fires occur in many temperate biomes such as forests, grasslands, and chaparral. Monitoring the location and areal extent of biomass burning and its associated effects are important in the context of the goals and objectives of different research programs:

- Fire changes the physical state of vegetation, releasing a variety of greenhouse gases into the atmosphere. There is presently great uncertainty as to the magnitude of the sources and sinks of these greenhouse gases. For example, the net annual release of carbon into the atmosphere due to clearing and conversion of tropical forests for agricultural purposes (where biomass burning is a key tool used in the conversion process) is thought to contribute approximately 30 % to the net annual increase in the concentration of atmospheric CO_2. In addition, there is an interest in changes in regional fire regimes under different climate change scenarios. For example, arguments have been made that an increase in average air temperature in northern latitudes will lead to a decrease in the natural fire return interval and an increase in fire severity in boreal forest and tundra ecosystems.
- The release of chemically-reactive gases during biomass burning strongly influences chemical processes within the troposphere. In tropical regions, biomass burning has been shown to strongly influence regional and global distributions of tropospheric ozone and has been related to acid deposition. Studies have shown that intensive biomass burning associated with naturally occurring forest fires, deforestation practices and savanna management, are major sources of trace gases such as NO, CO_2, CO, O_3, NOx, N_2O, NH_3, SOx, CH_4, other non-methane hydrocarbons, as well as an abundant source of aerosols (Stith et al., 1981; Crutzen et al., 1985; Fishman et al., 1986; Andreae et al., 1988; Browell et al., 1988; Kaufman et al., 1992). Preliminary global estimates indicate that annual biomass burning may be associated with 38 % of the ozone in the troposphere; 32 % of global carbon monoxide; more than 20 % of the world's hydrogen, non-methane hydrocarbons, methyl chloride and oxides of nitrogen, and approximately 39 % of the particulate organic carbon (Levine, 1991; Andreae, 1991). Although these estimates include a wide range of uncertainty, it is becoming evident that these emissions may be as important to global atmospheric chemistry as industrial activities in the developed world (Crutzen et al., 1985; Crutzen and Andreae, 1990).
- The results of natural fires or processes associated with fires affect the exchange of energy and water between land surfaces and the atmosphere. Fires can result in a decrease in the surface albedo and increase in the amount of solar radiation reaching the soil layer at local and regional scales. Removal of the plant canopy during fire reduces the amount of evapotranspiration and typically results in higher water runoff. In tropical forests, land clearing associated with biomass burning has resulted in a significant reduction of total precipitation in the region, and an increase in the surface runoff, soil erosion and river sedimentation.
- Fires have several direct and indirect effects on terrestrial ecosystems. First, the pattern of fire (which includes its spatial distribution, fire return interval, and severity of burning) directly controls plant community development within those landscapes where biomass burning occurs. Fire favours those plants and tree species which have developed adaptations to fire (e.g., vegetative reproduction and fire-resistant seeds and cones) and eliminates those species which are less resistant to fire. Second, fire indirectly affects plant community development in a variety of ways, including (a) addition of key plant nutrients through ash fertilization or increased soil decomposition; (b) depletion of key plant

nutrients through surface runoff or increased soil leaching; and (c) altering soil temperature and moisture. Finally, chemical reactions of gases released by fire lead to an increase in atmospheric ozone and the deposition of acidic compounds downwind from fires, which in turn can affect the physiology of plants and ecosystems in these areas. Therefore, for several reasons, fire detection and monitoring are considered necessary elements, and fire management is considered a consequential crucial issue (Van Lierop, 2009).

Fire Management

Since forests are ecosystems, the maintenance of forests is vital not only for the trees themselves, but also for the sustainability of the other forms of life that depend on forests. Forests are providers of environmental services: they protect the soil from desertification and avalanches, furnish a natural barrier against wind, attract increasing tourism and play an important role in the livelihoods of poor people. Therefore the reasons for protecting forests from fire, pollution and other possible damages are obvious; forests and their structural and biological diversity are an important part of the natural environment.

Legislation passed in some countries provides evidence that forests constitute a most important semi-renewable resource and encourage researchers to foster activities on forest ecosystems, as well as education and training on forestry. The strong importance of forests and forestry policy has been accepted by all the European member states. An accurate analysis of the relationship between humans and forests is essential for assessing fire incidence, ignition and management. Since humans are considered primarily responsible for forest fire occurrences, they must be considered as important components of any fire management planning. A balanced fire management system is made up of four elements: prevention, preparedness, suppression and recovery (WWF, 2003). Each element is equally important and directly related to the others.

The prevention and preparedness scheme evaluates the vulnerability of the territory to fire. Critical periods and areas on where forest fires could be more likely to occur are evaluated not only from experience but also using tools such as GIS mapping. Areas at high fire risk should be subjected to specific preventive measures of land-use planning: e.g. fuel loads can be modified for hazard reduction. A fire management system should be considered as an integral part of the landscape planning in all areas at high risk of forest fires. Moreover, a fire management policy will be more effective only if most of the resources and efforts are employed at the early stage of the firefighting chain (WWF, 2003). Fire risk assessment is a critical part of fire prevention, therefore pre-fire planning activities require objective tools to monitor when and where a fire is likely to occur, or would have more negative impacts. The objective of a dedicated Fire Detection and Monitoring System, on the other hand, is early warning, monitoring, and assessment of actual fires, using current earth-observing technologies.

4.4.1 Fire Risk Mapping

Scientific and technical background

An advanced scheme for fire risk assessment was developed by Chuvieco et al. (2010), which includes the two aspects of total risk: fire danger and vulnerability. The model is based on input variables of fire danger, considering the two main sources of ignition, human and natural, and vulnerability which is the assessment of potential damage caused by a fire (see Table 4.4.1). Three different vulnerability input variables are taken into account in the work presented in Chuvieco et al., (2010): the *socio-economic values,* the *degradation potential* and the *landscape value*. The final objective can be defined in a GIS system displaying fire risk maps at regional scales, which integrates two groups of fire risk conditions thus creating a group of four risk classes, using local information and geoinformation.

The fire risk assessment method presented in the Chuvieco paper is generally based on considering fire occurrence probability and potential damage. The first element, *fire danger*, considers the potential that a fire will ignite and propagate. The two main sources of ignition, human and natural, must both be taken into account in calculating the fire danger. However while human sources of ignition are undoubtedly the most common and diffuse worldwide (FAO, 2007), fires caused by lightning are also very relevant in some regions. In addition to ignition sources, the moisture status of plants has been judged necessary, since plants are the main ignition material in a forest fire. The propagation component of fire danger is associated with the potential for fire spread, which is a result of the quantity and spread of fuel, in addition to favourable terrain and weather conditions (mainly wind speed).

The second group of fire risk conditions can be associated with the vulnerability component, which is the assessment of potential damage caused by the fire and impacts on the exposed values. For Chuvieco et al. (2010), vulnerability can be divided in three aspects, as stated above: *socio-economic values* (properties, wood resources, recreational importance, carbon stocks, etc.), *degradation potential* (soil and vegetation conditions), and *landscape value* (uniqueness, conservation status, etc.).

Fire danger is defined as: “the resultant, often expressed as an index, of both constant and variable factors affecting the inception, spread, and difficulty of control of fires and the damage they cause”;

Fire hazard is “a measure of that part of the fire danger contributed by fuels available for burning”;

Fire risk is “(1) the chance of fire starting as determined by the presence and activity of causative agents, (2) a causative agent, (3) a number related to the potential of firebrands to which a given area will be exposed during the rated day” (FAO, 1986).

Factor	*Input data*	*Method*
Human (Vilar et al., 2008)	Historical occurrence	Logistic regression
Lightning (Nieto et al., in press)	Demographic data Vegetation-DTM	
Dead fuels moisture content (Aguado et al., 2007)	Meteorological data	Linear regression analysis
Live fuels moisture content (Chuvieco et al., 2004b; Garcia et al., 2008)	Satellite images	Statistical fitting Inversion of RTM
Propagation danger (Martín Fernández et al., 2002)	Fuel type maps Meteorological data	Behave Simulation
Socio-economic values (Rodríguez y Silva et al., 2007)	Forest maps Recreational areas Questionnaires	Empirical models
Degradatation potential	Soil maps Digital terrain model Climatic data Vegetation maps Field studies	Ecological models Qualitative cross-tabulation
Landscape value (Martínez-Vega et. al., 2007)	Protected areas Land cover	Landscape pattern

Table 4.4.1: Input factors for the fire risk assessment system (Chuvieco et al., 2010)

The terms *danger, hazard* and *risk* have often been used in an inconsistent and confusing manner in literature on wildfires. They are used without a clear agreement among specialists, countries or language traditions (Chuvieco et al, 2003). This lack of clear definitions of the terms could easily become an obstacle to fire risk research and management. A rigorous analysis of fire risk assessment must be supported by clear terminology in order to enable results to be understandable and shareable throughout the community of wildfire researchers and specialists.

In this context, Bachmann and Allgöwer (2001) suggested the term *fire danger* as useless for fire research because it refers to an abstract concept based on personal opinions. They described the term as being defined by subjective human and societal perceptions and assessments of events and outcomes that are considered harmful. Besides, they defined the term *fire hazard* as a synonym for the process of wildfires. Thus, they concluded with the suggestion of an overall term for wildfires of *fire risk*, since it takes account of the probability of a wildfire occurring at a specified location and under specific circumstances, together with its expected effects. A precise definition of the term *fire risk* for forest fire related research was also defined by FAO (FAO, 1986).

Fire risk requires identifying and assessing potentially contributing variables, referred to as causative agents. However, the definition and assessment of fire risk presents different meanings in different countries. Traditionally, forest fire risk has been computed at a national level or at local scales using different variables and approaches. Thus, the different data sources and methodologies involved lead to indices not immediately comparable (San-Miguel-Ayanz et al., 2003).

Variables involved in fire risk

There are several variables potentially contributing to forest fire risk assessment as well as methods of grouping them. A possible way of collection is based on time variability. Values of some variables change almost continuously during the day while other variables vary noticeable only over a long period: week, month or even years. Therefore, variables have been classified accordingly as short-term and long-term variables. Evapotranspiration, relative humidity, wind and air temperature offer examples of variables clearly changeable during the day. Fuel type, fire history, total population, topography, soil type and proximity to roads are variables with roughly stable behaviour over short periods (Figure 4.4.1).

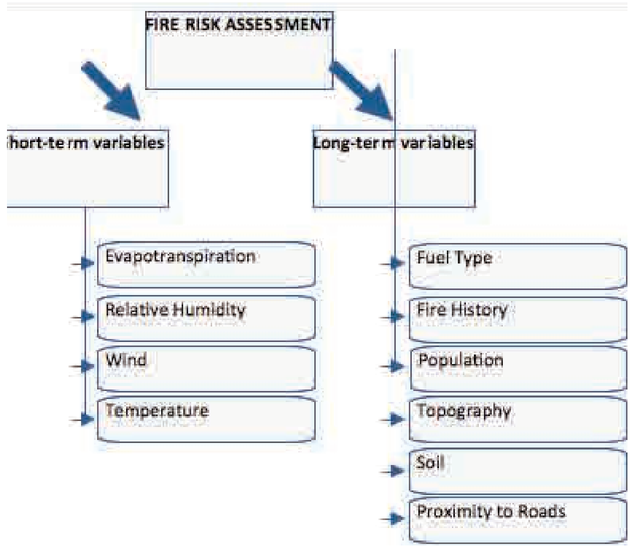


Figure 4.4.1: Potentially contributing variables for forest fire risk assessment

Alternatively, another possible way to collect contributing variables is to consider their nature. Variables could depend on meteorological conditions, vegetation conditions or human behaviour.

Meteorological-related variables

Fire occurrences and propagation are strongly related to particular meteorological conditions. Solar radiation, air temperature, relative humidity, precipitation, wind (average speed, turbulence intensity and direction) and vertical structure of the atmosphere are the main contributing meteorological variables (Viegas, 1998). Each of these variables plays a relevant role, even though their consequential high variability makes their management difficult.

Vegetation-related variables

Understanding water retention in plants and soil is basic to predicting moisture content of vegetation, and this plays an important role in fire ignition and propagation. If meteorological conditions are ignored, the most significant factors affecting the amount of water held and transported in vegetation are their chemical composition, internal structure and physical proprieties. This connection is better understood by examining the leaf structure at a fine level of detail. The amount of moisture held in the cell walls of fuel particles is related to the composition and crystalline structure of the walls, whereas liquid water held in the cell cavities is determined by the larger scale capillary structure. The loss of moisture from the interior of the leaf is prevented by a translucent waxy layer, the cuticle. The pigment chiefly responsible for the green colour characterizing living vegetation is the chlorophyll. Light passing through the upper tissues of the leaf is received by chlorophyll molecules in the palisade layer, specialized for photosynthesis, the process by which plant cells produce usable chemical energy from solar energy. The photosynthesis activity together with the moisture content has been used as possible indicators of vegetation status for fire susceptibility.

Human behaviour-related variables

Weather conditions and vegetation status are broadly involved in fire ignition and propagation. Nevertheless, especially in Europe, the causes of most fires are directly linked to human behaviour. The presence of settlements, agricultural burning, pyromaniacs, barbecues and cigarettes contribute to the increased risk of accidental fires. Values of these variables are present long-term and could be treated as static. Thus, the availability of ancient data is essential for providing reliable information about human-induced incidence on fires.

Hereafter variables chosen in the project by Chuvieco et al. (2010) are presented and explained.

Modelling human factors of fire ignition

In most countries human activities are mainly responsible for fire ignition. In Mediterranean areas, human factors cause more than 90 % of fires (Leone et al., 2003). In Spain, 96.1 % of all fires are human-induced (Dirección General de Biodiversidad, 2006). Modelling human behaviour, both in space and time, is particularly complex. Therefore more frequent studies are focused on variables related to land use or land use-change (rural abandonment, agricultural–forest interface or urban–forest interface), population trends, rural activities, and potential conflicts that may lead to vengeances or arson (Vega-García et al., 1995; Cardille et al., 2001; Leone et al., 2003; Martínez et al., 2009).

The approach used to consider human factors in fire risk assessment has been commonly based on statistical models, which have attempted to explain historical human-caused fire occurrence from a set of independent variables (Martell et al., 1989; Chou et al., 1993; Chuvieco et al., 2003; Martínez et al., 2004). Fires associated with negligence or arson can be approached by considering distances to roads and railroads, electricity powerlines and military establishments, while factors associated with recreational land use can be approached using the presence of urban–forest interfaces, hotels, cabins, and camping sites. Variables expressing each factor can be mapped at a defined spatial resolution in the fire risk assessment system using a wide variety of GIS analysis tools. The human component is expected to be stable for a whole fire season. Logistic regression techniques can be used to estimate the probability of fire occurrence from socio-economic variables. For example in Chuvieco et al (2010) the dependent variable was the number of fires caused by human activities in the period 1990–2004, derived from official fire statistics.

Ignition potential from lightning

In spite of the lesser importance of lightning over human factors for fire ignition, lightning strikes are also important factors to consider in fire danger estimation, since they tend to burn larger areas, because they occur in more isolated and steeper areas, and frequently have numerous simultaneous ignited spots, and therefore are more difficult to control (Wotton and Martell, 2005). Several studies have focused on analyzing the geographic variables that are more prone to causing fires due to lightning, such as topography (Díaz-Avalos et al., 2001), strike polarity (Latham and Schlieter, 1989) and fuel moisture content (Wotton and Martell, 2005).

Chuvieco et al. (2010) analyzed the structural factors associated with historical records of fires caused by lightning by comparing spatial patterns of affected and non-affected areas. The dependent variable in this case was the number of fires caused by lightning during the longest possible time period (when both lightning sources and fire statistics were available), while the independent variables were the total number of lightning strikes, vegetation and terrain characteristics, moisture codes derived from the U.S. National Fire Danger Rating System (FDRS, Bradshaw et al., 1983), and the Canadian Forest Fire Weather Index (FWI, Van Wagner, 1987). The analysis was restricted to daily meteorological database with at 3 km × 3 km resolution and for the period of 2002–2004. In a similar manner to the study of human factors, a logistic regression model was used to predict and explain historical fire occurrence caused by lightning. In this case, a pure binary variable was taken into account (fire/not fire). The outputs of the models showed good classification results, with 70 % of the cells correctly classified. The main indicative variable was the number of dry storms (with less than 2 mm rainfall).

Ignition potential associated with status of fuel moisture content

Fuel moisture content (FMC) is a critical variable for estimating ignition and fire propagation danger, since the amount of water in the vegetation is inversely related to ignition potential and rate of spread (Nelson, 2001). Following a common approach in forest fire literature, the estimation of FMC can be divided, as in Chuvieco et al. (2010), in terms of dead and live components. The former is estimated from meteorological variables while the later from satellite images.

The estimation of FMC of dead materials lying on the forest floor (leaves, branches, and debris) is included in most operational fire danger rating systems (Camia et al., 2003). It is most commonly estimated from meteorological variables, since dead fuels change their water content in parallel with atmospheric conditions. Weather changes affect the degree of water evaporation and absorption, especially temperature, rainfall and wind speed (Viney, 1991). The independent variables in this case were two moisture codes routinely used in fire danger estimation: the Fine Fuel Moisture Code (FFMC) and the 10-h code, being part of the Canadian and US fire danger systems, respectively. Similar results were obtained from the two moisture codes, but finally the 10-h code was selected, since it does not require wind speed as an input and therefore it is easier to compute. Once the empirical relations were established, they were extended to a grid of 1 km × 1 km resolution, interpolated from the data of the European Centre for Medium Range Weather Forecasting (ECMWF) using local algorithms.

For the estimation of FMC of live species vegetation, satellite remote sensing can be used as input. The use of satellite data in live FMC estimation has been discussed by different authors in recent years (Chuvieco et al., 2004; Danson and Bowyer, 2004; Maki et al., 2004; Dennison et al., 2005; Riaňo et al. 2005; Stow et al. 2005). In spite of the difficulty of determining the influence of water absorption over other factors that affect plant reflectance, several studies have found good relationships, especially in grasslands and some shrub species.

An approach to estimating FMC of live species is based on the inversion of simulation models of the radiative transfer function (RTM) (Pinty et al., 2004). The inputs are an 8-day composite of the first seven reflectance bands of MODIS (MOD09 product: Vermote and Vermeulen, 1999), as well as vegetation indices and the leaf area index (LAI) product derived from MOD15 on the same sensor (Knyazikhin et al., 1999). Considering the greater accessibility of AVHRR images and the good performance of the calibrated models, the empirical model based on these images can also be considered as a satisfactory method for estimating live FMC. To avoid cloud coverage and off-nadir observations, an 8-day compositing technique based on maximum daily temperatures can be used (Chuvieco et al. 2005). Therefore, the estimation of live FMC can be updated every 8 days.

Propagation potential

Most fire spread simulation models have been designed for local conditions and for active fires that have occurred or their occurrences have been simulated. The average propagation potential of each cell is produced, assuming a fire may occur anytime in any cell of the study areas. Another challenge was that fire propagation values should be calculated for coarse grid cells, since models are addressed to regional scales, which is uncommon in fire behaviour models. Despite these two limitations, average propagation conditions can be simulated, as in Chuvieco et al. (2010), using the Behave program (Andrews and Chase, 1990). Input conditions have to be selected based on the worst case scenario, that is, the fire is potentially propagated along the maximum slope and the wind speed is the average of maximum speeds for summer time. The simulated values of flame length and rate of spread have to be averaged for each fuel type and slope interval, so as to generate a potential propagation map of the study site.

Socio-economic values

Topics associated with values at stake (vulnerability) can be divided in two groups: those associated with economic and social factors, and those related to ecological components. Different approaches can be used for deriving each factor. The *tangible* resources are evaluated using direct methods, such as the market price, the age of the forest stand and the length of crop rotation periods. The Cost Avoidance Approach was used in Chapter 2 to determine the value of geo-information for disaster risk management. However, since timber has a clear market value it can be used as a means of valuation. While market value has been widely accepted in real estate and also by governments, there are some problems in estimating willingness to pay as expressed in Chapter 2 and therefore market value should be used with some caution.

The wood resources can be assessed following a mixed procedure that considers the American approach (only natural regeneration is considered) and the European approach (human-induced regeneration). The *intangible* resources were evaluated using indirect methods, such as the travel cost and contingent valuation methods. The former can be used to assess the recreational value of the landscape, while the latter is the basis to evaluate the cost of non-use and wildlife conservation of endangered species. The values associated with hunting and CO2 sinks have been priced according to the forest inventory (Chuvieco et al., 2010).

Degradation potential

The assessment of the vulnerability associated with ecological factors has to be focused on the response of vegetation to fire effects. This response has to be set up for two different time periods: short term (less than 1 year), focused on identifying the most erodible areas, and medium term (25 years) to identify changes in vegetation structure and composition caused by fire. Since vulnerability evaluation needs to be done before a fire occurs, no previous knowledge of fire characteristics and post-fire climatology has to be taken into account. Consequently, risk scenarios need to be created.

Among the different parameters associated with degradation, potential soil erosion has to be calculated in order to understand potential result of post-fire vegetation loss. In spite of the numerous modifications and criticism of the structure of the Universal Soil Loss Equation (USLE), it still constitutes a reference to assess the magnitude of soil loss in burned areas (Giovannini, 1999). Soil erodibility analysis is generally based on organic matter content, surface structure and soil crusting risk.

For the climate factor, the Fournier Index can be used as an indicator of the climate erosive ability. The Fournier Index is defined as the square of the mean amount of precipitation in the wettest month divided by the overall annual mean of precipitation. Details are available at http://www.ehow.com/how_10047009_calculate-fournier-index.html. Data limitations can often lead to a qualitative approach to classifying erodibility in categories from high to low sensitivity to fire effects. Vegetation post-fire response ability has to be considered as a predictive attribute.

The main vegetation communities can be grouped according to their vertical structural composition (trees and/or shrubs) and the reproductive strategy for each community. A vulnerability value has to be assigned as the inverse of its ability to respond to short-term effects (e.g. seeder shrubland = very high; resprouter shrubland = low; deficient seeder tree covered + seeder shrubland = very high; resprouter tree covered + mixed shrubland = medium vulnerability). The climatic limits to post-fire regeneration have to be based on historical water deficit indicators. The integration of the different components of post-fire short term degradation potential has to be determined by soil erodibility, vegetation vulnerability and water limitations. Scenarios of fire intensity have to be estimated for the Rothermel's standard fuel models (Anderson, 1982), contrasted on experimental fires (Baeza et al., 2002) and fire simulations carried out with the FARSITE fire simulator (Finney, 1998).

Landscape value

Landscape value is the third component to account for fire Vulnerability (Chuvieco et al., 2010). Fire managers take into account the intrinsic quality of the landscape to rank pre-fire planning, obviously along with other variables associated with human settlements and potential life threats. The evaluation of landscape characteristics has been approached by many authors in recent years, including a wide range of criteria: ecological (Kato et al., 1997; Nakagoshi and Kondo, 2002), aesthetic, population preferences, visual properties (Martínez-Vega et al., 2003; Arriaza et al., 2004). In Chuvieco et al. (2010) the consideration of landscape properties in relation to fire vulnerability assessment was approached from a weighted combination of the intrinsic values of the landscape and the legal status of protected areas (Martínez-Vega et al., 2007).

Model integration

The calculated input variables need to be converted to a common risk scale, and they should be properly weighted considering the importance of the different factors. Several methods have been proposed to find common scales of fire risk, being variable normalization, qualitative categorization and probabilistic approaches (Chuvieco et al., 2003). Variable normalization generates a common scale by converting each variable to a zero to one range, using either the minimum and maximum value, or the mean and standard deviation of the input variable. Qualitative groups imply conversion of the original scale to a categorical or ordinal one, using categories such as low, medium and high risk. Finally, the probabilistic approach requires the modelling of variables using any of the standard probability functions (normal, Poisson, Binary, etc).

Integration of risk indices

Once the risk variables have a common scale of danger, they can be combined in many different ways and using a wider range of techniques: qualitative cross-tabulation, multi-criteria evaluation, regression techniques or probabilistic models (Chuvieco et al., 2003). Reporting the methodology adopted in Chuvieco et al. (2010) the integration of the causative agents (human and lightning) was based on the Kolmogorov probabilistic rule (Tarantola, 2005), the integration of live and dead FMC was performed by averaging both FMC ignition potential values, weighted by the percentage cover of both dead and live fuels. For the integration of causative agents and FMC a multi-criteria evaluation technique (Gomez-Delgado and Barredo-Cano, 2006) was adopted. It was also assumed that high risk probability should be associated with situations when both high probability of having causative agents and FMC ignition potential occur. Assuming that both of these two variables are expressed on a Cartesian axis, the distance to the maxima should be a good indicator of risk conditions, since that point expresses the highest probability of both factors.

In the case of the integration between ignition and propagation danger, a similar approach was adopted, although in this case it was assumed that the worst conditions would occur either when the maximum ignition or propagation danger occurs. Therefore, in this case the maximum danger values should be those more distant from the origin. In both, the integration of ignition danger components, and between ignition and propagation danger, the dynamic factors such as FMC were weighted higher (four times), than the static factors (human, lighting and propagation), so as to be more sensitive to variables than change rapidly. For vulnerability variables, the criterion to convert the original quantitative scale of the socio-economic aspects and landscape values to a risk scale was based on qualitative weighting.

The final integration of the vulnerability component was based on four qualitative risk categories (low–moderate–high–extreme), so as to put those factors in relation to the soil degradation factor, which was already expressed in these four categories. A similar weight was applied to the three factors considered (socio-economic, degradation potential and landscape value), since they were considered to have a similar impact in the estimation of potential damage caused by fires. Additional scenarios could be considered in future works.

Fire Danger Classes	*FWI ranges (upper bound excluded)*
Very low	< 5.2
Low	5.2 - 11.2
Moderate	11.2 - 21.3
High	21.3 - 38.0
Very high	38.0 - 50.0
Extreme	>= 50.0

Table 4.4.2: Values of FWI used as thresholds of the fire danger classes in the EFFIS forecast module (http://forest.jrc.ec.europa.eu/effis/)

Fire Danger Forecast based only on Meteorological-related variables – The European Forest Fire Information System (EFFIS)

The fire danger forecast module of EFFIS (http://forest.jrc.ec.europa.eu/effis/) generates daily maps for 1 to 6 days projected fire danger level in EU using weather forecast data. The module is active from 1 March to 31 October and is fed together with meteorological forecast data received daily from French and German meteorological services (Meteo-France and Deutscher Wetterdienst DWD).

After a test phase of 5 years, during which different fire danger methods have been implemented in parallel, in 2007 the EFFIS network has adopted the Canadian Forest Fire Weather Index (FWI) System as the method to assess the fire danger level in a harmonized way throughout Europe. Calibration of the fire danger index is still ongoing, thus the fire danger forecast module of EFFIS is to be considered as in test or pre-operational mode. Fire danger is mapped in 6 classes (very low, low, medium, high, very high and extreme) with a spatial resolution of about 10 km (MF data) and 36 km (DWD data). The fire danger classes are the same for all countries and maps show a harmonized picture of the spatial distribution of fire danger level throughout EU. Values of FWI used as thresholds of the fire danger classes in the EFFIS forecast module maps are presented in Table 4.4.2.

Topic	Spatial distribution of areas prone to wildfire risk due to natural or human factors
Thematic content	4 risk classes, based on • Terrain • Land cover/distance relationships • Accessibility (Road network) • Vegetation status • Dead fuel moisture • Human factors • Lightning potential • Propagation potential • Socio-economic values • Degradation potential • Landscape value
Access	Web-based information system, unrestricted access
Scale	1:200,000 - 1:1,000,000
Accuracy	80 % correct hazard indication
Areal coverage	Regional
Spatial resolution	250 m - 1 km
Timeliness	Not relevant for risk assessment
Update frequency	< 1 week for moisture data
Data format	Not applicable

Table 4.4.3: Technical Profile for Fire Risk Assessment

Taking into account the state of development in Fire Risk Mapping as described above, a Technical Profile was generated as shown in Table 4.4.3.

Appraisal Results

The availability of Fire Risk Maps was considered very important by end-users for both **strategic** and **operational benefits**.

Concerning **operational benefits** (Figure 4.2.2), a high benefit rating was assigned by more than 75 % of end-users for *critical infrastructure protection*, followed by security (>55 %). As to be expected with a risk map mainly designed for support of pre-disaster activities in the way of risk reduction and preparedness, *health care* and *humanitarian aid* were considered as issues benefitting less from this product.

Non-end-users (Figure 4.4.3) likewise highlighted the benefit for *critical infrastructure* and confirmed the end-users' lower appraisal for *health care* and *humanitarian aid*, but gave a distinctly lower high-benefit score for *security*.

In the context **strategic benefits**, the Fire Risk Map was considered as highly beneficial for the *support of preventive strategies* (>70 % of end-users) and for *reducing losses in public economy* (>60 %), in accordance with the major objectives of risk mapping (Figure 4.4.4). Benefits for support of *superregional consistency and cooperation* and the *efficiency* and *public acceptance of plans and policies* were considered less important.

Appraisal results from non-end-users differ slightly from those of end-users; while they agree on the high benefit of a Fire Risk Map for *support of preventive strategies* (also >70 %), they give the lowest high benefit score for *reducing losses in public economy* (<50 %, but 0 % for low benefit) (Figure 4.4.5).

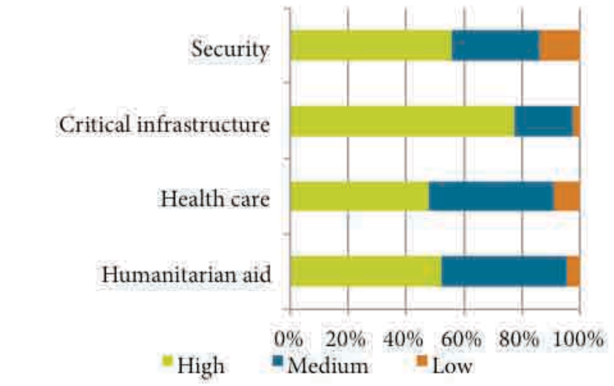


Figure 4.4.2: Operational Benefits of Fire Risk Map (end-user appraisal)

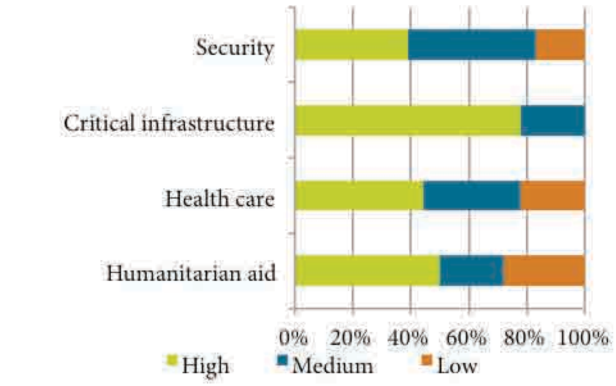


Figure 4.4.3: Operational Benefits of Fire Risk Map (non-end-user appraisal)

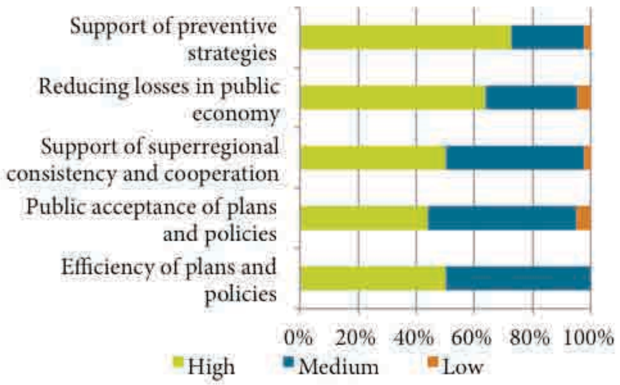


Figure 4.4.4: Strategic Benefits of Fire Risk Map (end-user appraisal)

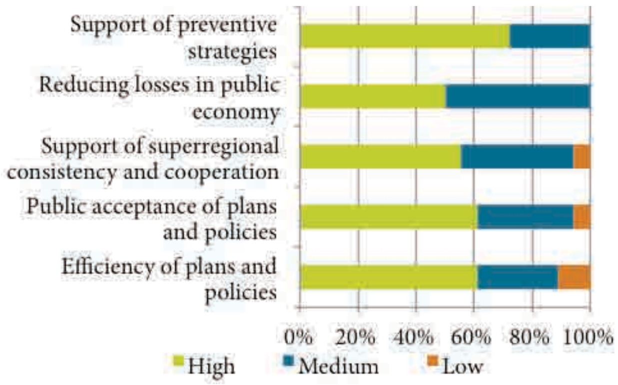


Figure 4.4.5: Strategic Benefits of Fire Risk Map (non-end-user appraisal)

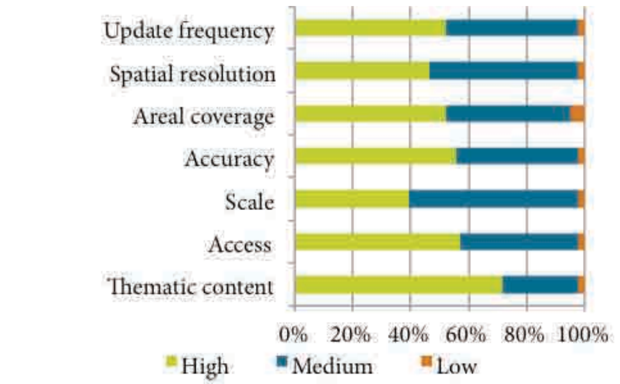


Figure 4.4.6: Criticality of specific features of Fire Risk Map (end-user appraisal)

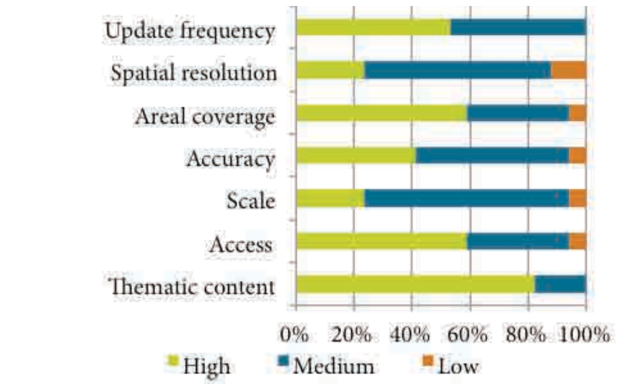


Figure 4.4.7: Criticality of specific features of Fire Risk Map (non-end-user appraisal)

Concerning the **criticality of specific product features** (Figure 4.4.6), *thematic content* was evaluated as highly critical by more than 70 % of end-users, which is plausible in view of the complex data base underlying the fire risk assessment model.

Access to the product resource, *accuracy* (i.e. reliability of hazard indication), *update frequency* and *areal coverage* were also considered highly critical by more than 50 % of end-users.

Thematic content is the most important feature also for non-end-users (Figure 4.4.7), with more than 80 % rating it as highly critical. Compared with the end-users' appraisal, *scale* and *spatial resolution* were considered even less critical.

4.4.2 Fire Detection and Monitoring System

Scientific and technical background

The creation of such a system relies on the availability of near-real-time low-cost satellite images, with global coverage and medium spatial resolution, in order to produce raster maps of active fires and burned areas with high temporal resolution. A summary of the state-of-the-art and of systems that already exist is presented in the following.

Remote sensing for Fire Detection and Monitoring

Fire information derived from remote sensing data is the product of interdisciplinary work designed to meet the needs of the Global Change research and the fire applications community. This information has been developed in response to a growing demand for spatially explicit fire data to parameterize and validate various regional and global models. Fire is recognized as an important component of trace gas and particulate emission modelling, climate modelling, atmospheric transport and chemistry models, ecosystem dynamics models and models of land use change. Fire is also a land management issue and a natural hazard.

A vast volume of literature is available on remote sensing for applications on fires, and several papers (e.g. Chuvieco 1999, Ahern et al., 2001, Xiao et al., 2009) show that three main lines of research are being followed:

- evaluation of new sensors;
- development or adaptation of methods for burned land discrimination, based on SAR interferometry, spectral unmixing, logistic regression and change detection analysis,
- spectral analysis of burned areas for the purpose of defining more accurate indices for burned land discrimination.

Information from high and medium resolution sensors can be used to calculate, in a semi-automatic manner, the extent of burned areas, based on the calculation of different vegetation indices, using red and near-infrared spectral data (Chuvieco et al., 2002), or using supervised classification methodologies such as maximum likelihood (Boschetti et al., 2007).

There are many satellite sensors that are widely used in fire detection and monitoring, especially:

- Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
- Advanced Land Imager (ALI) on EO-1 satellite
- Advanced Very High Resolution Radiometer (AVHRR)
- Moderate Resolution Imaging Spectroradiometer (MODIS)
- Landsat 5 TM (Thematic Mapper, no longer operational but historical data available)
- Landsat 7 ETM+ (Enhanced Thematic Mapper Plus)
- Landsat 8 Operational Land Imager (OLI)
- Spot 4 and 5
- Quickbird-2
- IKONOS-2
- Worldview2
- Deimos

The characteristics of most of them are listed in Table 4.4.4

Each sensor has its own advantages and disadvantages in terms of spatial and temporal resolutions, cost, and acquisition time. The high spatial resolution sensors have low temporal resolution (or there is no past data because data were only acquired on demand); additionally, the cost of data from these sensors ranges from $ 80 to thousands of dollars, depending on the sensor. Consequently it is unfeasible to use this kind of product for monitoring active fires and burned areas and to establish an early-warning system.

An important initiative aimed at refining and articulating the international requirements for fire related observations is the GOFC-GOLD-Fire Mapping and Monitoring Theme (http://www.fao.org/gtos/gofc-gold/f_fire.html) that aims to make the best possible use of existing and future satellite observing systems, for fire management, policy decision-making and global change research. One of the primary goals of GOFC-GOLD Fire is to establish a network of fire validation sites and protocols, providing accuracy assessment for operational products and a test bed for new or enhanced products, leading to standard products of known accuracy. Topics of the fire program include:

- Availability of observations
- Harmonization and standardization
- Validation
- Adequacy and advocacy of products
- Regional networks and capacity building
- Shared data, information and knowledge

	Landsat 5 TM/7 ETM+	ASTER	Spot 4[a]	Spot 5[a]	AVHRR	IKONOS-2
Owner	NASA	NASA	Space Imaging (France)	Space Imaging (France)	NOAA	Space Imaging (France)
Launch Date	March 1984/April 1999	December 1999	March 1998	May 2002	Since June 11, 1978, several satellite sensors have been launched	September 1999
Status	Landsat 7 ETM+: the Scan Line Corrector aboard malfunctioned on May 31, 2003. Data only in the middle part of the images can be used.	Working	Working	Working	Recently launched sensors (2000, 2002, 2005) still work well. Continuous historical data from 1978 to present are available.	Working
Spatial Resolution (m)	15-120	15-90	20 (10 m monochromatic)	10 (2.5 m panchromatic)	1100	1-4
Temporal Resolution (day)	16 [b]	16 [b]	3 [b]	3 [b]	1	1-3 [b]
Scene Size (km x km)	185 x 185	60 x 60	56 x 56	56 x 56	2400 x 6400	11.3 x 11.3
Price for each achieved raw data scene (US $)	600	Free[c]	1200-1900	3375-6750	Free for raw L1B data; $190 for geo registered L1B.	7/km^2, minimum 49 km^2

	MODIS	ALI	Quickbird-2
Owner	NASA	NASA	DigitalGlobe (USA)
Launch Date	December 1999, Terra satellite; April 2002, Aqua satellite.	November 2000	October 2001
Status	Terra MODIS band 5 and Aqua MODIS band 6 have erroneous data.	Working	Working
Spatial Resolution (m)	250-1000	30 (10 m panchromatic)	0.6-2.44
Temporal Resolution (day)	1-2	16 [b]	1-3.5 [b]
Scene Size (km x km)	2300 x 2300	37 x 185	16.5 x 16.5
Price for each achieved raw data scene (US $)	Free[c]	250-500	22.5/km^2, minimum 25 km^2

Table 4.4.4: Launch date, status, and spatial and temporal resolutions of major satellite sensors used for fire detection purposes

(a) There is an additional sensor (Vegetation sensor) on Spot 4 and 5 satellites, which has a resolution of 1 km for the whole field of view of 2400 km, offering almost daily coverage of the whole of the earth's surface. Of its 4 spectral bands, 3 bands characterize vegetation (0.61-0.68 µm red band, 0.78-0.89 µm near infrared, and 1.58-1.75 µm short wave infrared) and the fourth band (0.43-0.47 µm, blue) is for atmospheric correction.

(b) This is the potential temporal resolution for a specific location, because the historical data may not be available if no one requested the satellite to collect data on the actual date for that location.

(c) The price of higher-level products (such as temperature and reflectance) derived from the raw radiance data are $80 per scene. Only ASTER and MODIS provide higher-level products.

The GOFC-GOLD Fire Implementation Team is also an international forum for ensuring the provision of long-term, systematic satellite observations necessary for the production of the full suite of fire products. The team works with the GOFC-GOLD Regional Networks to bring together fire data providers and fire data users to exchange information on capabilities and needs. The networks allow for lateral exchange of information and provide a means for strengthening regional and in particular national related fire activities. Contributory projects to GOFC-GOLD are listed at http://gofc-fire.umd.edu/projects/contributory.php. Amongst the different projects considered by GOFC-GOLD, the MODIS fire products and the related FIRMS products (http://earthdata.nasa.gov/data/near-real-time-data/firms) are considered among the most used reliable low cost products to monitor and detect hotspots and burned areas worldwide.

The MODIS product has a 1-2 day temporal and a 250-1000 m spatial resolution; the data are free and cover more spectral bands than other satellites (up to 36 bands). MODIS products are built and improved based on experience with fire assessments primarily using the NOAA-AVHRR and GOES systems (NOAA, 2002), and it has to be considered that no other system provides the instrument characteristics needed for an effective global fire monitoring program. The MODIS sensor was designed to include characteristics specifically for fire detection and provides a unique capability in terms of fire monitoring. The fire products provide an identification of the occurrence of thermal anomalies, an estimate of the total emitted power from the fire, and the burned area. The products are in differing stages of maturity and each product has an explicit validation program.

The German Aerospace Center (DLR) launched an experimental fire detection satellite referred to as BIRD (Bispectral InfraRed Detection) with a spatial resolution of 370 m, in November 2001, operating until 2003 (Oertel et al., 2010, Ruecker et al., 2011). The main objectives of the experimental satellite were to demonstrate new small satellite technology, and to investigate new infrared array sensors for the detection of high temperature events such as forest fires. The satellite included a two channel Hot Spot Recognition System (HSRS) which was able to detect smaller fires than the MODIS sensors, and also was capable of better characterization of fire fronts. However, due to its higher spatial resolution, its temporal resolution was lower than that of MODIS. A significant outcome of this mission was the ability to characterize fire radiative power (FRP). Experiments have been undertaken to compare the measured FRP by the MODIS and BIRD satellites. At present two new fire satellites are proposed for launch in the near future forming the FireBIRD mission. These include the TET-1 (Technologie-Erprobungsträger-1 or Technology Testing Device-1) and BIROS (Berlin InfraRed Optical System). On board processing will be extremely rapid allowing for the facilitation of new services for fire managers at fire fronts.

MODIS Algorithm to detect fire hotspots

The MODIS algorithm for fire hotspot detection is performed using a contextual algorithm (Giglio et al., 2003) that exploits the strong emission of mid-infrared radiation from fires (Dozier, 1981; Matson and Dozier, 1981). The algorithm examines each pixel of the MODIS swath, and ultimately assigns each one into one of the following classes: missing data, cloud, water, non-fire, fire, or unknown. The algorithm uses brightness temperatures derived from the MODIS 4 μm and 11 μm channels, denoted as T 4 and T 11, respectively. Cloud and water pixels are identified using internal cloud and water masks within the MODIS Level 1A geolocation products (MOD13 and MYD03), respectively, and pixels are assigned accordingly. Processing then continues on the remaining pixels over land.

A preliminary classification is used to eliminate obvious non-fire pixels. For those potential fire pixels that remain, an attempt is made to use the neighbouring pixels to estimate the radiometric signal of potential fire pixels in the absence of fire. Valid neighbouring pixels in a window centred on the potential fire pixel are identified and used to estimate a background value. The window starts as a 3×3 pixel square ring around the potential fire pixel. Due to the triangular along-scan response of the MODIS instrument (Kaufman et al., 1998), the two along-scan pixels adjacent to the potential fire pixel are deemed unreliable and are excluded from the background characterization. The ring is increased to a maximum of 21×21 pixels as necessary, until at least 25 % of the pixels within the window have been deemed valid, and the number of valid pixels is at least eight. During this step, an optimized nearest-neighbour search is used to correct for the 'bowtie' effect, or overlap between MODIS scans (Nishihama et al., 1997). If the background characterization was successful, a series of contextual threshold tests are used to perform fire detection. Relative thresholds are adjusted based on the natural variability of the background. Additional specialized tests are used to eliminate false detections caused by sun glint, desert boundaries, and errors in the water mask. Candidate fire pixels that are not rejected in the course of applying these tests are assigned a class of fire. Pixels for which the background characterization could not be performed, i.e. those having an insufficient number of valid pixels, are assigned a class of unknown. A detailed description of the detection algorithm is given in (Giglio et al., 2003).

The Fire Information for Resource Management System (FIRMS) is a web application that delivers global MODIS hotspots and fire locations in an easy to use format (http://earthdata.nasa.gov/data/near-real-time-data/firms, Figure 4.4.8). FIRMS host the following data: NRT MODIS Active Fire Data, Collection 5 MODIS Active Fire Data, MODIS Burned Area. These active fire locations are processed by LANCE using the standard MODIS MOD14/MYD14 Fire and Thermal Anomalies product. Each active fire location represents the centre of a 1 km pixel that is flagged by the algorithm as containing one or more fires within the pixel. FIRMS also offers monthly MODIS Burned Area (MCD45) images through Web Fire Mapper.

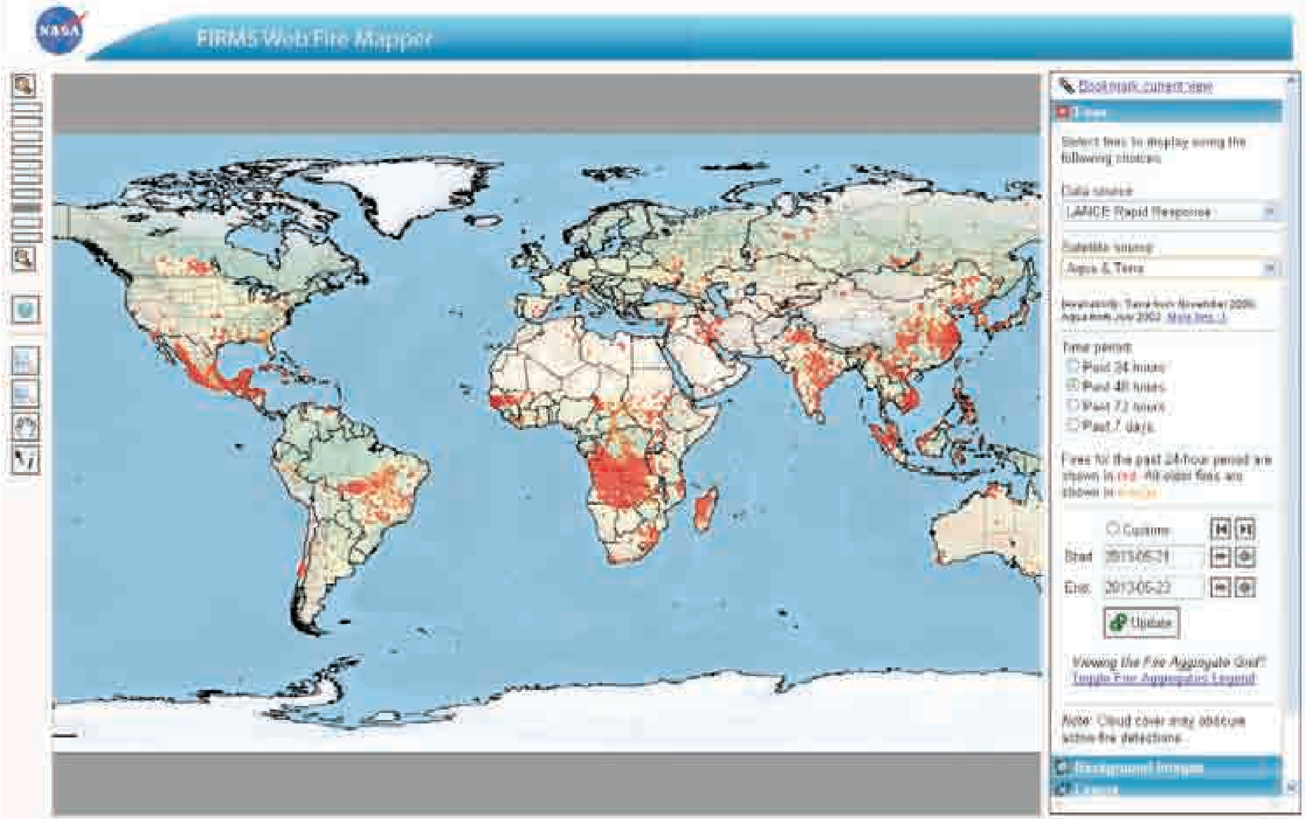


Figure 4.4.8: FIRMS web application (http://earthdata.nasa.gov/data/near-real-time-data/firms)

Remote Sensing for detection and monitoring of burned areas

Burned areas are characterized by deposits of charcoal and ash, removal of vegetation, and alteration of the vegetation structure (Roy et al., 1999). Some authors have shown higher accuracies in the Near-Infrared and Short Wave Infrared (NIR–SWIR) spectral domain for burned land discrimination (Trigg and Flasse, 2000), as well as indices based on the Red and Near-Infrared region (R-NIR). It has to be noted that the availability of SWIR bands in satellite sensors is quite recent (1998 for SPOT HRV and SPOT Vegetation; 1999 for MODIS, 2000 for NOAA AVHRR) and therefore, for historical mapping of burned areas, the R-NIR range remains critical. In addition, the SWIR detectors of the ASTER satellite are no longer functioning due to anomalously high SWIR detector temperatures (since 12 January 2009).

The most commonly used parameters for estimates of burn severity and area are the Normalized Burn Ratio (NBR), the differenced Normalized Burn Ratio (dNBR), and the Normalized Difference Vegetation Index (NDVI) (Kasischke and French 1995). Usually, researchers use these indices with a threshold value or a regression equation to predict the burn area and burn severity. In addition, some researchers observe temporal differencing of spectral transformation (TCT) to detect the burned area (Rogan and Yool, 2001). Three vegetation indices based on the Red–Near-Infrared spectral domain are also considered very useful in burned area detection (Chuvieco E., 2002), namely:

- The *Soil Adjusted Vegetation Index (SAVI)* (Huete, 1988), which has shown to be very sensitive to discriminate vegetation amount in sparsely vegetated areas;
- The *Global Environmental Monitoring Index (GEMI)*, claimed to be less affected by soil and atmospheric variations than NDVI (Pinty and Verstraete, 1992);
- The *Burned Area Index (BAI)*, defined by Martin (1998), specifically to discriminate re-affected areas. This index is computed from the spectral distance from each pixel to a reference spectral point, where recently burned areas tend to converge.

As described above, applications of this kind give better results when applied on high resolution satellite images. In 2010 a review of the satellite remote sensing use in forest health studies, fire fuel mapping, fire risk estimation, fire detection, post-fire severity mapping, and relative water stress monitoring (Wang et al., 2010) concluded that MODIS data are more appropriate for most remote sensing applications for forest health than other current satellite data, when considering temporal and spatial resolutions, cost, and availability of bands.

MODIS Algorithm to detect and monitor burned areas

Previously, in the absence of accurate burned area products, burned area assessments have been created on the basis of calibrating the available active fire data from regional AVHRR and global MODIS data. However several remote sensing, environmental, and fire behaviour factors limit the accuracy of such derived fire affected area data sets. The availability of robustly calibrated, atmospherically corrected, cloud-screened, geo-located data provided by the latest generation of moderate resolution remote sensing systems allows for major advances in satellite mapping of fire affected area.

A complementary MODIS algorithm defined for mapping fire affected areas has been developed, and the first global burned area product from 2000 onwards is now being generated as part of the MODIS Land collection 5 product suite. The MODIS algorithm used to map burned areas takes advantage of spectral, temporal, and structural changes (Roy et al., 2005). It detects the approximate date of burning for 500 m areas by locating the occurrence of rapid changes in daily surface reflectance time series data. The algorithm maps the spatial extent of recent fires and not of fires that have occurred in previous seasons or years. The algorithm is applied independently to geo-located pixels over a long time-series of reflectance observations. A bi-directional reflectance model is inverted against multi-temporal reflectance observations to provide predicted reflectances and uncertainties for subsequent observations. A statistical measure of the difference between the observed *Bi-Directional Surface Reflectance (BRF)* and the predicted BRF at the viewing and illuminating angles of the observation is used to quantify changes from a previously observed state. Large discrepancies between predicted and measured values are attributed to change. A temporal constraint is used to differentiate between temporary changes, such as shadows, that are spectrally similar to more persistent fire induced changes. The identification of the date of burning is constrained by the frequency and occurrence of missing observations and to reflect this, the algorithm is run to report the burn date with an 8 day precision. The MODIS burned area product, and the details of the algorithm, are described in Roy et al., (2002); Roy et al. (2005); and Roy et al. (2008). As well, how to use the product is detailed in the MODIS Collection 5 Burned Area Product - MCD45 user's guide.

The global monthly MODIS mosaics of burned areas are available for visualization in the 3-dimensional World Windvirtual globe. World Wind was developed by NASA Ames Research Centre, and is distributed as open source software. At the same time, the MODIS Burned Area Product is available free of charge from the Land Processes Distributed Active Archive Center (LP-DAAC) using the EOS Data Gateway web interface located at http://reverb.echo.nasa.gov. Additionally, an ftp server is maintained by the University of Maryland, mostly to provide support to the science users who need to download systematically large volumes of data, and implement their own applications. MODIS Burned Area (MCD45) images are offered through Web Fire Mapper, running on the FIRMS application.

Validation of MODIS FIRE Products

The validation of the MODIS active fires and burned area product relies mainly on the use of high-resolution Landsat scenes. Stage 1 validation was conducted parallel to the development of the product with a number of validation sites in Africa, Australia, Brazil, Siberia and the United States. Stage 2 validation of the Level 3 combined Aqua-Terra burned area product is currently ongoing. A comprehensive validation over Africa has been completed, and validation in Europe, India, Australia and Siberia is currently ongoing.

Taking into account the state of development in Detecting and Monitoring Fires worldwide as described above, a Technical Profile was generated as shown in Table 4.4.5.

Topic	Detection and growth monitoring of active wildfire
Thematic content	Active fire areas, differentiated by radiative power
Access	Upon registration via internet
Scale	1 : 50,000
Accuracy	< 10 % false alarm
Areal coverage	Global
Spatial resolution	250 m
Timeliness	Maximum 1 day
Update frequency	1 day
Data format	Raster Maps

Table 4.4.5: Technical Profile for Fire Detection and Monitoring System

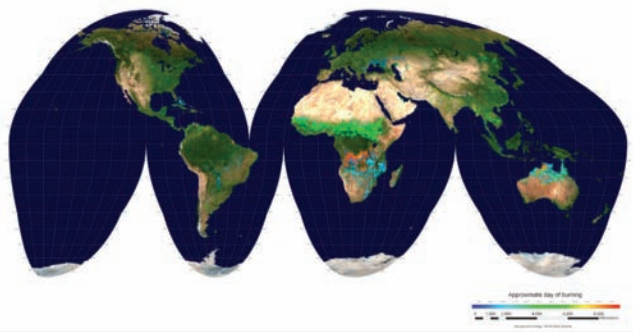
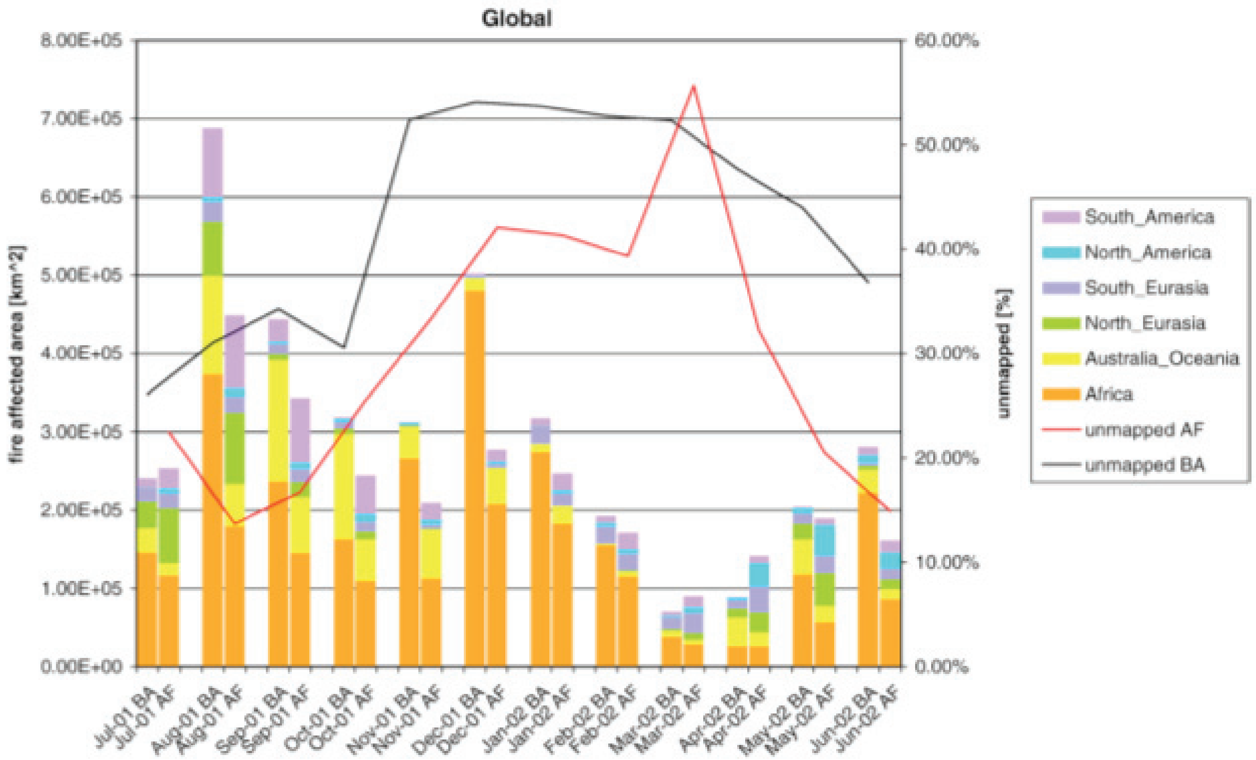


Figure 4.4.9: MODIS Burned Area Product

Figure 4.4.10: MODIS Burned Area Product, Greece affected areas after occurrences of 2007 fires



Burned Area (BA) product (left bar) and Active Fire (AF) product (right bar). The black lines show the global percentage of unmapped pixels in the monthly burned area product; the red lines show the global average of the percentage of unmapped days according to the active product.

Figure 4.4.11: Monthly histograms of fire affected areas by continent detected by MODIS data

Appraisal Results

In rating the **operational benefits** of a Fire Detection and Monitoring System, more than 75 % of end-users gave a high benefit score with regard to *critical infrastructure*, followed by *humanitarian aid, health care* and *security* (all about 60 %) (Figure 4.4.12). These results are similar to those for the Fire Risk Map (Figure 4.4.2), but with more or less higher scores for benefit for *humanitarian aid* and *health care*, as can be expected for a system for early warning, alert and monitoring of actual disaster events, in comparison with a map depicting mere disaster risks.

This trend in the end-users' appraisal of operational benefits was confirmed by the non-end-users (Figure 4.4.13), but with distinctly lower high benefit scores especially with regard to *security, humanitarian aid* and *health care*.

Regarding the **strategic benefits** of a Fire Detection and Monitoring System, end-users considered it as highly beneficial for *support of preventive strategies* (>75 %) (Figure 4.4.14), and also for *efficiency of plans and policies* and *reducing losses in public economy* (both >60 %). The relatively high benefit score for the purposes of prevention, ascribed to a detection and monitoring system, of the same order of magnitude as for the corresponding risk map (Figure 4.4.4), probably reflects the information potential of historical data sets provided by such a system, but could be partially attributed also to the use of an up-to-date monitoring information in the context of strategic planning of fire containment operations.

The assessments of **strategic benefits** provided by non-end-users for (Figure 4.4.15) are very similar to those by end-users, but with a general trend to lower scores for high benefit rating.

Regarding the **criticality of specific product features**, more than 60 % of end-users emphasize *thematic content*, *accuracy, update frequency, areal coverage* and *timeliness* as more

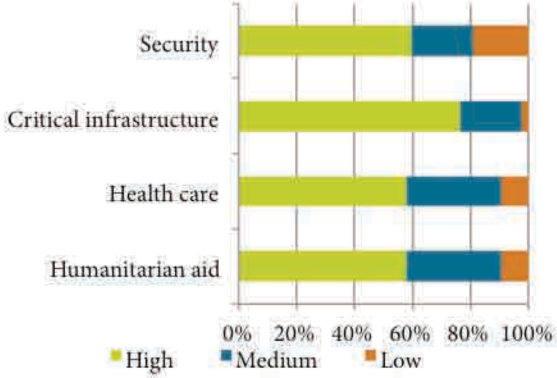


Figure 4.4.12: Operational Benefits of Fire Detection and Monitoring System (end-users)

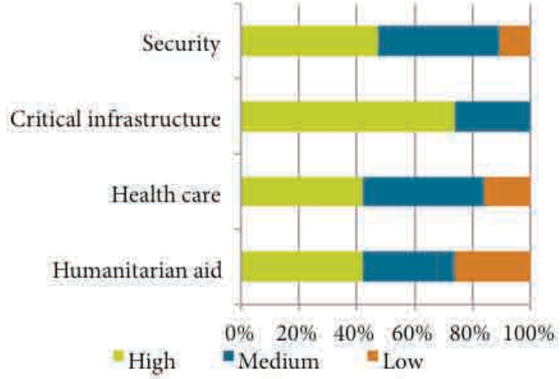


Figure 4.4.13: Operational Benefits of Fire Detection and Monitoring System (non-end-users)

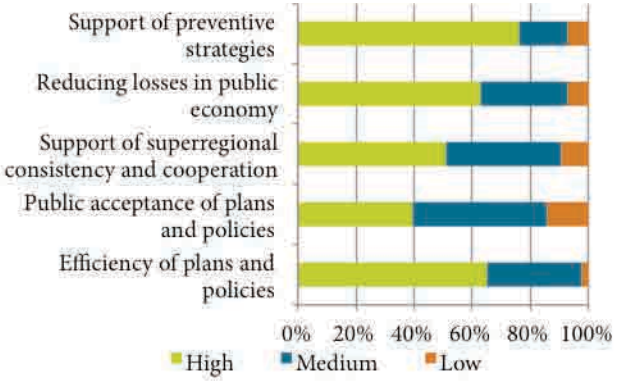


Figure 4.4.14: Strategic Benefits of Fire Detection and Monitoring System (end-users)

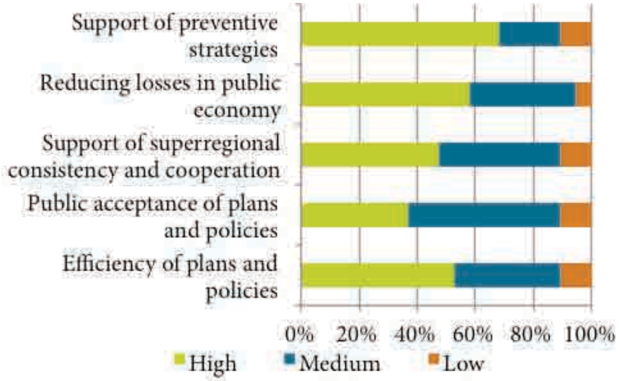


Figure 4.4.15: Strategic Benefits of Fire Detection and Monitoring System (non-end-users)

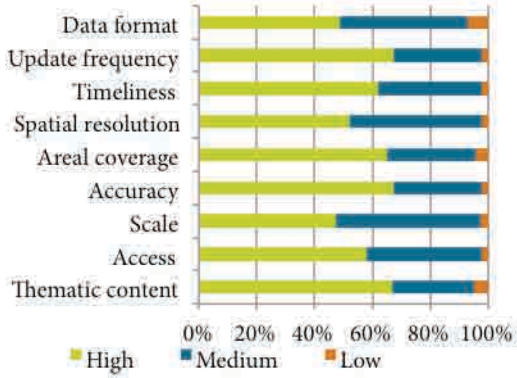


Figure 4.4.16: Criticality of product features of Fire Detection and Monitoring System (end-users)

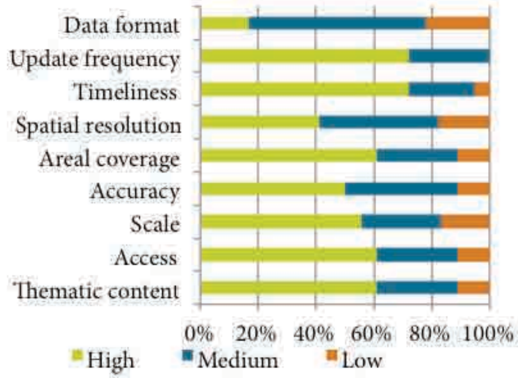


Figure 4.4.17: Criticality of product features of Fire Detection and Monitoring System (non-end-users)

or less equally important in a Fire Detection and Monitoring System (Figure 4.4.16). As to be expected for a detection and monitoring system, *update frequency*, i.e. repetition time, was rated higher in comparison with the Fire Risk Map (Figure 4.4.16). *Scale, spatial resolution* and *data format* were considered less important, as was the case for Fire Risk Maps.

Non-end-users considered *update frequency* and *timeliness* the most critical features (Figure 4.4.17). In comparison to end-users, they rated *scale* and *timeliness* as more critical, but *spatial resolution, accuracy* and especially *data format* as less critical.

4.5 Landslide Hazard Assessment

Irasema Alcántara Ayala

The instability of slopes has been defined by Brunsden (1984) as the mass movement processes involved in the movement of hillslope materials under the influence of gravity and without a transport agent such as water, air or ice. The Working Party on World Landslide Inventory identifies a landslide as “the movement of a mass of rock, debris or earth down a slope” (Cruden, 1991).

The degree of landslide hazard and its impact on society are very much related to the velocity of movement. Extremely rapid landslides with velocities of 5 m/sec occurring on vulnerable communities can produce considerable damage, whereas slow movements may affect structures, although they can be maintained (Table 4.5.1).

Scientific and technical background

For a few decades, landslides have been classified according to different aspects, such as morphological attributes; type and velocity of movement; age of the movement; degree of activity; and climate.

Landslides can be typologically characterized as outlined in Table 4.5.2 (Varnes, 1978; EPOCH, 2003):

- *Falls* involve the detachment of materials from steep slopes; movement takes place by falling, bouncing or rolling.
- *Topples* result from the overthrow or forward rotational movement, out of the slope, of a mass of soil and/or rock in relation to an axis.
- *Slides* can be regarded as the downslope movement of soil and/or rock masses on a surface of rupture.
- *Flows* are spatially continuous movements in which

Class	*Description*	*Typical velocity*	*Expected damages and population reaction*
1	Extremely rapid	5 m/sec	
2	Very rapid	3 m/min	Disaster of major violence; buildings destroyed by impact of displaced material; many deaths; escape unlikely
3	Rapid	1.8 m/h	Some lives lost; velocity too great to permit all persons to escape
4	Moderate	13 m/month	Escape evacuation possible; structures destroyed
5	Slow	1.6 m/year	Remedial constructions can be undertaken during movement; insensitive structures can be maintained with frequent maintenance work if total movement is not large during a particular acceleration phase
6	Very slow	>15 mm/year	Some permanent structures undamaged by movement
7	Extremely slow	<15 mm/year	Imperceptible without instruments; construction possible with precautions

Table 4.5.1: Mass movement classification based on velocity of displacement (Australian Geomechanics Society, 2002 after Cruden and Varnes, 1996)

shear surfaces are small, closely spaced and usually not preserved after the event. The distribution of velocities in the displacing mass is similar to a viscous fluid (Cruden and Varnes, 1996).

- *Lateral spreads* imply a lateral extension of a cohesive soil or rock mass combined with a general subsidence of the fractured mass of cohesive material into softer underlying material. The rupture surface is not a surface of intense shear. Spreads may result from liquefaction or flow of the softer material (Varnes, 1978).

There are different factors that contribute dynamically to the change of slope stability. Frequently, it is the combination of natural processes and human activities that determines the "preparation" of the slopes to become unstable. Among the natural factors are hillslope material properties, including geological structures (i.e. joints, faults, fractures, bedding and foliation planes, inclination, etc.), and tectonic uplift. Weathering and erosion, groundwater level, hydrological conditions, vibrations produced by earthquakes, and presence of old movements are also very important. In terms of anthropogenic conditioning, deforestation, land use change, removal of lateral support by construction of terraces such as cuts and mining, play a significant role as determining factors for hill slope instability.

Landslide triggering mechanisms exceed thresholds of slope resistance; they also involve both natural and human induced processes. Precipitation, seismicity and volcanic activity are comprised within the main natural triggering mechanisms, whereas all kinds of activities affecting or transforming the morphology of a slope and causing an instantaneous failure can be considered as human induced.

Symptoms of instability of slopes can be easily recognized even by non-technical personnel. Generation of cracks and steps, the inclination of vegetation and other objects, unusual humps in the ground, street pavements or sidewalks, or offset fence lines, are common signs of instability that can be easily identified.

Movement Type	*Type of material*		
	Rock	*Debris*	*Soil*
Fall	Rock Fall	Debris Fall	Soil Fall
Topple	Rock Topple	Debris Topple	Soil Topple
Slide (Rotational)	single (slump) multiple successive	single multiple successive	single multiple successive
Slide (Transitional) Non-rotational	Block Slide	Block Slide	Slab Slide
Planar	Rock Slide	Debris Slide	Mud Slide
Lateral spreading	Rock Spreading	Debris Spread	Soil (Debris) Spreading
Flow	Rock Flow (Sackung)	Debris Flow	Soil Flow
Complex (with run-out or change of behaviour downslope)	e.g. Rock Avalanche	e.g. Flow Slide	e.g. Slump - earthflow

Table 4.5.2: Mass movement classification based on process type and material (Cruden and Varnes 1996; EPOCH, 2003)

Landslide mapping and inventories

Given its geomorphological nature, the footprints of landslides on the landscape are valuable features for their identification, classification, and mapping. Active landslides are more easily recognized than those dormant, abandoned or in a relict state. Moreover, semi-arid conditions also provide better scenarios for landslides identification, as vegetation does not cover their morphological attributes as in the case of tropical environments.

Geomorphological mapping has been demonstrated to be one of the best ways to illustrate and synthesize relevant landforms and processes (Figure 4.5.1). They represent actual field conditions and observations and can be integrated for modelling by digital analysis, based on e.g. Digital Elevation Models (DEM) within GIS platforms.

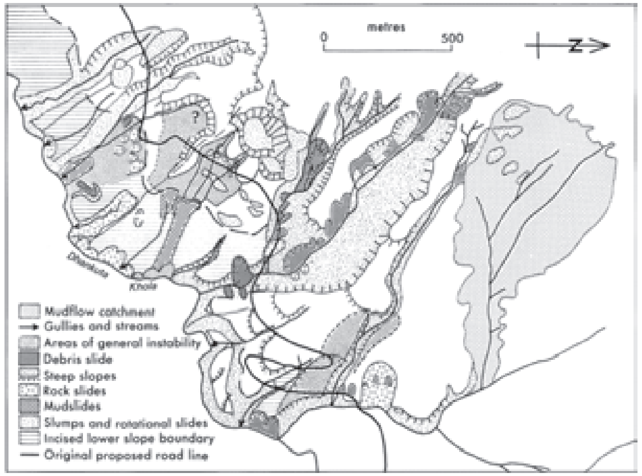


Figure 4.5.1: Geomorphological map of mass movement processes along the Dankhuta Khola River, Eastern Nepal (Brunsden, 2001)

Landslide susceptibility and landslide hazard maps

There is a vast body of literature concerning the generation of landslide susceptibility maps. They are usually based on landslide inventories and can be developed by using remote sensing techniques and GIS, or the application of statistical methods. Spatial distribution of factors influencing the stability of a slope can be included (frequently natural elements), and particular analysis or modelling can be performed, depending on the triggering mechanism (e.g. precipitation, earthquake, or volcanic activity). The quality of the landslide susceptibility maps produced and the representation of the real terrain conditions are dependent on the accuracy of information used as an input. Of particular importance is the information on topography and the adequate characterization of hillslope materials. The usefulness of maps is not solely related to the scale but also to the accuracy of the input data. An example of a landslide susceptibility map is shown in Figure 4.5.2.

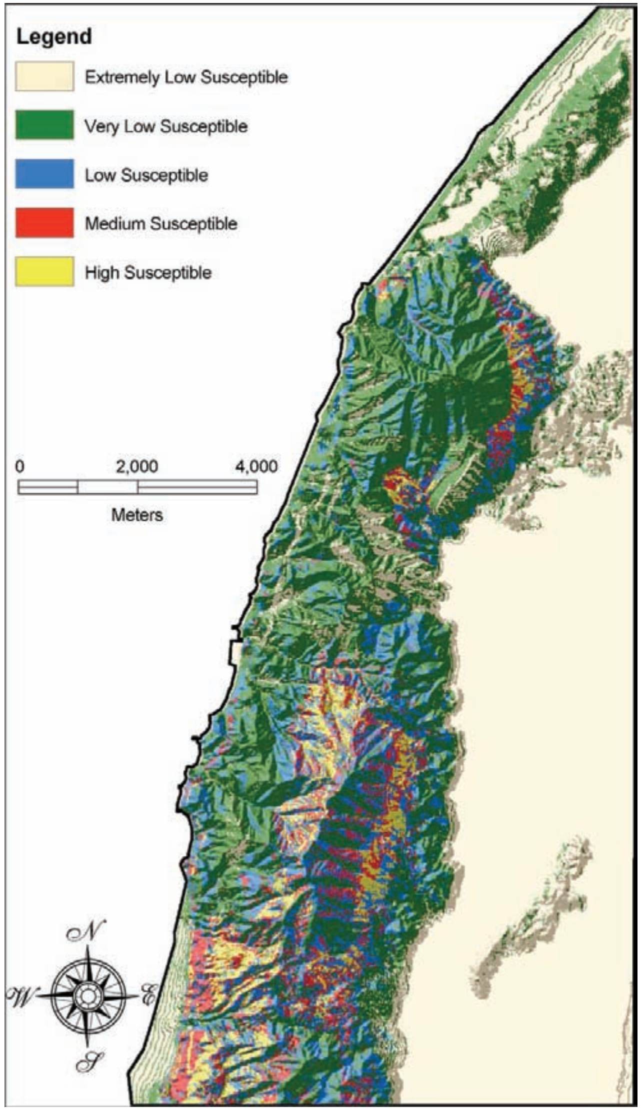


Figure 4.5.2: Landslide susceptibility map of the Kakuda-Yahiko Mountains (Ayalew and Yamagishi, 2005)

The main difference between landslide susceptibility and landslide hazard maps is that the latter include an intensity-frequency relationship, and specific associations are made with triggering mechanisms (Figure 4.5.3). GIS is most extensively used for analyzing landslide hazard and risk. Nonetheless, as pointed out by Carrara et al. (1999), there are several problematical aspects that need to be addressed:

- "Computer-generated results …. considered to be more objective and accurate than products derived by experts in the conventional way through extensive field mapping;
- The use of GIS and the production of less accurate hazard maps by users that are not experts in earth sciences;
- The increased focus on the use of new computational techniques for landslide hazard assessment, and less interest on the collection of reliable data".

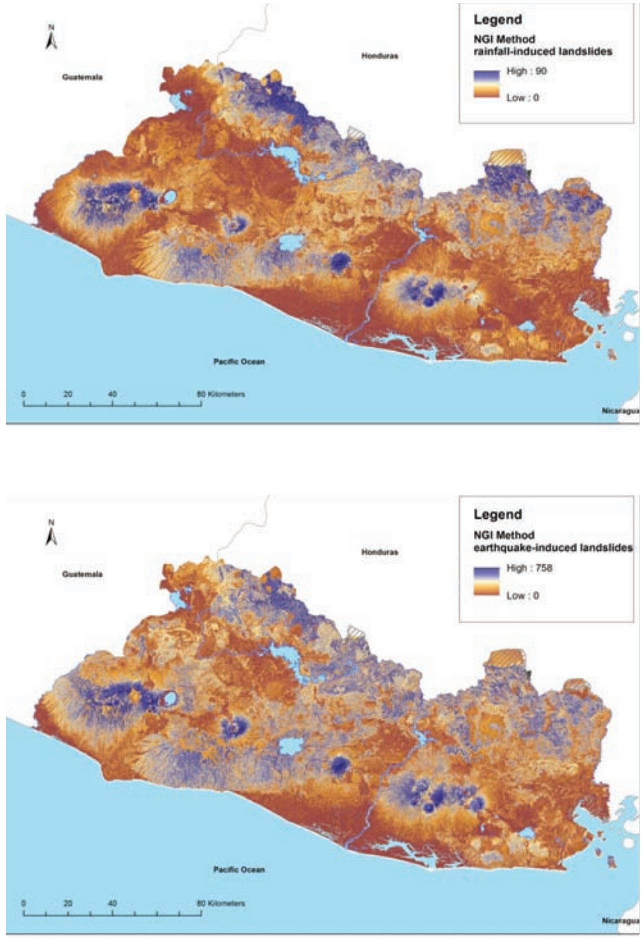


Figure 4.5.3: Landslides hazard induced by rainfall (upper figure) and earthquakes (lower figure), by using the NGI method (Nadim et al., 2013)

Landslide assessments have been undertaken on local, regional, and global scales. However, their certainty is determined by the information used to carry out such assessments. Frequently, a series of assumptions are made in order to produce landslide hazard or risk assessments. Approaches for landslide hazard and risk evaluations (Figure 4.5.4) comprise information that determines the susceptibility of a given terrain to land sliding, triggering mechanisms, vulnerability and exposed population (Nadim et al., 2006).

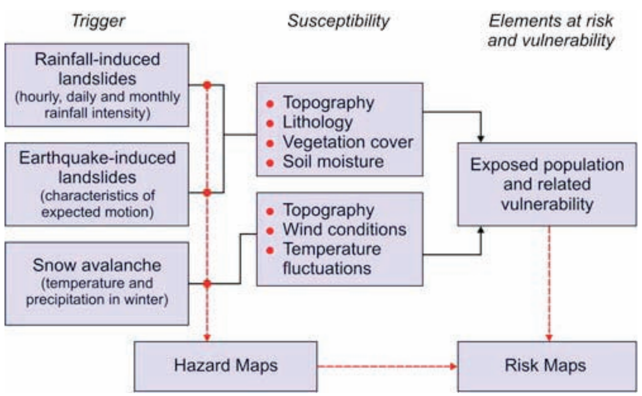


Figure 4.5.4: Approach for landslide hazard and risk evaluation (Nadim et al., 2006)

Taking into account the methodological state of the art in Landslide Hazard Mapping as described above, a Technical Profile was generated as shown in Table 4.5.3.

Topic	Areas prone to rain-triggered landslides, combined with an alert function
Thematic content	• Topographic base map • Lithology • Pedology • Landuse/landcover • Rainfall data
Access	Web-based informavtion system, unrestricted access
Scale	1 : 50,000
Accuracy	80 % correct hazard indication
Areal coverage	Regional
Spatial resolution	10 m
Timeliness	24 h
Update frequency	24 h for rainfall data
Data format	Not applicable

Table 4.5.3 Technical Profile for Landslide Hazard Assessment

Appraisal results

Among the **operational benefits**, more than 85 % of end-users gave the product a high benefit rating with regard to the maintenance of *critical infrastructure*, followed by *security* and *humanitarian aid* (both nearly 60 %) (Figure 4.5.5). This seems plausible in view of the structural damage which can be caused by landslides, and the information potential of a Landslide Hazard Map for local risk assessment and preparedness. The end-users' appraisal was more or less confirmed by the non-end-users who gave even some more emphasis to the high benefit for *critical infrastructure*, without any low benefit appraisal (Figure 4.5.6).

Regarding the **strategic benefits**, end-users emphasized the product's high benefit mostly for the *support of preventive strategies* (>70 %) and the *efficiency of plans and policies* (>65 %), followed by a >60 % score for high benefit for *reducing losses in public economy* (Figure 4.5.7). This appraisal clearly reflects the importance of hazard information for preventive planning. In comparison, benefits to *public acceptance of plans and policies* and *support of superregional consistency and cooperation* were seen as less critical (both with high benefit scores <45 %), probably with respect to the specific local characteristics of landslide hazard. This trend in the end-users appraisal is mostly confirmed by the non-end-users, with a general tendency towards lower benefit ratings (Figure 4.5.8).

End-users rated the **criticality of product features** as generally high, with >60 % but for *update frequency* and *timeliness* (both >50 %) (Figure 4.5.9). The slightly lower criticality assigned to the time-related features might reflect the importance of the product for structural planning, i.e. for rather long-term processes. In comparison, the criticality assessments by non-end-users are more differentiated, with lesser emphasis on *spatial resolution* and *scale* (Figure 4.5.10).

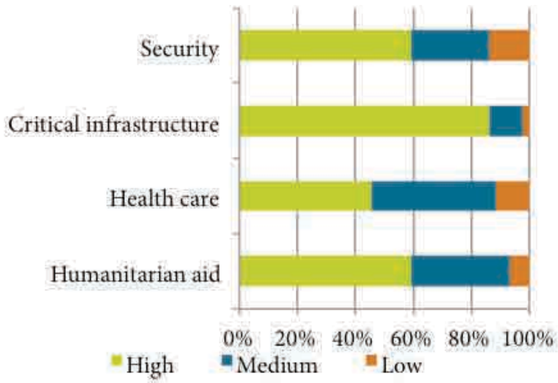


Figure 4.5.5: Operational Benefits of Landslide Hazard Assessment (end-users appraisal)

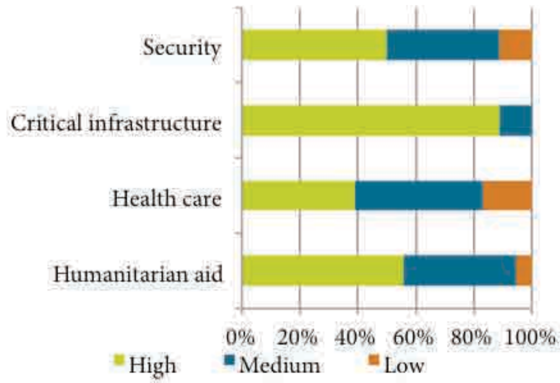


Figure 4.5.6: Operational Benefits of Landslide Hazard Assessment (non-end-users appraisal)

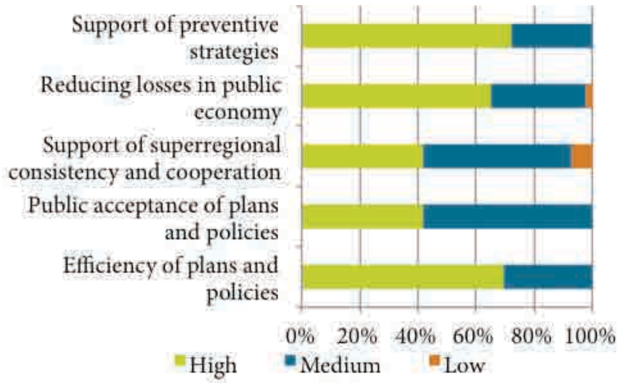


Figure 4.5.7: Strategic vBenefits of Landslide Hazard Assessment (end-users appraisal)

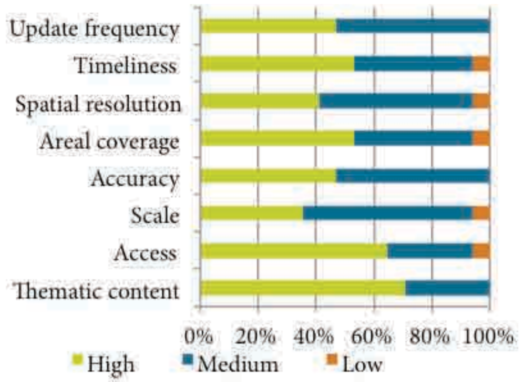


Figure 4.5.8: Strategic Benefits of Landslide Hazard Assessment (non-end-users appraisal)

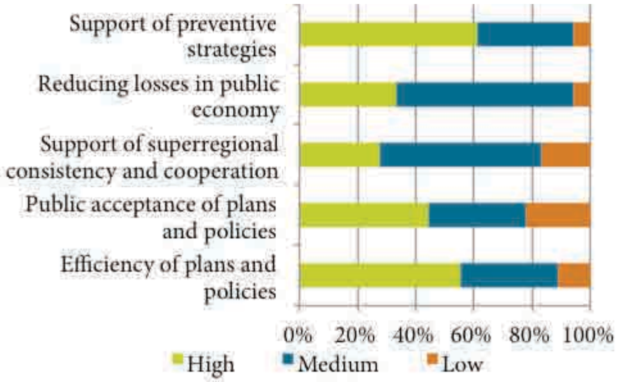


Figure 4.5.9: Criticality of product features of Landslide Hazard Assessment (end-users appraisal)

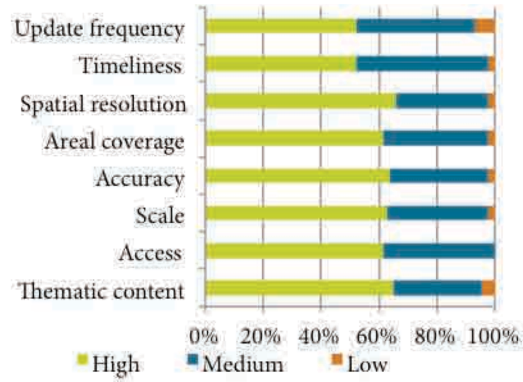


Figure 4.5.10: Criticality of product features of Landslide Hazard Assessment (non-end-users appraisal)

4.6 Geospatial data provision and costs aspects

Niels van Manen and John Trinder

A mere benefit assessment of geoinformation as presented in Chapters 4.1 to 4.5 would be insufficient without addressing also the aspects of data provision and related costs. Available geoinformation that would satisfy the technical profiles which served as a reference for the benefit assessments, differs greatly in terms of data sources as well as costs, keeping in mind that the technical profiles were designed to illustrate the state-of-the-art, i.e. research and development, not necessarily the state of operational implementation.

Therefore, provision of basic geodata for the reference products as described in the technical profiles is discussed in the following, as well as the relative costs, with emphasis on remotely sensed data. Some consideration is also given to potential cost reductions by modifying the specifications in the technical profiles. Costs of the provision of geoinformation are not directly related to the value of geoinformation for disaster risk management. As expressed in Chapter 2, the value of geoinformation can be assessed by costs avoided by the availability of geoinformation. In principle this is not related to the costs of acquiring the geoinformation, though it should guide the choice of methods of data collection in order to avoid unsustainable acquisition costs.

4.6.1 Geospatial data provision

Depending on the general application objective, the reference set of technical profiles can be categorized into three major types of geospatial information: hazard and risk assessment mapping, hazard and risk monitoring, and damage assessment mapping.

Hazard and risk assessment mapping

Risk assessment for the hazards addressed in Chapters 4.1 to 4.5, except for drought vulnerability which requires regional to global coverage, tends to require detailed maps mostly with high spatial resolutions:

- Flood Risk Maps with 1:2,000 to 1:10,000 map scales and a spatial resolution of 1 m to 5 m, with an update frequency of 5 years;
- Urban Classification for Earthquake Risk Mapping Analysis with 1:2,000 to 1:10,000 map scale, with an accuracy of 1 m and an update frequency of 5 years;
- Drought Vulnerability Mapping based on low spatial resolution data with timing a function of drought conditions;
- Fire Risk Assessment with 1:200,000 to 1:1,000,000 map scale and spatial resolution of 250 m to 1 km, with an accuracy of hazard indication of 80%;
- Landslide Hazard Assessment Mapping with 1:50,000 map scale and spatial resolution of 10 m, with an update frequency of 24 h for rainfall data.

Detailed geospatial information required for flood and earthquake risks mapping at scales of 1:2,000 to 1:10,000, would be expensive and time consuming to acquire. The technical profiles indicate that the map products can be in raster or vector form. The most economic products derived from either digital aerial images or satellite images are orthophoto maps which are raster products. Vector map products are more time consuming to produce because they involve manual interpretation of image content. However, the user of the orthophoto maps must be familiar with their interpretation.

Acquisition of orthophoto maps and Digital Elevation Models (DEM) may be done by aerial imaging, including the application of Unmanned Airborne Vehicles (UAV), airborne lidar (Light Detection and Ranging), or high spatial resolution satellite sensors with spatial resolutions of 0.5 m or less. DEMs may also be acquired from existing databases. Other information may be collected by in situ surveys. Forward planning and dedication of appropriate financial resources are required to cover, not only the flight campaigns for the acquisition of images or lidar data, but also the processing of the data to digital orthophoto map products.

Aerial systems based on medium to large format aerial cameras or smaller format light weight cameras on UAVs provide overlapping aerial images that will allow the derivation of map data by standard digital aerial photogrammetry methods. The accuracy of these products is primarily dependent on the Ground Sampling Distance (GSD), which is a function of the camera pixel size, the focal length of the camera and the flying height. While automated procedures allow for rapid derivation of elevations and orthophoto maps from images, there is still a significant requirement for inputs from highly trained technical and professional personnel.

Airborne lidar data will also be acquired from aerial systems with accuracies of the order of 0.15 m to 0.2 m. The data provider may supply various levels of data processing. A raw data product will include elevations of the terrain surface as well as of land cover structures such as vegetation, buildings, and other objects. Through further processing, at additional cost, the overall terrain surface can be extracted, which is critical especially for flood risk mapping.

High resolution satellite data must be purchased from the satellite providers at market prices. Processing of this data by expert personnel will be based on existing photogrammetric software for generating orthophotos and elevations.

Existing DEM data should be used with caution if the consistency of the data has not been proven. There are a number of recent examples where new elevation data of some large areas of Europe have been acquired by airborne lidar to ensure improved flood risk mapping.

Since the acquisition of large scale data as described above is expensive and the costs may be beyond regional capacity, alternatively smaller scale and lower accuracy maps/GIS data may be an option. A comparison of costs of medium resolution data (10 m or larger) and high resolution data (less than 2 m) are given below (section 4.6.2). Medium and low resolution data cannot provide information with the same accuracy or resolution as would be available from larger scales, but it may be a more affordable option and still be of benefit for flood risk mapping and urban classification for earthquake risk analysis. Images would be available from medium resolution remote sensing satellites including optical and synthetic aperture radar (SAR) systems, and could also be produced more rapidly, since the data would be less expensive to purchase and would require less processing. The output could still include physical earthquake vulnerability of urban areas based on density, quality and possibly age of buildings.

The spatial resolutions of the data required for fire risk assessment are relatively low and hence low spatial resolution satellite images can be employed. For example, the multi-channel low resolution sensor MODIS has significant advantages since the data is free and it provides a unique capability in terms of fire monitoring. Nevertheless, processing of the data must be undertaken by highly qualified personnel.

Because of the nature of drought as a slow-onset hazard with high spatial extension, the Technical Profile for Drought Vulnerability Map is based on low resolution maps with timing a function of the drought conditions. This data should be available from low cost or free medium to low spatial resolution satellite images which are unlikely to be affected by clouds. The processing of the data would need to be undertaken by trained personnel.

The assessment of drought impacts can be based on a number of indicators, such as those developed within the UNDP Disaster Risk Index (DRI) framework providing statistical evidence of links at the global scale between vulnerability to natural hazards and levels of development. The absence of geospatial reference data at local scales has reportedly limited the adoption of other indicators. There are clearly opportunities for geoinformation technologies to play a more significant role in drought vulnerability mapping and assessment in the future by linking geoinformation with socio-economic data describing drought vulnerability and drought impacts.

The generation of Landslide Hazard Maps is described in detail in chapter 4.5, with comprehensive tables including a range of data sources, such as airborne, satellite, field, laboratory and real-time data for modelling landslide initiation and run-out. Satellite-based data sources would include imagery from medium resolution satellites such as Landsat 8, SPOT4 or SPOT5, DMSII constellation, or RapidEye as well as SAR. Relative cost figures for these systems are given below in section 4.6.2.

Hazard and risk monitoring

Two types of monitoring systems are discussed:

- the Flood Risk Monitoring System with map scales of 1:25,000 to 1:3,000,000, geometric accuracy of 5 m to 500 m and spatial resolution 10 m to 1000 m according to the thematic class;
- the Fire Detection and Monitoring System, providing mapping products with 1:50,000 scale and 250 m spatial resolution, with daily update frequency and timeliness of 1 day during a fire event.

The Flood Risk Monitoring System requires less detailed information than the Fire Risk Map and could be derived for extensive flood hazard areas using the flood risk maps as a base with updates provided by satellite images. However, if the hazard area is small, the updated information should be provided by manned or UAV photography. Major advances are being made in a wide variety of applications of UAVs for localised aerial photography and their applications will increase in the future.

Satellite remote sensing is clearly important for fire detection and monitoring, based on a range of optical and SAR sensors. The MODIS satellite is an important source of data for fire detection and monitoring as described in Chapter 4.4, but the repeat cycle of 1 to 2 days limits its ability to monitor rapidly moving fires, indicating the need for a dedicated small satellite constellation for fire monitoring.

Damage assessment mapping

Three types of mapping products are discussed, two referring to floods and the third referring to earthquake damage.

- Flood Inundation Maps with a scale range of 1:1,000 to 1:1,000,000 and spatial resolution from 0.5 m to 250 m, given a timeliness of few hours after an emergency;
- Flood Damage Assessment Maps with a scale range of 1:1,000 to 1:60,000 and 30 m spatial resolution, required 1 to 2 days after the emergency;
- Earthquake Damage Assessment Maps scaled 1:500 to 1:10,000 with 0.2 m - 2 m geometric accuracy, provided a few hours after the disaster.

The Technical Profiles of Flood Inundation Maps and Flood Damage Maps vary significantly in scale, while the data required for earthquake damage assessment and rescue are very large scale. However, the base data for these maps should already be available from existing flood risk maps and earthquake risk maps with, in most cases, similar scales. Details of inundation and flood damage, or earthquake damage must be added to the base data after the event. If much smaller scales were to be used, new images would have to be acquired from satellites or UAVs. Since details are required within a few hours, aircraft or UAV borne photography could be provided, under the clouds if necessary, given that the necessary aerial photography equipment is available near the location of the disaster, and wind forces are within reasonable limits.

For the low resolution inundation maps, high altitude aircraft flights or optical satellite data such as the free of charge Landsat 8 data may be also appropriate if cloud free, but the 16 day repeat cycle of Landsat 8 may limit its suitability for damage assessment. Other optical or SAR constellations referred to above maybe more appropriate and acquired under the International Charter Space and Major Disasters. Voluntary input by NGOs and aid forces could significantly reduce costs of the acquisition and processing of the map products.

Often floods and especially earthquakes occur in remote areas and hence arranging for aerial photography may take time. Therefore, satellite based optical images (given cloud free conditions) or SAR imagery could be acquired free of charge under the International Charter Space and Major Disasters as a rapid alternative to aerial data acquisition. Timing of data acquisitions over the disaster site would depend on when the satellite passes over the site, but daily coverage is usually possible. The 24 hour operation of SAR satellites may enable quicker acquisition of images over the affected area at night. There is likely to be a time lag in supplying the product to users assessing inundation or earthquake damage, and procedures such as downloading map data over the internet directly to the site of the damage need to be further developed and implemented. The processing of the images to extract orthophoto damage maps would be largely automatic, but the extraction of actual damage to buildings would require further interpretation by users.

4.6.2 Costs aspects

There are three major challenges to face if more specific cost estimations are expected for the 10 reference products as described by the Technical Profiles, namely:

- the different cost categories that are relevant for products or systems, e.g. regarding the amount of 'input' that is readily available at minimal cost in terms of suitable data and mature soft- and hardware,
- variations in costs charged by different providers, and
- variation in costs due to where and when and under which programmatic conditions a given system is developed, implemented and operated.

Two extremely different examples may serve to illustrate this problem:

- An Inundation Map is a standard product, which can be derived from available multi-purpose satellite imagery and provided at relatively low cost or cost free e.g. in the framework of the International Charter Space and Major Disasters.
- In contrast, a Fire Detection and Monitoring System fulfilling the standards of the respective technical profile would partially require the data quality that was demonstrated by the German BIRD mission, i.e. the implementation of a fully fledged operational follow-on satellite mission.

Some exemplary relative cost figures for imagery from satellites with different spatial resolution are listed in Table 4.6.1, derived from the respective satellite providers' web sites, to provide a quick overview on the cost range. Costs of satellite-based Digital Elevation Models are in the range of $US 9 (SPOT) to 30 (TerraSAR-X) per km². Taking Turkey as an example, the estimated costs of providing maps from high resolution satellite images with 1 m spatial resolution

System	*Resolution*	*Costs ($US/km²)*
Landsat 8	30 m	free
DMCII	22 m	0.36 (for 3 data takes to avoid cloud cover)
SPOT 4 and 5	10 m	0.65
		2.6 (30' x 30' (54 km x 54 km) coloured ortho image)
RapidEye	6.5 m	1.28
TerraSAR-X	up to 18 m	2.3
	2 m	8.8

Table 4.6.1: Exemplary cost figures for remote sensing imagery (2013 prices based, approximated), derived from the respective satellite providers' web sites

in 2013 would be of the order of $US 200 per km²; the cost of deriving maps from high resolution aerial photography would be a factor of 50 to 100 more expensive. The typical costs of mapping from UAV photography are not yet readily available.

In addition, it should be pointed out that many data sets are available free of charge and can be downloaded from the web. Others are available as free web-services. A repository of free geospatial data and products has been compiled by UN-SPIDER on http://www.un-spider.org/page/6665/free-data-sources.

Furthermore, the 10 reference products relate to very different disaster types and different phases of disaster management. The cost-benefits-relation of products related more specifically to the emergency preparedness and response phases can be more easily modelled (e.g. by the Cost Avoidance Approach demonstrated in Chapter 2), because there is plenty of empirical data on the actual losses caused by various disaster types in different parts of the world.

Other products such as damage assessment maps contribute to recovery and reconstruction because they help to estimate the damages and needs or to monitor the financial performance of recovery activities, in both ways optimising the efficiency of recovery spending.

Geospatial information on risk and vulnerability, on the other hand, will support effective policies of mitigation and risk reduction. Whereas these preventive approaches as such are generally acknowledged as the option of choice to obtain higher efficiency in disaster management (see Chapter 2), the specific impact of geoinformation is more difficult to quantify. At present, any research on this point has to involve the explicit and tacit knowledge of stakeholders, practitioners and experts. To overcome the limitations of questionnaire and appraisal based approaches regarding this issue, it seems worthwhile to explore the potential of more elaborate methods for capturing the indispensable knowledge of stakeholders and end-users, for example by developing and performing exercises based on dedicated disaster management games software ('serious gaming').

5. Results summary and discussion

Robert Backhaus and John Trinder

Addressing the issue of evaluating contributions geoinformation can make in support of Disaster and Risk Management (DRM) requires exploring a wide interdisciplinary field, mainly under two headings:

- the *economic aspects*, which call for assessing the monetary value of benefits likely to be gained from applying geoinformation to DRM, and
- the practical impacts of such an application, i.e. assessing the *qualitative benefits* considering specific operational and strategic aspects of DRM.

With regard to the thematic and structural extent of this field of study, both aspects had to be analysed by pragmatic approaches, allowing for sufficient complexity reduction and focussing. Given the lack of validated computer-based models, stakeholder and expert surveys were the method of choice.

- The *economic aspects* were studied by a comprehensive analysis of applicable methodical approaches, followed by a case study to illustrate the potential of the Cost Avoidance Approach (Chapter 2).
- The assessment of *specific operational and strategic benefits* was based on technical descriptions of 10 short-listed geoinformation products and systems (Technical Profiles), and included the assessment of critical technical features (Chapters 3, 4). The results of a global stakeholder survey were complemented by outlining the scientific and technical background of the geoinformation products and systems (Chapters 4.1 to 4.5, respectively), and by discussing costs aspects of geodata provision (Chapter 4.6).

Major results of the study are summarized and discussed in the following.

5.1 Economic valuation

Determining the *economic value* of geospatial information in DRM remains an understudied topic within the thriving field of study dedicated to the economics of natural hazards and disaster management. Chapter 2 provides a review of methodical approaches. The Namibia flooding disaster of 2009 was selected to illustrate the application of the Cost Avoidance Approach for a case study. The floods had a major impact on Namibia's economy, reducing the GDP from an expected 1.1 % to 0.5 %. The total damages and losses, without considering the impacts of loss of life, were estimated to be $US 214.6 million (in 2009 value of $US).

A questionnaire was designed to chart the economic value of single geospatial information products, and a survey was carried out with Namibian stakeholders to estimate the cost savings that could have been realized given the availability of a Flood Early Warning System. The response to the survey was low and did not allow for statistical analysis. However, the results showed that the respondents estimated that savings could have been of the order of 45 % of the total damages and losses, with significant variation in the areas *Infrastructure, Productivity, Social* and *Cross Sectoral*. This figure is in agreement with data published in the literature on damage reduction from early flood warning, ranging between 35 and 47 %. Therefore a potential reduction of damage and losses in the Namibia floods of about 40 %, if a Flood Early Warning System had been available, can be assumed to be realistic, despite the low response rate to the survey.

The questionnaire is published in the Annex and may serve as a template for modification and application to other cases and geoinformation products.

5.2 Operational and strategic benefits

A global survey was carried out by way of two consecutive web-based polls.

The first poll resulted in a shortlist of 10 geoinformation products or systems considered most important by the global stakeholder community, represented by 222 respondents. There were no significant differences between responses from users, value-adders or providers of geoinformation for Disaster and Risk Management. The stakeholder community ascribed highest importance to geoinformation about *Flood, Earthquake, Drought, Fire,* and *Landslide* hazards.

The shortlist items were detailed by way of compact Technical Profiles and appraised for specific benefits in the course of the second poll, which was addressed mainly but not exclusively to end-users.

5.2.1 Scientific and technical aspects

Each of the hazards addressed has its own characteristics and so have the respective geoinformation products and systems. Accordingly, Chapters 4.1 to 4.5 provide insight into the scientific and technical background of each shortlisted geoinformation item, which is summarized as follows.

Flood and Flood Risk: Mapping, Monitoring and Damage Assessment

Flood disasters have increased recently and their frequency is likely to increase further in the future, due to the impacts of climate change and increases in settlements along rivers and coastlines. Four flood-related products were presented in the shortlist:

- Flood Risk Maps delineate areas prone to flooding, and infrastructure at risk, to support flood mitigation and preparedness.
- Flood Risk Monitoring Systems should detect and monitor critical changes in risk factors over time.
- Inundation Maps are prepared immediately after a flood event has taken place and delineate the actual flooded areas including the water depths.
- Flood Damage Assessment Maps aim to present details of socio-economic damage.

A number of existing well-developed flood mapping and early warning systems was described, particularly in Europe. Further investigations are recommended on the most cost-efficient ways to provide the different types of geoinformation for the derivation of the above products. This would benefit the economies of geoinformation for flood risk assessment and management. In addition, as flood risks increase, new areas that may emerge due to the impacts of climate change should be identified and the risk assessed.

Earthquake Risk Analysis and Damage Assessment

Since earthquakes are unpredictable and usually occur infrequently, the application of geoinformation is primarily applied for the physical description of vulnerabilities, which describe the susceptibilities of all kinds of human-made structures such as buildings, roads, infrastructures. The geoinformation required includes GIS databases based on the zonation of regions potentially subject to impacts of earthquakes, such as ground-shaking, fault rupture, and soil liquefaction, and on parameterization of the terrain form from digital elevation models. Many regions can be unexpectedly hit by an earthquake, and are unprepared for this disaster. Given the increasing availability of space borne optical and SAR systems, Earthquake Risk Analysis Maps on vulnerable areas can be developed worldwide at increasingly less cost. Methods should also be developed to reduce the time lag in the provision of geoinformation to the disaster site, e.g. communications technologies for downloading map data over the internet.

Methods should be further investigated for predicting earthquakes, based on the precise measurements of GNSS reference stations (Global Navigation Satellite Systems) around the globe, and on SAR interferometry.

Drought Vulnerability Mapping

Drought vulnerability is a crucial element of drought risk, which is the susceptibility to the damaging effects of drought hazard.

Drought hazard assessment is based on several indicators most of which may be derived from low resolution satellite data, so the application of geoinformation for drought hazard assessment should be low cost. People's vulnerability to drought, however, is complex, and has to be derived from historical and prevailing cultural, social, environmental, political and economic contexts. Hence, drought vulnerability indicators are based on global socio-economic databases available mostly on a national aggregation level, or geospatial datasets with a very coarse resolution, some of which are derived from satellite acquisitions. This is a limiting factor for the spatial resolution of drought vulnerability maps.

Given these restrictions, Drought Vulnerability Maps should be developed well in advance of the onset of a drought. Preparedness and response to drought disasters should also be supported by timely drought hazard assessment and monitoring.

Fire Risk Mapping and Fire Detection and Monitoring

Fire risk consists of fire danger and vulnerability. Fire danger is determined by the sources of ignition, human and natural. Fire risk takes into account the impact of fire on exposed socio-economic, recreational, ecological and cultural values.

Medium resolution geoinformation can play an important role by providing information on fire danger as well as vulnerability. Since humans play an important role in fire ignition, it is necessary to model human behaviour in relation to fire risk. This involves variables related to land use or land use-change, agricultural–forest or urban–forest interfaces, population trends, rural activities, and potential conflicts.

Fire Detection and Monitoring may contribute to risk assessment, but is mainly needed for disaster response support. While the MODIS instrument onboard of the Terra and Aqua satellites can be used for monitoring fires and determining damage, its repeat cycle of 1 to 2 days limits its ability to monitor rapidly changing fires. There are no satellites specifically available for tracking fires. A fire monitoring system that can detect the movement of wildfires could be realized with a constellation of dedicated low resolution fire satellites similar to the Bird and the proposed FireBIRD satelllites, which could monitor the globe continuously and indicate the occurrence and behaviour of wildfires. This would need to be achieved by international cooperation of nations affected by wildfires in both the northern and southern hemispheres. While local fire monitoring is possible with manned aircraft or UAV, on critical fire storm days, the local weather conditions during fire storms often preclude flying. The costs of such a constellation would be minimal compared with the potential damages and losses due to fires on a global scale.

Landslide Hazard Assessment

The six classes of landslides and the conditions under which they can occur were described, as well as the natural triggering mechanisms of precipitation, seismicity and volcanic activity. Human induced triggers can include all kinds of activities affecting or transforming the morphology of a slope and causing an instantaneous failure. The degree of hazard and impact is related to the velocity of movement which can vary from extremely rapid to extremely slow motion.

The provision of geoinformation for Landslide Hazard Assessment Mapping in areas subject to the risk of landslides is an essential task for the safety of lives and property. The examples presented demonstrate the work that is undertaken at some locations around the world. Such efforts must be extended to those areas not currently covered by appropriate mapping.

5.2.2 Cost aspects

A detailed specific comparison between benefits and costs was beyond the scope of this study, due to the widespread range of prices for different types and sources of geodata, the differences in data availability among different countries, and the differences between the shortlisted geoinformation items which range from one-time local mapping products to spatially extended monitoring systems. Instead, an overview on relative costs of satellite data together with an outline of the specific data requirements for the shortlisted geoinformation products, is given in Chapter 4.6.

Depending on the specific application goal and the target region, there is ample room for cost-effective modification of the methods used for deriving this geoinformation, especially with respect to spatial resolution. The application of UAVs for provision of geoinformation on damage due to disasters should also be further investigated.

5.2.3 Appraisal results

Due to the necessarily more elaborate appraisal scheme in the second poll, the number of responders was lower, amounting to 70 participants including 51 end-users.

Whereas this number of participants cannot be taken as being equivalent to a fully representative global response, it surely represents a global group of engaged stakeholders with a significant interest in the evaluation of geoinformation for DRM.

The poll results are presented in detail in Chapters 3 and 4. In summary, they give evidence of the following points:

- Besides geoinformation on actual damage assessment, the stakeholder community emphasizes the importance of risk and vulnerability mapping/monitoring.
- A vast majority of end-users ascribe a high to medium benefit to all shortlisted geoinformation items for all the operational and strategic issues addressed.
- 55 to 80 % of responding end-users ascribe a high benefit to all 10 shortlisted geoinformation products for reducing losses in public economy and supporting preventive strategies.
- End-users ascribe a high benefit of geoinformation provided on actual disaster events as well as for the support of preventive activities.
- In comparison, non-end-users generally tend to underestimate the benefit potential.
- End-users and non-end-users mostly differ in their assessment of the criticality of specific technical product features.

From the methodical point of view, the study clearly shows the indispensable value of user knowledge when it comes to evaluating geoinformation for Disaster and Risk Management. To overcome the limitations of questionnaire-based surveys, the potential of dedicated management games could be further explored.

6. References

ACIL Tasman, 2008. The value of spatial information – The impact of modern spatial information technologies on the Australian economy. http://www.crcsi.com.au

Adams, B.J., 2004. Improved Disaster Mangement through post Earthquake Building Damage Assessment using Multi-temporal Satellite Imagery, Proceedings of the ISPRS XXth Congress, Vol 35. http://www.isprs.org/proceedings/XXXV/congress/comm7/papers/121.pdf

Adams, B.J., et al., 2004. Application of High-Resolution Optical Satellite Imagery for Post-Earthquake Damage Assessment: The 2003 Boumerdes (Algeria) and Bam (Iran) Earthquakes. Research Progress and Accomplishments: 2003-2004, Multidisciplinary Center for Earthquake Engineering Research (MCEER), 173-186. https://mceer.buffalo.edu/publications/resaccom/04-SP01/12_Eguchi.pdf

Ahern, F.J., Goldammer, J G., and Justice, C.O., 2001. Global and Regional Vegetation Fire Monitoring from Space: Planning a Coordinated International Effort, The Hague.

Alexander, L.V., X. Zhang, T.C. Peterson, J. Caesar, B. Gleason, A.M.G. Klein Tank, M. Haylock, D. Collins, B. Trewin, F. Rahimzadeh, A. Tagipour, K.R. Kumar, J. Revadekar, G. Griffiths, L. Vincent, D.B. Stephenson, J. Burn, E. Aguilar, M. Brunet, M. Taylor, M. New, P. Zhai, M. Rusticucci, and J.L. Vazquez-Aguirre, 2006. Global observed changes in daily climate extremes of temperature and precipitation. Journal of Geophysical Research – Atmospheres, 111, D05109.

Alfieri, L., Salamon, P., Pappenberger, F., Wetterhall, F., and Thielen, J., 2012. Operational early warning systems for water-related hazards in Europe. Environmental Science & Policy, 21, 35–49.

Altan, O., Backhaus R., Boccardo, P., and Zlatanova S. (Eds.), 2010. Geoinformation for Disaster and Risk Management: Examples and Best Practices. Published by Joint Board of Geospatial Information Societies (JB GIS) and United Nations Office for Outer Space Affairs (OOSA), Copenhagen.

Altan, O., Kemper, G., 2008. System architecture for earthquake, tsunami preparedness and warning. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVII, Part B4, 1061-1071, Beijing.

Anderson, M.B., 1990. Analyzing the Costs and Benefits of Natural Disaster Responses in the Context of Development. http://www.crid.or.cr/digitalizacion/pdf/eng/doc260/doc260-a.pdf

Anderson, H.E., 1982. Aids to determining fuel models for estimating fire behavior. USDA, Forest Service, General Technical Report INT-122, Ogden, UT.

Andreae, M.O., 1991. Biomass burning: its history, use, and distribution and its impact on environmental quality and global climate. J. S. Levine (Ed.), Global Biomass Burning, Cambridge, MA, 3-21.

Andreae, M.O., Browell E.V., Garstang M., Gregory G.L., Harriss R.C., Hill G.F., Jacob D.J., Pereira M.C., Sachse G.W., Setzer A.W., Silva Dias P.L., Talbot R.W., Torres A.L., Wofsy S.C., 1988. Biomass-burning and associated haze layers over Amazonia. Journal of Geophysical Research, 93, 1509-1527.

Andrews, P.L., Chase, C.H., 1990. The BEHAVE fire behavior prediction system. The Compiler 8, 4–9.

Aragoneses, C., Rábade, J.M., 2008. Propuesta metodológica para el Análisis de la Vulnerabilidad y de la Gravedad Potencial de los Incendios Forestales en el marco de la Protección Civil. González, A., Memorias del Segundo Simposio Internacional Sobre Políticas, Planificación y Economía de losProgramas de Protección Contra Incendios Forestales: Una Visión Global. Gen. Tech. Rep. PSW-GTR-208.

Arriaza, M., Cañas-Ortega, J.F., Cañas-Madueño, J.A., Ruiz-Aviles, P., 2004. Assessing the visual quality of rural landscapes. Landscape and Urban Planning 69, 115–125.

Australian Geomechanics Society, 2002. Landslide risk management concepts and guidelines. Australian Geomechanics Society sub-committee on landslide risk management, 51–70.

Ayalew, L. and Yamagishi, H., 2005. The application of GIS-based logistic regression for landslide susceptibility mapping in the Kakuda–Yahiko Mountains, Central Japan. Geomorphology, 65, 15–31.

Bachmann, A., Allgöwer, B., 2001. A consistent wildland fire risk terminology is needed! Fire Management Today 61, 28–33.

Backhaus, R., and Beule, B., 2005. Efficiency Evaluation of Satellite Data Products in Environmental Policy. Space Policy 21, 173-183.

Baeza, M.J., Luis, M.D., Raventos, J., Escarre,A., 2002. Factors influencing fire behavior in shrublands of different stand ages and the implications for using prescribed burning to reduce wildfire risk. Journal of Environmental Management 65, 199–208.

Bai Z.G., Dent D.L., Olsson L., Schaepman M.E., 2008. Global assessment of land degradation and improvement 1: identification by remote sensing. Report 2008/01, FAO/ISRIC, Rome/Wageningen. http://www.fao.org/nr/lada/dmdocuments/GLADA_international.pdf

BCPR-UNDP, 2004. A Global Report: Reducing Disaster-Risk, A Challenge for Development, New York.

Benson, C., Clay, E.J., 2004. Understanding the Economic and Financial Impacts of Natural Disasters. Washington: The International Bank for Reconstruction and Development/ The World Bank.

Benson, C., Twigg, J., 2004. Measuring Mitigation. Methodologies for assessing natural hazard risks and the net benefits of mitigation. A scoping study. http://reliefweb.int/sites/reliefweb.int/files/resources/EF2C968CE8E53ACF-C1256FE000592D6C-Measuring_Mitigation_report.pdf

Birkmann, J., Mucke, P., 2011. World Risk Report. United Nations University, Institute for Environment and Human Society.

Boschetti M., Bocchi S., Brivio P. A., 2007. Assessment of pasture production in the Italian Alps using spectrometric and remote sensing information. Agriculture, Ecosystems and Agriculture, Ecosystems and Environment, 118, 267–272.

Bradshaw, L., Deeming, J., Burgan, R.E., Cohen, J., 1983. The 1978 National Fire-Danger Rating System: Technical Documentation No. GTR INT-169, USDA. Forest Service, Ogden, UT.

Browell, E.V., Gregory G.L., Harriss R.C., 1988. Tropospheric ozone and aerosol distributions across the Amazon Basin. Journal of Geophysical Research, 93, 1431-1451.

Brunsden, D., 1984. Mudslides. Brunsden D., Prior D.B., (Eds.) Slope instability, Chapter 9, New York, NY.

Brunsden, D., 2001. A critical assessment of the sensitivity concept in geomorphology. Catena, 42, 99-123.

Burke E. J. , Brown S. J., 2008. Evaluating Uncertainties in the Projection of Future Drought. Journal of Hydrometeorology, Vol. 9, No. 2, 292–299.

Carrara A., Guzzetti F., Cardinali M., Reichenbach P., 1999. Use of GIS Technology in the Prediction and Monitoring of Landslide Hazard. Natural Hazards 20, 117-135.

Camia, A., Leblon, B., Cruz, M., Carlson, J.D., Aguado, I., 2003. Methods used to estimate moisture content of dead wildland fuels. Chuvieco, E. (Ed.), Wildland Fire Danger Estimation and Mapping. The Role of Remote Sensing Data, Singapore, 91–117.

Cardille, J.A., Ventura, S.J., Turner, M.G., 2001. Environmental and social factors influencing wildfires in the Upper Midwest, United States. Ecological Applications 11, 111–127.

Cardona, O.D., M.K. van Aalst, J. Birkmann, M. Fordham, G. McGregor, R. Perez, R.S. Pulwarty, E.L.F. Schipper, and B.T. Sinh, 2012. Determinants of risk: exposure and vulnerability. Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (Eds.), Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge, UK, and New York, NY, 65-108.

Carson, R.T., Wilks, L., Imber, D., 1994: Valuing the preservation of Australia's Kakadu Conservation Zone. Oxford Economic Papers, Vol. 46(0), 727-49.

Carsell, K. M., Pingel, N. D., Asce, M., Ford, D. T., 2004. Quantifying the Benefit of a Flood Warning System. Nat. Hazards Rev., 5, 131–140.

CEA, 2007. Reducing the Social and Economic Impact of Climate Change and Natural Catastrophes: Insurance Solutions and Public-Private Partnerships, Brussels.

Chou, Y.H., Minnich, R.A., Chase, R.A., 1993. Mapping probability of fire occurrence in San Jacinto Mountains, California, USA. Environmental Management 17, 129–140.

Chuvieco, E. (Ed.), 1999. Remote Sensing of Large Wilddfires in the European Mediterranearn Basin.

Chuvieco, E., Martin, M.P., Palacios, A., 2002. Assessment of different spectral indices in the red-near-infrared spectral domain for burned land discrimination. International Journal of Remote Sensing, 23, 5103–5110.

Chuvieco, E., Allgöwer, B., Salas, F.J., 2003. Integration of physical and human factors in fire danger assessment. Chuvieco, E. (Ed.), Wildland Fire Danger Estimation and Mapping. The Role of Remote Sensing Data. World Scientific Publishing, Singapore, 197–218.

Chuvieco, E., Cocero, D., Riaño, D., Martín, M.P., Martínez-Vega, J., de la Riva, J., Pérez, F., 2004. Combining NDVI and surface temperature for the estimation of live fuel moisture content in forest fire danger rating. RSE 92, 322–331.

Chuvieco, E., Ventura, G., Martín, M.P., Gomez, I., 2005. Assessment of multitemporal compositing techniques of MODIS and AVHRR images for burned land mapping. RSE 94, 450–462.

Chuvieco, E., Aguado, I., Yebra, M., Nieto, H., Salas, J., Martín, P., Vilar, L., Martínez, J., Martín, S., Ibarra, P., de la Riva, J., Baeza, J., Rodríguez, F., Molina, J.R., Herrera, M.A., Zamora, R., 2010. Development of a framework for fire risk assessment using remote sensing and geographic information system technologies. Ecological Modelling 221, 46–58.

Comerio, M., Gordon, P., 1998. Defining the Links between Planning, Policy Analysis, Economics, and Earthquake Engineering. http://peer.berkeley.edu/publications/peer_reports/reports_1998/9804.pdf

Cruden, D.M., 1991. A simple definition of a landslide. Bulletin International Association for Engineering Geology, 43, 27-29.

Cruden, D.M., Varnes, D.J., 1996. Landslide types and processes. Turner, A.K., Schuster, R.L. (Eds.), Landslides: investigation and mitigation (Special Report). National Research Council, Transportation and Research Board Special Report 247, Washington, DC, 36–75.

Crutzen, P. J., A. C. Delany, J. Greenberg, P. Haagenson, L. Heidt, R. Lueb, W. Pollock, W. Seiler, A. Wartburg, and P. Zimmerman, 1985. Tropospheric chemical composition measurements in Brazil during the dry season, J. Atmos. Chem., 2, 233-256.

Crutzen, P.J., M.O., Andreae, 1990. Biomass burning in the tropics: impact on atmospheric chemistry and biogeochemical cycles. Science, 250, 1669-1678.

Dai, A., 2011. Drought under global warming: a review. Wiley Interdisciplinary Reviews: Climate Change, 2(1), 45-65.

Danson, F.M., Bowyer, P., 2004. Estimating live fuel moisture content from remotely sensed reflectance. RSE 92, 309–321.

Day, H. J., 1970. Flood warning benefit evaluation - Susquehanna River Basin (urban residences). Weather Bureau, Office of Hydrology, Silver Spring, Md.

Dennison, P.E., Roberts Dar, A., Peterson, S.H., Rechel, J., 2005. Use of Normalized Difference Water Index fornmonitoring live fuel moisture content. IJRS 26, 1035–1042.

De Groeve, T., 2010. Flood monitoring and mapping using passive microwave remote sensing in Namibia. Geomatics, Natural Hazards and Risk, 1(1), 19–35. doi:10.1080/19475701003648085.

Diamond, P. A., Hausman, J. A., 1994. Contingent Valuation: Is Some Number Better than No Number? American Economic Association, 8(4), 45–64.

Díaz-Avalos, C., Peterson, D.L., Alvarado, E., Ferguson, S.A., Besag, J.E., 2001. Space–time modelling of lightning-caused ignitions in the Blue Mountains, Oregon. Canadian Journal of Forest Research 31, 1579–1593.

Dirección General de Biodiversidad, 2006. Los incendios forestales en España. Ministerio de Medio Ambiente Madrid.

Dozier, J., 1981. A method for satellite identification of surface temperature fields of subpixel resolution. Remote Sensing of Environment, 11, 221-229. http://dx.doi.org/10.1016/0034-4257(81)90021-3

Ebi, K.L., Teisberg, T.J., Kalkstien, L.S., Robinson, L., Weiher, R.F., 2004. Heat Watch/Warning Systems save Lives. Estimated Costs and Benefits for Philadelphia 1995-98. http://www.udel.edu/SynClim/BAMS_Ebi_Kalkstein.pdf

EM-DAT, 2012. EM-DAT online database. Retrieved 11 December, 2012. http://www.emdat.be/result-country-profile

ENSURE Project, 2010a. WP1: State-of-the-art on vulnerability type – Deliverable 1.1.3: Methodologies to assess vulnerability of structural, territorial and economic systems, European Commission 7th Framework Programme. http://www.ensureproject.eu/ENSURE_Del1.1.3.pdf

ENSURE Project, 2010b. WP2: Integration and Connection of Vulnerabilities – Deliverable 2.1.2: Relation between systemic and physical vulnerability and relation between systemic, social, economic, institutional and territorial vulnerability, European Commission 7th Framework Programme. http://www.ensureproject.eu/ENSURE_Del2.1.2.pdf

EPOCH, 1993. The temporal occurrence and forecasting of landslides in the European community. Flageollet, J. C. (Ed.), Contract No. 90 0025, 3 Volumes.

Eriyagama, N., Smakhtin, V., Gamage, N., 2009. Mapping drought patterns and impacts: a global perspective. International Water Management Institute. IWMI Research Report 133, Colombo. http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB133/RR133.pdf

Erlich, M., 2007. OSIRIS - an example of citizen-oriented technology development in the area of dissemination of information on flood risk management. Flood Risk Management in Europe, Advances in Natural and Technological Hazards Research Volume 25, 43-60.

EU, 2007. Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, Commission of the European communities (EU), Brussels.

FAO, 1986. Wildland Fire Management Terminology. Food and Agriculture Organization of the United Nations, FAO Forestry Paper 70.

FAO, 2007. Fire Management-Global Assessment 2006. A Thematic Study Prepared in the Framework of the Global Forest Resources Assessment, 2005.

Federal Emergency Management Agency, 1997. Report on Costs and Benefits of Natural Hazard Mitigation. http://www.fema.gov/pdf/library/haz_cost.pdf

Federal Emergency Management Agency, 1998. Protecting Business Operations. Second Report on Costs and Benefits of Hazard Mitigation. http://www.fema.gov/pdf/library/haz_pbo.pdf

Finney, M.A., 1998. FARSITE: Fire Area Simulator - Model development and evaluation. USDA Forest Service, RMRS-RP-4.

Fishman, J., Minnis P., Reichle Jr. H.G., 1986. Use of satellite data to study tropospheric ozone in the tropics. Journal of Geophysical Research, 91, 14451-14465.

Frich, P., L.V. Alexander, P.M. Della-Marta, B. Gleason, M. Haylock, A.M.G. Klein Tank, Peterson T., 2002. Observed coherent changes in climatic extremes during the second half of the twentieth century. Climate Research, 19(3), 193-212.

Fritz, S., Scholes, R. J., Obersteiner, M., Bouma, J., Reyers, B., 2008. A Conceptual Framework for Assessing the Benefits of a Global Earth Observation System of Systems. Systems Journal, IEEE, 2(3), 338–348.

Giglio, L., Descloitres, J., Justice, C.O., Kaufman, Y., 2003. An enhanced contextual fire detection algorithm for MODIS. Remote Sensing of Environment, 87, 273-282.

Giovannini, G., 1999. Post-fire soil erosion risk. How to predict and how prevent. Proceedings of the Advanced Study Course on Wildfire Management. European Commission, Athens, 305–321.

Gomez-Delgado, M., Barredo-Cano, J.I., 2006. Sistemas de informacion geografica y evaluacion multicriterio en la ordenacion del territorio. RA-MA, Madrid.

Hallegatte, S., 2012. A Cost Effective Solution to Reduce Disaster Losses in Developing Countries and Evacuation: Hydro-Meteorological Services, Early Warning, and Evacuation.

Herath, S., 2003. Flood Damage Estimation of an Urban Catchment using Remote sensing and GIS. International Training Program on Total Disaster Risk Management. http://www.adrc.asia/publications/TDRM2003June/10.pdf

Hodgson, M.E., Davis, B.A., Kotelenska, J., 2010. Remote sensing and GIS DATA/information in the emergency response/Recovery phase. PS Showalter and Lu, Y (Eds.), Geotechnical Contributions to Urban Hazard and Disaster Analysis, 327-354. http://dx.doi.org/10.1007/978-90-481-2238-7

Hodgson, M.E., Battersby, S.E., Liu, S., Sulewski, L., 2013. Gospatial and Remote Sensing Data Use by States and Counties in Disaster Response and Recovery: A Nationwide Survey, Final Report 20 February. Department of Homeland Security, Science and Technology Directorate, 121. http://people.cas.sc.edu/hodgsonm/Published_Articles_PDF/Survey%20Geospatial%20Remote%20Sensing%20Data%20Use%20State%20Counties_2-20-2013.pdf

Huete, A.R., 1988. A soil-adjusted vegetation index (SAVI), Remote Sens. Environ. 25, 295-309.

International Organization of Supreme Audit Institutions, 2013. INTOSAI 5540: Use of Geospatial Information in Auditing Disaster Management and Disaster-related Aid, Copenhagen.

IPCC, 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (Eds.), Cambridge, UK, and New York, NY.

Jiang, J., and Cao, S., 1994. Real-time disaster monitoring system by using SAR, Microwave instrumentation and satellite photogrammetry for remote sensing of the Earth, Rome, 91-97.

Johnson, S. R., Holt, M. T., 1986. The Value of Climate Information. Policy Aspects of Climate Forecasting. Proceedings, May 4, Resources for the Future, Washington, DC, 53–78.

Justice C.O., Holben B.N., Gwynne M.D., 1986. Monitoring East African vegetation using AVHRR data. International Journal of Remote Sensing, 7, 1456-1474. http://dx.doi.org/10.1080/01431168608948948

Justice, C., Kendall, J.D., Dowty, P.R., Scholes, R.,J., 1996. Satellite remote sensing of fires during the SAFARI campaign using NOAA advanced very high resolution radiometer data. J Geophy Res.

Kasischke, E.S., N.H.F. French, 1995. Locating and estimating the areal extent of wildfires in Alaskan boreal forests using multiple season AVHRR NDVI composite data. Remote Sensing of Environment, 51, 263-275.

Kato, Y., Yokohari, M., Brown, R.D., 1997. Integration and visualization of the ecological value of rural landscapes in maintaining the physical environment of Japan. Landscape and Urban Planning, 39.

Kaufman, D.L., Erlander, M.G., Clare-Salzler, M., Atkinson, M.A., Maclaren, N.K., Tobin, A.J., 1992. Autoimmunity to two forms of glutamate decarboxylase in insulin-dependent diabetes mellitus. J Clin Invest, 89(1), 283–292.

Kaufman, Y.J., Justice, C.O., Flynn, L.P., Kendall, J.D., Prins, E.M., Giglio, L., Ward, D.E., Menzel, W.P., and Setzer, A.W., 1998. Potential global fire monitoring from EOS-MODIS. Journal of Geophysical Research, 103, 32215-32238.

Kerle, N., Heuel, S., Pfeifer, N., 2008. Real-time data collection and information generation using airborne sensors. In: Zlatanova, Li (Eds.), Geospatial Information Technology of Emergency Response, 43-74.

Klafft, M., Meissen, U., 2011. Assessing the Economic Value of Early Warning Systems. Proceedings of the 8th International ISCRAM Conference, Lisbon.

Knyazikhin, Y., Glassy, J., Privette, J.L., Tian,Y., Lotsch,A., Zhang, Y., Wang, Y., Morisette, J.T., Votava, P., Myneni, R.B., Nemani, R.R., Running, S.W., 1999. MODIS leaf area index (LAI) and fraction of photosynthetically active radiation absorbed by vegetation (FPAR) product (MOD15). Algorithm Theoretical Basis Document. http://eospso.gsfc.nasa.gov/atbd/modistables.html

Kochi, I., John Loomis, J., Patricia Champ P., Donovan G., 2009. Health and Economic Impact of Wildfires: Literature Review and Impact Assessment. González-Cabán, A., Proceedings of the third international symposium on fire economics, planning, and policy: common problems and approaches. Gen. Tech. Rep. PSW-GTR-227 (English) U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA, 102-115.

Krek, A., Frank, A. U., 1999. Optimization of Quality of Geoinformation Products. Whigham, P.A., (Ed.), Proceedings of 11th Annual Colloquium of the Spatial Information Research Centre, SIRC'99, University of Otago, 151-159.

Kundak, S., 2010. The Role of Great Investments and New Development Plans Regarding to the Change of Vulnerability in Urban Areas, Final Report, International Post-Doctoral Research Fellowship Programme, TUBITAK, Istanbul.

Latham, D.J., Schlieter, J.A., 1989. Ignition probabilities of wildland fuels based on simulated lightning discharges. No. Research Paper INT-411, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Leone, V., Koutsias, N., Martínez, J., Vega-García, C., Allgöwer, B., Lovreglio, R., 2003. The human factor in fire danger assessment. Chuvieco, E. (Ed.), Wildland Fire Danger Estimation and Mapping. The Role of Remote Sensing Data, Singapore, 143–196.

Levine, J.S., 1991. Global biomass burning: atmospheric, climatic, and biospheric implications. J. S. Levine (Ed.), Global Biomass Burning, Cambridge, MA.

Lloyd-Hughes, B., Saunders M.D., 2002. A drought climatology for Europe. International Journal of Climatology, 22 (13), 1571-1592.

Macauley, M.K., 2005. The Value of Information: A Background Paper on Measuring the Contribution of Space-Derived Earth Science Data to National Resource Management.

Maki, M., Ishiahra, M., Tamura, M., 2004. Estimation of leaf water status to monitor the risk of forest fires by using remotely sensed data. RSE 90, 441–450.

Martell, D.L., Bevilacqua, E., Stocks, B.J., 1989. Modelling seasonal variation in daily people-caused forest fire occurrence. Canadian Journal of Forest Research 19, 1555–1563.

Martin, M.P., 1998. Fire Detection and Fire Growth Monitoring Using Satellite Data. Chuvieco, E., (Ed.), Remote sensing of large wildfires in the European Mediterranean Basin, Berlin/Heidelberg, 6.1-6.22.

Martínez, J., Chuvieco, E., Martin, M.P., 2004. Estimating human risk factors in wildland fires in Spain using logistic regression. II. International Symposium on Fire Economics, Planning and Policy: A Global Vision, Córdoba.

Martínez, J., Vega-García, C., Chuvieco, E., 2009. Human-caused wildfire risk rating for prevention planning in Spain. Journal of Environmental Management 90, 1241–1252.

Martínez-Vega, J., Martín, M.P., Romero, R., 2003. Valoración del paisaje en la Zona de Especial Protección de Aves Carrizales y Sotos de Aranjuez (Comunidad de Madrid). GeoFocus 3, 1–21.

Martínez-Vega, J., Romero, R., Echavarría, P., 2007. Valoración paisajística y ecológica de la Comunidad de Madrid: su integración en un índice sintético de riesgo de incendios forestales. Revista de Teledetección 28, 43–60.

Matson, M. and J. Dozier, 1981. Identification of subresolution high temperature sources using a thermal IR sensor, Photo. Engr. and Remote Sensing, 47 (9), 1311-1318.

McKee, T.B., Doesken, N.J., Kleist, J., 1993. The relationship of drought frequency and duration to time scales. Proceedings of the 8th Conference on Applied Climatology, Anaheim, CA, 179-184.

Mechler, R., 2003. Natural Disaster Risk and Cost-Benefit Analysis. http://www.bvsde.paho.org/bvsacd/cd46/cap3-cost.pdf

Middelkoop, H., Daamen, K., Gellens, D., Grabs, W., Kwadijk, J. C. J., Lang, H., Parmet, B.W. A. H., Schadler, B., Schulla, J., Wilke, K., 2001. Impact of climate change on hydrological regimes and water resources management in the Rhine basin. Climatic Change, 49, 105–128. http://dx.doi.org/10.1023/A:1010784727448

Millennium Challenge Corporation, 2008. Economic rates of return models. http://www.mcc.gov/pages/activities/activity/economic-rates-of-return

Multihazard Mitigation Council, 2002. Parameters for an Independent Study to Assess the Future Benefits of Hazard Mitigation Activities. http://www.nibs.org/client/assets/files/mmc/July%202002%20Phase%20I%20Final%20Report.pdf

Munasinghe, M. and Clarke, C. (Eds.), 1995. Disaster Prevention for sustainable development. Economic and Policy Issues. The International Bank for Reconstruction and Development/ The World Bank, Washington, DC. http://www.disaster-info.net/lideres/spanish/mexico/biblio/eng/doc6536/doc6536-contenido.pdf

Mundy, B., McLean, D., 1998. The addition of contingent valuation and conjoint analysis to the required body of knowledge for the estimation of environmental damage to real estate. The Journal of Real Estate Practice and Education, 1998.

Munich Re Group, 2012. TopicsGeo: Earthquake, Flood, nuclear accident, Analyses, assessments, positions. http://www.munichre.com/publications/302-07225_en.pdf

Munich RE, 2012. NatCatSERVICE. http://www.munichre.com/en/reinsurance/business/non-life/georisks/natcatservice/default.aspx

Nadim, F., Kjekstad, O., Peduzzi, P., Herold, C., Jaedicke, C., 2006. Global landslide and avalanche hotspots. Landslides, V3(2), 159-173. http://dx.doi.org/10.1007/s10346-006-0036-1

Nadim, F., Jaedicke, C., Smebye, H., Kalsnes, B., 2013. Assessment of Global Landslide Hazard Hotspots. K. Sassa, B. Rouhban, S. Briceño, M. McSaveney and B. He (Eds.), Landslides: Global Risk Preparedness, Berlin/ Heidelberg, 59-71. http://dx.doi.org/10.1007/978-3-642-22087-6_4

Nakagoshi, N., Kondo, T., 2002. Ecological land evaluation for nature redevelopment in river areas. Landscape Ecology 17 (Suppl. 1), 83–93.

National Oceanic and Atmospheric Administration (NOAA) 2001 Report. http://www.darp.noaa.gov/library/pdf/cvblue.pdf

National Oceanic and Atmospheric Administration (NOAA), National Environmental Satellite, Data, and Information Service, Office of Systems Development, 2002. Geostationary Operational Environmental Satellite System (GOES) GOES -R Sounder and Imager Cost/Benefit Analysis (CBA). http://www.goes-r.gov/downloads/GOES-R%20Sounder%20and%20Imager%20Cost%20Benefit%20Analysis%20%28CBA%29/GOES-R_CBA_Final_Jan_9_2003.pdf

National Research Council, 2007. Successful response starts with a map: Improving Geospatial Support for Disaster Management. Natural Hazards, special issue: 'Flooding in Europe: Risks and Challenges', Washington, DC.

Nelson, R.M., 2001. Water relations of forest fuels. Johnson, E.A., Miyanishi, K. (Eds.), Forest Fires: Behavior and Ecological Effects, San Diego, CA, 79–149.

Nishihama, M., Wolfe, R., Solomon, D., Patt, F., Blanchette, J., Fleig, A., Masuoka, E., 1997. MODIS Level 1A Earth Location: Algorithm Theoretical Basis Document, Version 3.0, SDST-092, Technical report, NASA, GSFC, Washington, DC. http://modis.gsfc.nasa.gov/data/atbd/atbd mod28 v3.pdf

OAS: Organization of American States, 1991. Primer on Natural Hazard Management in Integrated Regional Development Planning. Chapter 8 - Floodplain Definition and Flood Hazard Assessment, Washington, DC. http://www.oas.org/DSD/publications/Unit/oea66e/ch08.htm#chapter 8 floodplain definition and flood hazard assessment

Oertel, D., Lorenz, E., and Halle, W., 2010. Detection and Monitoring of Wildfires by a Constellation of Small Satellites with Infrared Sensor Systems. Altan, O., Backhaus R., Boccardo, P., and Zlatanova S. (Eds.), Geoinformation for Disaster and Risk Management: Examples and Best Practices, Copenhagen, 13-17.

Ordnance Survey, 2013. Assessing the value of OS OpenData to the Economy of Great Britain – Synopsis. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/207692/bis-13-950-assessing-value-of-opendata-to-economy-of-great-britain.pdf

Orlowsky, B., Seneviratne S.I., 2011. Global changes in extremes events: Regional and seasonal dimension. Climatic Change. http://dx.doi.org/10.1007/s10584-011-0122-9

Oxera, 2013. What is the Economic Impact of Geo Services? Prepared for Google.

Palmer, W.C., 1965. Meteorological Drought. US Weather Bureau, Report 45, Washington, DC.

PDNA/ The Government of the Republic of Namibia, 2009. Post-Disaster Needs Assessment - Floods 2009.

Peduzzi P., Dao H., Herold C., Mouton F., 2003. Global Risk And Vulnerability Index Trends per Year (GRAVITY) Phase III: Drought analysis. United Nations Environment Programme Global Resource Information Database – Geneva UNEP/DEWA/GRID.

Peduzzi, P., Dao, H., Herold, C., Mouton, F., 2009. Assessing global exposure and vulnerability towards natural hazards: the Disaster Risk Index. Natural Hazards and Earth System Science, 9(4), 1149-1159. http://dx.doi.org/10.5194/nhess-9-1149-2009

Penning-Rowsell, E., Johnson, C., Tunstall, S., Tapsell, S., Morris, J., Chatterton, J., Coker, A., et al., 2003. The Benefits of flood and coastal defence: techniques and data for 2003. Flood Hazard Research Centre, Middlesex University.

Pinty, B., M.M. Verstraete, 1992. Modeling the scattering of light by homogeneous vegetation in optical remote sensing, Journal of the Atmospheric Sciences, 55, 137-150.

Pinty, B., Widlowski, J.L., Taberner, M., Gobron, N., Verstraete, M.M., Disney, M., Gascon, F., Gastellu, J.P., Jiang, L., Kuusk, A., 2004. Radiation Transfer Model Intercomparison (RAMI) exercise: results from the second phase. Journal of Geophysical Research 109, D06210. http://dx.doi.org/06210.01029/02003JD004252

Reed B.C., Brown J.F., Vandere Zee D., Loveland T.R., Merehant J.W., Ohlen D.O., 1994. Measuring phenological variability from satellite imagery. Journal of Vegetation Science, 5, 703-714. http://dx.doi.org/10.2307/3235884

Reiter, L., 1991. Earthquake Hazard Analysis. Issue and Insights, New York, NY.

Riaño, D., Vaughan, P., Chuvieco, E., Zarco-Tejada, P., Ustin, S.L., 2005. Estimation of fuel moisture content by inversion of radiative transfer models to simulate equivalent water thickness and dry matter content: analysis at leaf and canopy level. IEEE Transactions on Geoscience and Remote Sensing 43, 819–826.

Rogan, J., S.R. Yool, 2001. Mapping fire-induced vegetation depletion in the Peloncillo Mountains, Arizona and New Mexico. International Journal of Remote Sensing, 22 (16), 3101-3121.

Rogers, D., Tsirkunov, V., 2010. Costs and benefits of early warning systems. Global Assessment Report on Disaster Risk Reduction, ISDR/ The World Bank, Washington, DC. http://www.preventionweb.net/english/hyogo/gar/2011/en/bgdocs/Rogers_&_Tsirkunov_2011.pdf

Roulston, M.S., Kaplan, D. T., Hardenberg, J., Smith, L.A., 2003. Using medium-range weather forecasts to improve the value of wind energy production. Renewable Energy, 28, 585–602.

Roy, M., Brodeur J., Cloutier C., 1999. Seasonal abundance of spider mites and their predators on red raspberry in Quebec. Environ. Entomol. 28, 735-747.

Roy D.P., Lewis P.E., Justice C.O., 2002. Burned area mapping using multi-temporal moderate spatial resolution data – a bi-directional reflectance model-based expectation approach. Remote Sensing of Environment, 83, 263-286.

Roy, D.P., T. Landmann, 2005. Characterizing the surface heterogeneity of fire effects using multi-temporal reflective wavelength data, International Journal of Remote Sensing, 26, 4197-4218.

Roy, D.P., L. Boschetti, C.O. Justice, J. Ju, 2008. The Collection 5 MODIS Burned Area Product - Global Evaluation by Comparison with the MODIS Active Fire Product. Remote Sensing of Environment, 112, 3690-3707.

Ruecker G., Lorenz, E., Hoffmann A., Oertel, D., Tiemann J., and Halle W., 2011. High Resolution Active Fire Monitoring for Global Change Analysis: The Upcoming FireBIRD Satellite Mission. The 5th International Wildland Fire Conference, Sun City, South Africa. http://www.wildfire2011.org/material/papers/Gernot_Ruecker.pdf

San-Miguel-Ayanz, J., Carlson, J.D., Alexander, M., Tolhurst, K., Morgan, G., Sneeuwjagt, R., Dudley, M., 2003. Current methods to assess fire danger potential. SDI-LAC Newsletter Vol. 9, No. 7.

Schwieger V., Altan O., Müller H., Friesecke F., Kötter T., 2006. The Contribution of the Surveying Profession to Disaster Risk Management, A publication of FIG Working Group 8.4.

Shamaoma, H., N. Kerle and D. Alkema, 2006. Extraction of Flood-Modelling Related Base-Data from Multisource Remote Sensing Imagery. Proceedings of the ISPRS Commission VII Symposium, Remote Sensing: From Pixels to Processes, Enschede.

Smyth, A.W., Altay, G., Deodatis, G., Erdik, M., Franco, G., Guelkan, P., Kunreuther, H., Lus, H., Mete, E., Seeber, N., Yuezueguellue, O., 2002. Probabilistic Benefit-Cost Analysis for Earthquake Damage Mitigation: Evaluating Measures for Apartment Houses in Turkey. http://info.worldbank.org/etools/docs/library/152948/SmythKunreuther_EarthquakeCostBenefit.pdf

Srivastava, Y.K., Doley, B., Pal, D.K., Das, R.K., Sudhakar, S., Adiga, S., Venkatachary, K.V., Srivastava, S.K., 2000. High Resolution Remote Sensing Data & GIS Techniques in Updation of Infrastructure Details for Flood Damage Assessment - A Case Study. http://www.gisdevelopment.net/aars/acrs/2000/ts8/hami0002pf.htm

Stewart, T.R., 1997. Forecast Value: Descriptive Decision Studies. http://www.albany.edu/cpr/stewart/Papers/StewartDescValueWCF1997cap.pdf

Stith, J.L., Radke, L.F., Hobbs, P.V., 1981. Particle emissions and the production of ozone and nitrogen oxides from the burning of forest slash. Atmospheric Environment 15, 73-82.

Stow, D., Niphadkar, M., Kaiser, J., 2005. MODIS-derived visible atmospherically resistant index for monitoring chaparral moisture content. IJRS 26, 3867–3873.

Tarantola, A., 2005. Inverse Problem Theory and Methods forModel Parameter Estimation. Society for Industrial and Applied Mathematics, Philadelphia.

Taubenböck, H., M. Wurm, M. Netzband, H. Zwenzner, A. Roth, A. Rahman and S. Deech, 2011. Flood risks in urbanized areas - multi-sensoral approaches using remotely sensed data for risk assessment. Hazards Earth Syst. Sci., 11, 431-444. www.nat-hazards-earth-syst-sci.net/11/431/2011/

te Linde, A.H., P. Bubeck, J.E. Dekkers, H. de Moel, J.C.J.H. Aerts, 2011. Future flood risk estimates along the river Rhine. Nat. Hazards Earth Syst. Sci., 11, 459-473. www.nat-hazards-earth-syst-sci.net/11/459/2011/

Teimouri M., M.R. Delavar, S. Kolyaiea, S.H. Chavoshia, H. Kiavarz Moghaddamc, 2008. A SDSS-based Earthquake Damage Assessment for Emergency Responsibility: Case study in Bam. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol XXXVII, Part B8, Commission VIII. http://www.isprs.org/proceedings/XXXVII/congress/8_pdf/2_WG-VIII-2/55.pdf

Teisberg, T. J., Weiher, R. F., 2009. Background Paper on the Benefits and Costs of Early Warning Systems for Major Natural Hazards 1.

The Boston Consultancy Group, 2012. Putting the U.S. Geospatial Services Industry On the Map.

The World Bank/ United Nations, 2010. Natural Hazards, UnNatural Disasters: The Economics of Effective Prevention. The International Bank for Reconstruction and Development/ The World Bank, Washington, DC.

Theilen-Willige B., Wenzel H., 2011. Remote Sensing and GIS Contribution To Earthquake Disaster Preparedness In Hungary, Gi4DM 2011. http://www.isprs.org/proceedings/2011/Gi4DM/CDDATA/index.html

Thieken, A.H., Müller, M., Kleist, L., Seifert, I., Borst, D., Werner, U., 2006. Regionalisation of asset values for risk analyses. Nat. Hazards Earth Syst. Sci., 6, 167-178. www.nathazards-earth-syst-sci.net/6/167/2006/

Thompson, R. J., P. van Oosterom, S. Zlatanova, N. v/d Giesen and B. Goulevitch, 2011. Monitoring the extend of flooding- based on a case study in Queensland. Altan, Backhause, Boccardo, Zlatanova (Eds.), International Archives ISPRS XXXVIII, 7th Gi4DM, Antalya.

Townshend J.R.G., Justice C.O., 1986. Analysis of the dynamics of African vegetation using the normalized difference vegetation index. International Journal of Remote Sensing, 7, 1435-1445. http://dx.doi.org/10.1080/01431168608948946

Trigg, S., S. Flasse, 2000. Characterising the spectral-temporal response of burned savannah using in situ spectroradiometry and infrared thermometry. International Journal of Remote Sensing, 21, 3161–3168.

Turk, T., Gumusay, U., 2008. Design and Application of Disaster Information System Infrastructure on the North Anatolian Fault Zone (NAFZ), Beijing. http://www.isprs.org/proceedings/XXXVII/congress/8_pdf/2_WG-VIII-2/33.pdf

UNDP, 2004. Vision of Risks: A Review of International Indicators of Disaster Risk and its Management. A Report for the ISDR Inter-Agency Task force on Disaster Reduction WG3: Risk, Vulnerability and Disaster Impact Assessment.

UNDP, 2011. Mainstreaming Drought Risk Management. United Nations Development ProgrammeDrylands Development Centre.

UNISDR, 2009a. 2009 UNISDR Terminology On Disaster Risk Reduction, United Nations International Strategy for Disaster Reduction (UNISDR), Geneva.

UNISDR, 2009b. Drought Risk Reduction Framework and Practices: Contributing to the Implementation of the Hyogo Framework for Action. United Nations International Strategy for Disaster Reduction (UNISDR), Geneva.

van Lierop P., 2009. FAO and Partners in Fire Management: A Participatory and Integrated Approach.

van Wagner, C.E., 1987. Development and structure of the Canadian Forest Fire Weather Index System. Forestry Technical Report No. 35, Canadian Forest Service, Ottawa.

Varnes, D. J., 1978. Slope movement types and processes. Schuster, R. L. & Krizek, R. J., (Eds.), Special Report 176: Landslides: Analysis and Control, Transportation and Road Research Board, National Academy of Science, Washington DC., 11-33.

Vega-García, C., Woodard, T., Adamowicz, Lee, B., 1995. A logic model for predicting the daily occurence of human caused forest fires, IJWF 5, 101–111.

Venkatachary, K.V., K. Bandyopadhyay, V. Bhanumurthy, G. S. Rao, S. Sudhakar, D. K. Pal, R. K. Das, Utpal Sarma, B. Manikiam, H. C. Meena Rani, S. K. Srivastava, 2001. Defining a Space-Based Disaster Management System for Floods: A Case Study for Damage Assessment due to 1998 Brahmaputra Floods. Current Science, 80 (3), 369-377.

Vermeiren, J., Stichter, S., Wason, A., 2004. Costs and Benefits of Hazard Mitigation for Building and Infrastructure Development: A Case Study in Small Island Developing States. http://www.oas.org/CDMP/document/papers/tiems.htm

Vermote, E.F., Vermeulen, A., 1999. Atmospheric Correction Algorithm: Spectral Reflectances (MOD09). NASA.

Vicente-Serrano, S.M., S. Begueria, J.I. Lopez-Moreno, 2010. A multi scalar drought index sensitive to global warming: The standardized precipitation evapotranspiration index. Journal of Climate, 23(7), 1696-1718.

Viegas, D.X., 1998, Weather, fuel status and fire occurrence: predicting large fires. J.M. Moreno (Ed.) Large Forest Fires, Leiden, 31-49.

Viney, N.R., 1991. A review of fine fuel moisture modelling. IJWF 1, 215–234.

Wang, J., T.D. Sammis, V.P. Gutschick, G., Mekonnen, S.O. Dennis, R.E. Harrison, 2010. Review of Satellite Remote Sensing Use in Forest Health Studies. The Open Geography Journal, 2010, 3, 28-42.

Whitehead, J., Marbell, W., 2013. The economic benefits of geospatial technology, PositionIT June, 43-52. http://www.eepublishers.co.za/images/upload/positionit_2013/processing-tech_geospatial_june13.pdf

Williamson, R.A., Hertzfeld, H.R., Cordes, J. and Logsdon, J.M., 2001. The Socioeconomic Benefits of Earth Science and Applications Research: Reducing the Risks and Costs of Natural Disasters in the United States. Space Policy, 18 (1), 57–65.

Williamson, R.A., Hertzfeld, H.R., Sen, A., 2003. Weather Satellites and the Economic Value of Forecasts. Evidence from the electric power industry. http://www.gwu.edu/~spi/assets/docs/Weather.pdf

Wotton, B.M., Martell, D.L., 2005. A lightning fire occurrence model for Ontario. Canadian Journal of Forest Research 35, 1389–1401.

WWF, 2003. Forest Fires in the Mediterranean: a burning issue. http://mediterranean.panda.org/?8022/Forest-fires-in-the-Mediterranean-a-burning-issue

Xiao, J., Jie, LI, ZHANG J., 2009. The Identification of Forest Fire Based on Digital Image Processing. 2nd International Congress on Image and Signal Processing. http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=5303627&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D5303627

Yamazaki, F., Mitomi, H., Yusuf, Y., and Matsuoka, M., 2003. Urban Classification of Metro Manila for Seismic Risk Assessment using Satellite Images. Fifth Multi-lateral Workshop on Development of Earthquake and Tsunami Disaster Mitigation Technologies and Their Integration for the Asia-Pacific Region, EDM Technical Report, No. 16. http://ares.tu.chiba-u.jp/~papers/Technical%20Report/EQTAP2003_Yamazaki.pdf

Yamazaki, F., Yano, Y., Matsuoka, M., 2005. Visual Damage Interpretation of buildings in Bam City Using Quickbird Images Following the 2003 Bam, Iran, Earthquake. Earthquake Spectra, Vol 21, 329-336. http://ares.tu.chiba-u.jp/~papers/paperIJ/Spectra/EQS00S329_2005Yamazaki.pdf

Yamazaki, F., Matsuoka, M., 2006. Remote Sensing Technologies for Earthquake and Tsunami Disaster Management. Asia Conference on Earthquake Engineering. Theme: Seismic Hazards and Damage Mitigation in the Asian Region. http://ares.tu.chiba-u.jp/~papers/paper/ACEE/ACEE2006-IA4_Yamazaki.pdf

Zhang, Y., N. Kerle, 2008. Satellite remote sensing for near-real time data collection. Zlatanova and Li (Eds.), Geospatial information technology for emergency response, ISPRS Book series 6, London, 75-102.

Zlatanova, S., A.G. Fabbri, 2009. Geo-ICT for risk and disaster management. Scholten, van Velde, van Manen (Eds.), Geospatial technology and the role of the location in science, Dordrecht, Heidelberg, London, New York, 239-266.

Zribi M., Amri R., Lili-Chabaane Z., Wagner W., Hasenauer S., Duchemin B., Boulet G., Moenot B., 2012. Analysis of drought events in a North Africa semi-arid region, using SPOT-VEGETATION and C band scatterometer satellite. Data Geophysical Research Abstracts Vol. 14, EGU 2012-10951.

Zwenzner, H., Voigt, S., 2009. Improved estimation of flood parameters by combining space based SAR data with very high resolution digital elevation data. Hydrol. Earth Syst. Sci., 13, 567–576. http://www.hydrol-earth-syst-sci.net/13/567/2009/hess-13-567-2009.pdf

Annex I: Chapter 2, How to determine the economic value of geoinformation in Disaster and Risk Management

The Questionnaire

Introduction

Dear Participant,

This questionnaire will address the added value of geo-information during the Namibian flood of spring 2009, by assessing the potentials of an early warning system. As the main rivers in the northern area of Namibia are rain fed and have their headwaters upstream in other countries, an early warning system has high promises. Your experience and knowledge as an expert are very important for this research.

Your answers will be contributing to the VALID project, which is an initiative of the *Joint Board of Geospatial Information Societies* (JBGIS) and the *United Nations Platform for Space-based Information for Disaster Management and Emergency Response* (UN-SPIDER), and my master thesis for the MSc in Earth Science and Economics at the VU University Amsterdam. The VALID project aims to assess the impact and value of geo-information in risk and disaster management and seeks to improve future information systems.

You have been recommended for participation by Guido Van Langenhove, head of the Hydrological Services Namibia, Department of Water Affairs. Your answers will be treated confidentially and the main findings and results will be communicated to you. If there are any further questions, please do not hesitate to contact me by e-mail.

A short example will be provided on how to fill in the questionnaire on the second page, it will take you approximately 10-15 minutes. May I kindly ask you to send your answers by e-mail to: [illegible] **BEFORE 15th of July 2012.**

Thank you for your time and participation,

Tessa Belinfante

MSc. Student VU University Amsterdam

Intern at UN-SPIDER office in Bonn

[illegible]

Instructions

Open questions:

If there is a dotted line, please delete the dots and type your answer. There is no limitation to what and how much you can type.

Multiple choice:

To make a choice you can type an X instead of the bullet.
For example: How would you describe your experience with questionnaires?

- O No experience
- O Little experience
- O Some experience
- X Considerable experience
- O A lot of experience

Scale

If you are asked to give the upper and lower boundary of your estimate, and you believe this to be 15% and 40% you can indicate as follows.

		X					x												

0 10 20 30 40 50 60 70 80 90 100%

You may also be asked to indicate your opinion on a scale ranging from 1-5, where 1=low, 5=high, 0=none, X=don't know.

Structure

The first section you will be asked about your (professional) background, followed by a second section concerning what geo-information products you used in 2009 in general, as it is important to know what was(n't) there. In the third section you are asked about the present state of the early warning system and what future developments you would like to see. The fourth section will address what damages and losses could have been avoided in 2009, in order to assess the potential value of an early warning, for the scenario described in that section.

Important notes:

The following definitions are adopted by this research:

- **Geo-information product**: The end product of spatial information, not the raw data.
- **Damage:** The replacement value of totally or partially destroyed physical assets that must be included in the reconstruction programme.
- **Losses:** The alteration of flows in the economy that arise from the temporary absence of the damaged assets.

Section 1: Personal details and questions

[illegible]

1.4 How would describe your experience with the use of geo-information?

- O No experience
- O Little experience
- O Some experience
- O Considerable experience
- O A lot of experience

Section 2: Use of geo-information in 2009

The following questions will be about the geo-information products that were available during the 2009 flood.

2.1 What geo-information products did you use (column 1) and what concrete actions resulted from this information during the 2009 flood (column 2)?

2.2 How much do you think the product improved decision making and resulting actions during the 2009 flood, compared to NOT having this type of product? Please indicate this estimated impact of the geo-information product in column 3.

	Geo-information product:	**Supported action:**	**Impact (1-5)*:**
Example:	*Satellite based flood inundation map*	*Evacuation of people*	*4*
1			
2			
3			
4			
5			
...			

(1=low, 5=high, 0=none, X=don't know)

2.3 What caused the low level of effective response after the early warning given in spring 2009? More answers are possible.

- O Monitoring and warning capacity
- O Communication of warning
- O Awareness of communities
- O Response capacity on local level
- O Other:..............................

Section 3: Present situation

3.1 How do you assess the following;

Questions:	*Pre-2009 flood Scale (1-5)**	*At present Scale (1-5)**
The awareness of communities to flood risk?		
The response capacity on a local level?		
The monitoring and warning capacity?		
The dissemination and communication of the warning?		

**(1=low, 5=high, 0=none, X=don't know)*

3.2 Has the early warning system improved since 2009; if yes *in what aspects*?
(For example in terms of usage of (new) geo-info products, communication, materials available, etc.)

....

....

3.3 What future developments in the use and application of an early warning system you would like to see?

....

....

3.4 Do you have any further comments regarding the evaluation of the early warning system?

....

....

Section 4: Impact of Flood Information System

[illegible]

4.2 What percentage of the human lives lost in 2009 could have been avoided if there was such a flood information system in place assuming:

- Effective communication
- Adequate follow-on actions

Please provide the upper and lower boundary of your estimate: for example: 20-35%

0 10 20 30 40 50 60 70 80 90 100%

4.3 How much more effective, in terms of avoiding damages and losses, could the following measures have been in the 2009 flood, had there been such a flood information system in place giving 10 days advance notice? Remember the assumption that you have <u>all capacities</u> needed to respond.

Preventive actions:	*Effectiveness (1-5)*:*
Evacuation of communities	
Evacuation of livestock	
Protection agriculture (remove stocks and (if possible) equipment at flood prone areas)	
Protection commerce & industry (if possible: protection of premises, remove stocks and equipment at flood prone areas)	
Protection of housing/education/health buildings	
Supply of boats and emergency supplies	
...	
...	

**(1=little more, 5=much more, 0=no more, X=don't know)*

Effectiveness in terms of avoiding damages and losses

Section 5: Wrap up

5.1 Are there any further comments or remarks you would like to make regarding this questionnaire?

....

....

♦

This is the end of the questionnaire. Thank you very much for your participation. May I kindly ask you to send your answers by e-mail to: [illegible]

Annex II: Contact information of editors and authors

Editors		
Name	*Affiliation*	*E-mail*
Orhan Altan, Coordinating Editor	1st VP of ISPRS and Member of the ICSU Executive Board	oaltan@itu.edu.tr
Robert Backhaus	Senior Advisor German Remote Sensing Data Center (DFD)	robert.backhaus@dlr.de
Piero Boccardo	Politecnico di Torino	piero.boccardo@polito.it
Fabio G. Tonolo	ITHACA, ISPRS WG VIII/1 co-chair	fabio.giuliotonolo@polito.it
John Trinder	UNSW Honorary Fellow	j.trinder@unsw.edu.au
Niels van Manen	Researcher Spatial Information Laboratory, VU University Amsterdam	n.van.manen@vu.nl
Sisi Zlatanova	ISPRS WG chair, Member IRDR SC	s.zlatanova@tudelft.nl

Authors			
Name	*Affiliation*	*E-mail*	*Chapter(s)*
Irasema Alcántara Ayala	Universidad Nacional Autónoma de México (UNAM), Member IRDR SC	irasema@igg.unam.mx	4.5
Robert Backhaus	German Remote Sensing Data Center (DFD)	robert.backhaus@dlr.de	3, 4, 5
Alessandro Demarchi	DIST - Politecnico di Torino	alessandro.demarchi@polito.it	4.2
Niels van Manen	VU University Amsterdam	n.van.manen@vu.nl	2, 4.6
Francesca Perez	DIST - Politecnico di Torino	francesca.perez@polito.it	4.3
John Trinder	UNSW Honorary Fellow	j.trinder@unsw.edu.au	4.6, 5
Rossella Vigna	DIST - Politecnico di Torino	rossella.vigna@polito.it	4.4
Sisi Zlatanova	ISPRS WG chair, Member IRDR SC	s.zlatanova@tudelft.nl	4.1
Luciana Dequal	ITHACA (Information Technology for Humanitarian Assistance, Cooperation and Action)	luciana.dequal@ithaca.polito.it	7 (Annex)
Yerach Doytsher	International Federation of Surveyors (FIG)	doytsher@technion.ac.il	7 (Annex)
Hermann Drewes	International Association of Geodesy (IAG)	drewes@dgfi.badw.de	7 (Annex)
Georg Gartner	International Cartographic Assiciation (ICA - ACI)	georg.gartner@tuwien.ac.at	7 (Annex)
Christian Heipke	International Society for Photogrammetry and Remote Sensing (ISPRS)	heipke@ipi.uni-hannover.de	7 (Annex)
Alik Ismail-Zadeh	International Union of Geodesy and Geophysics (IUGG)	alik.ismail-zadeh@kit.edu	7 (Annex)
Anne Knauer	United Nations Office for Outer Space Affairs (OOSA/UN-SPIDER)	anne.knauer@unoosa.org	7 (Annex)
François Lefeuvre	International Union of Radio Science (U.R.S.I.)	francois.lefeuvre@cnrs-orleans.fr	7 (Annex)
Roland Oberhänsli	International Union of Geological Sciences (IUGS)	R.Oberhaensli.IUGS@geo.uni-potsdam.de	7 (Annex)
Mike Meadows	International Geographic Union (IGU - UGI)	mmeadows@mweb.co.za	7 (Annex)
Anthony Milne	Geoscience and Remote Sensing Society (GRSS)	a.milne@unsw.edu.au	7 (Annex)
Abbas Rajabifard	Global Spatial Data Infrastructure Association (GSDI)	abbas.r@unimelb.edu.au	7 (Annex)
Stefan Voigt	DLR Center for Satellite Based Crisis Information (DLR-ZKI)	stefan.voigt@dlr.de	7 (Annex)

Annex III: Profiles of contributing institutions

DLR Center for Satellite Based Crisis Information (DLR/ZKI)

The Geoscience and Remote Sensing Society (GRSS)

Global Spatial Data Infrastructure Association (GSDI)

Information Technology for Humanitarian Assistance, Cooperation and Action (ITHACA)

International Cartographic Association (ICA - ACI)

The International Federation of Surveyors (FIG)

International Geographical Union (IGU - UGI)

The International Society for Photogrammetry and Remote Sensing (ISPRS)

International Union of Geodesy and Geophysics (IUGG) and International Association of Geodesy (IAG)

The International Union of Geological Sciences (IUGS)

International Union of Radio Science (U.R.S.I.)

United Nations Office for Outer Space Affairs (OOSA)

DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center

DLR Center for Satellite Based Crisis Information

Stefan Voigt

About DLR/ZKI

The DLR-Center for Satellite Based Crisis Information (ZKI) provides a 24/7 service for the rapid provision, processing and analysis of satellite imagery during natural and environmental disasters, for humanitarian relief activities and civil security incidences worldwide. The resulting satellite based information products are provided to relief organisations and public authorities and are also available on the ZKI website. According to the requirements of the user, the information products are delivered in the form of maps, GIS-ready geodata or dossiers which are then used to support disaster management operations.

ZKI Crisis Mapping Activation

The increasing number of natural disasters, humanitarian emergency situations and threats to the civil society increases the demand for timely and precise information for many different types of scenarios and situations. ZKI uses all kinds of satellite imagery for the extraction of relevant crisis information such as flood extent, damaged infrastructure, endangered population or evacuation areas, just to name a few examples. Besides response and assessment activities, ZKI derives geoinformation products for use in medium term rehabilitation, reconstruction and crisis prevention activities. It operates in the national and international context, closely networking with German public authorities at national and state level, non-governmental organisations, satellite operators and space agencies.

Figures 1 and 2: DLR/ZKI crisis room, where the 24/7 teams are conducting the rapid mapping work.

Support for Disaster Management

Each phase of the disaster management cycle has different demands on the satellite information products and ZKI makes important contributions especially during the emergency relief phase, but also for rehabilitation and recovery actions as well as early warning and disaster prevention. In its function as a crisis mapping service, ZKI creates crisis maps immediately after an event with specific information about the disaster extent (e.g. flooded area) and estimated damages (e. g. affected houses, infrastructure, etc.) in order to assist decision making in situation centres and during relief actions in the field. Further analyses and monitoring of the disaster situation can support planning and reconstruction activities as well as the development of vulnerability studies for specific regions. ZKI also supports the development of early warning systems in the domain of natural hazard prevention.

Humanitarian Aid

In case of humanitarian crises ZKI assists relief efforts in cooperation with international partner organisations, and provides user specified information and map products, such as for refugee camp and situation maps. These maps can be a valuable contribution for logistic support and operation planning in the respective camps or areas. In the frame of these activities, ZKI closely cooperates with international relief organisations and several UN organisations.

Civil Security

The increasing importance of the topic “civil security” within the projects of ZKI is leading to research activities with an increased focus on search and rescue work, monitoring of critical infrastructure, or illicit extraction of natural resources. Also the monitoring of international conflicts and crisis regions is an element of the development of methods and concepts for crisis prevention in terms of civil security.

Training

In order to continuously improve service and products, ZKI cooperates very closely with relief organisations and provides training and consulting for field practitioners, situation centre staff and decision makers in the frame of dedicated projects. ZKI provides training for geospatial support in disaster management. The target audience are personnel of national and international relief organisations as well as governmental agencies interested in disaster management and emergency response to natural hazards and humanitarian disasters. The short term technical training courses are tailored to the client's needs and vary from acquainting the participants with satellite image interpretation methods to rapid mapping techniques in emergency response for professionals. The main goal is to enable and strengthen the competence and expertise of decision makers, coordinators and emergency relief workers to make use of spatially derived information for the coordination and implementation of emergency response.

Last but not least, ZKI offers a comprehensive internal training program for DLR personnel to continuously strengthen capacities and realise certified quality of rapid mapping in terms of disaster response inside DLR.

Center for Satellite Based Crisis Information
– Emergency Mapping & Disaster Monitoring –

www.zki.dlr.de

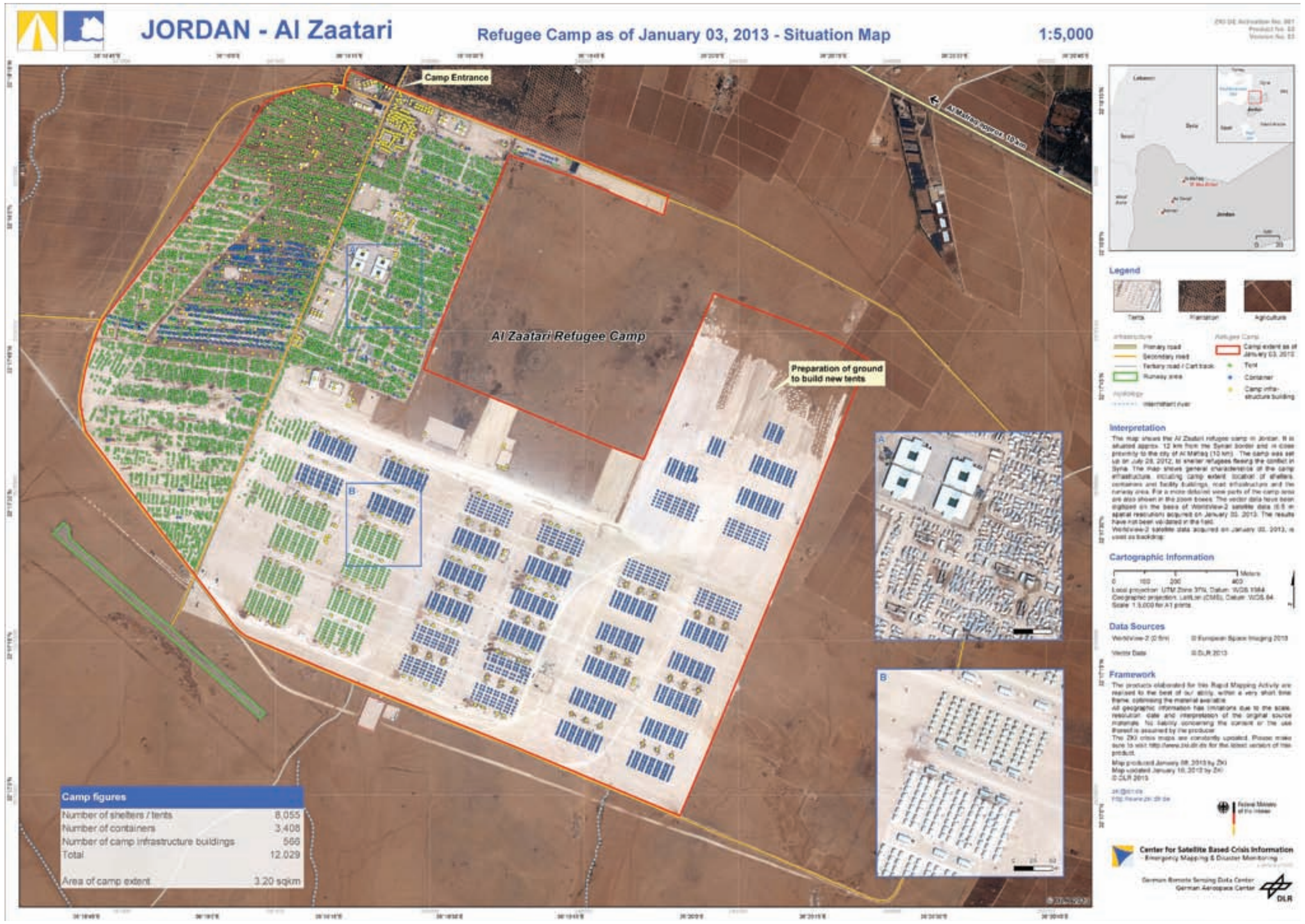


Figure 3: Situation map of the camp Al Zaatari in Jordan, January 2013

The Geoscience and Remote Sensing Society

Anthony Milne

The Geoscience and Remote Sensing Society (GRSS) seeks to advance science and technology in geoscience, remote sensing and related fields using conferences, education, and through member participation in Technical Committees, Workshops, Publications and local and regional based Society Chapters.

Fields of Interest

The fields of interest of the Society are the theory, concepts, and techniques of science and engineering as they apply to the remote sensing of the Earth, its land, oceans and atmosphere, as well as the processing, interpretation and dissemination of this information for the benefit of humankind. These fields are grouped into:

- Remote Sensing of Solid Earth and Geodynamic Processes
- Remote Sensing and Mitigation of Natural Disasters
- Remote Sensing of Land and Surface Processes
- Remote Sensing of Atmosphere and Ocean
- Remote Sensing of the Cryosphere
- Remote Sensing Analysis Techniques
- Electromagnetics and Radiative Transfer
- Sensors and Platforms
- Education and Policy

GRSS Members have both scientific and engineering backgrounds

Those with engineering backgrounds often support geoscientific investigations with the design and development of hardware and data processing techniques, requiring them to be familiar with geosciences such as geophysics, geology, hydrology and meteorology Scientists bring analytical skills and background expertise that help determine the use of remote sensing in solving particular human and environmental problems and in providing information for resource management. This fusion of scientific and engineering disciplines within the geophysical and geospatial worlds gives GRSS a unique interdisciplinary character and an exciting role in furthering remote sensing science and technology.

GRSS WAS STARTED IN 1962 as the Geoscience Electronic Group, which was reorganized as the Geoscience and Remote Sensing Society in 1980 to create an international society for the rapidly expanding field of remote sensing. It has always been a society without borders, and today, with over 3500 individual members, is continuing this original vision and contributing to the advancement of the use and application of remote sensing for societal benefits.

IGARSS – the International Geoscience and Remote Sensing Symposium is the flagship conference of the society and has grown from 430 participants 30 years ago to over 2000 today. This annual gathering of world-class scientists, engineers, and educators engaged in the fields of geosciences and remote sensing from around the world features papers and posters on cutting edge research in all areas of remote sensing and environmental applications such as disaster monitoring and management. GRSS also co-sponsors more than twenty Symposia worldwide on an annual or biannual basis.

Publications

GRSS publishes four journals.

Transactions on Geoscience and Remote Sensing (TGRS), our flagship journal, publishes advances in the development of sensing instruments and techniques used for the acquisition of geoscientific information.

Geoscience and Remote Sensing Letters (GRSL) is a quarterly publication for short papers addressing new ideas and formative concepts in remote sensing as well as new results.

Selected Topics in Applied Earth Observations and Remote Sensing (JSTARS) addresses current issues and techniques in applied remote and in situ sensing, their integration, and applied modeling and information creation for understanding the earth environments

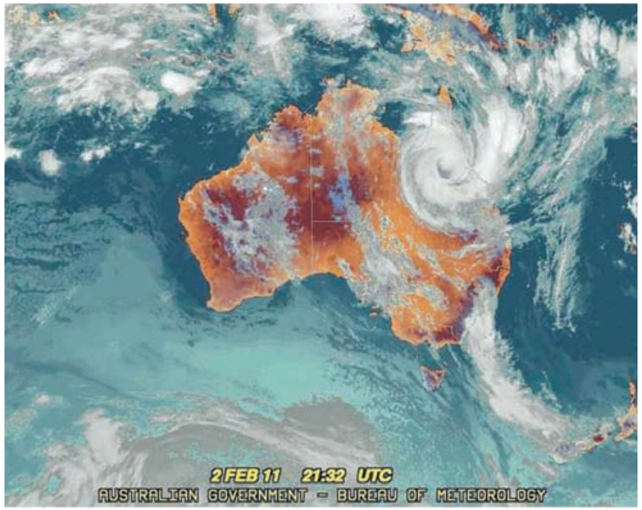


Figure 1: Cyclone Yasi (2 February 2011) was one of the most powerful cyclones to have affected Australia's north since records commenced (www.bom.gov.au).

IEEE Geoscience and Remote Sensing Magazine is published four times per year and provides news of general interest to GRSS members and special articles on current missions, projects, short features and book reviews.

Technical Committees

The GRSS Technical Committees serve the community by providing independent a forum for technical assessments, research collaborations and guidance to the Society on key issues in remote sensing policy and practice.. The technical committees are open to all members. Committees include; Data Archiving and Distribution; Instrumentation and Future Technologies; Data Fusion and Spaceborne Imaging Spectroscopy

Local Chapters

With over 48 local chapters around the globe, members can get involved with other GRSS members. Chapters offer both technical and social events as well as networking and career advancement opportunities.

GRSS Hazards and Disaster Support

Individual Society members have been at the forefront of research into the applications of remote sensing for disaster management and hazard risk reduction. New instruments for use on both aircraft and satellite platforms have been developed to improve the detection, mapping and monitoring of natural and human induced hazards. Processing techniques for deriving near real-time data and information extraction for use in pre-preparedness planning and active event mapping have been developed. Areas of interest include; integrated earth observation systems; earthquake and crustal deformation detection; flood mapping; local, regional and global rainfall measurement and cyclone prediction; drought and soil moisture retrieval methods, and fire detection, mapping and vulnerability assessment.

At a Society level GRSS is working with international agencies including UN-SPIDER and GEO and with individual country organizations to improve access to remotely sensed information, provide technical support for rapid response mapping and processing solutions for using high resolution image data to meet the information requirements for community disaster preparation and planning.

www.grss-ieee.org

Find us on Facebook and LinkedIn.

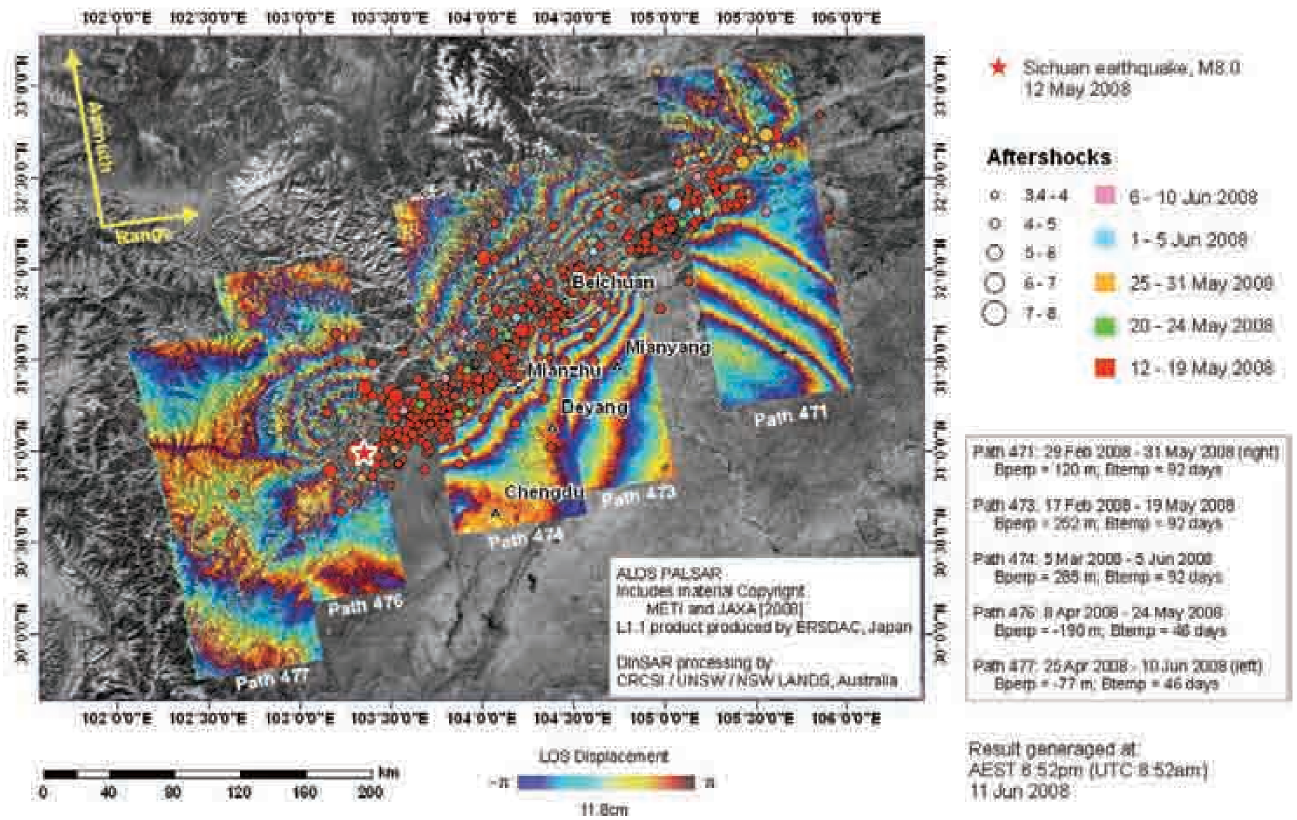


Figure 2: Ground displacement map and location of aftershocks following a magnitude 8.0 earthquake in Sichuan, China, derived from Differential InSAR (DInSAR) techniques using JAXA ALOS PALSAR data, January 2008 (www.gmat.unsw.edu.au/LinlinGe/Earthquake/).

Global Spatial Data Infrastructure Association

Abbas Rajabifard

GSDI Responds to Disaster Management

We are an inclusive association of organizations, agencies, firms, and individuals from around the world promoting international cooperation and collaboration in support of local, national and international spatial data infrastructure developments that will allow nations and their citizens to better address social, economic, and environmental issues of pressing importance such as natural disasters.

A continuing theme of GSDI activities is realizing spatially enabled societies. The pressing needs of societies are a particular emphasis of GSDI conferences. Major studies include a focus on disaster prevention, warning, management, response, and recovery. In this context, GSDI is very supportive of disaster management initiatives and contributes to global disaster management. For example, we encourage the building of long-term Spatial Data Infrastructure (SDI) from local to global scales within and among all nations of the world to help and facilitate informed decision making.

If the components of an SDI are in place and are in use on a daily basis by local users for accomplishing mapping, vehicle routing, asset management, service delivery and similar tasks, then the information infrastructure is much more likely to be available and useful for accomplishing similar tasks during a calamity.

Mission Statement

- serve as a point of contact and effective voice for those in the global community involved in developing, implementing and advancing spatial data infrastructure concepts
- foster spatial data infrastructures that support sustainable social, economic, and environmental systems integrated from local to global scales
- promote the informed and responsible use of geographic information and spatial technologies for the benefit of society.

SDIs to facilitate data discovery, access and in response to global needs and challenges

The Organizational Structure

The GSDI Association consists of a Council comprised of the delegates from the Full Member organizations and two representatives from the International Geospatial Society, the Board of Directors which is the main administrative body of the Council and the Standing Committees.

Activities of GSDI

Conferences: One of the principal activities of the association is to provide a GSDI Conference for SDI-related professionals, scientists, and applications, on a regular basis to share and exchange ideas.

Small Grants Program

The GSDI Association supports an annual small grants program to support national or sub-national activities that foster partnerships, develop in-country technical capacity, improve data compatibility and access, and increase political support for spatial data infrastructure and earth observations application development.

Develop Partnerships and Spread Knowledge

GSDI provides a global venue for networking, communicating and learning among its members. Through the Geographic Information Knowledge Networks (GIK Network) GSDI enhances communications and sharing among geospatial specialists and organizations from all nations and for the global geographic information community at large (www.giknetwork.org).

Open Access to Data, Tools and Learning Materials

The GSDI Association and its members promote open access to the greatest extent possible to spatial data as well as to educational materials on how to use geospatial technologies and establish SDI to facilitate informed decision making.

GSDI supports and encourages partnerships and collaborations on global disaster management initiatives and the development of technical platforms at any jurisdictional level

In support of a technical platform to facilitate disaster management, and in line with the theme of GSDI activities in spatially enabled societies and government, the GSDI Executive member and past President, Prof Abbas Rajabifard, from Melbourne University, is leading a new partnership with IBM, the University of Melbourne and National ICT Australia in the development of the next generation of IT-based open source platform for multi-hazard disaster management.

The Australia Disaster Management Platform (ADMP) is a multi-hazard platform to support preparedness, response, recovery and mitigation. A collaboration between University of Melbourne, IBM and NICTA (National ICT Australia), the project aims to develop new technologies that represent a step-change in the ability to manage disasters. It will provide the opportunity for relevant organizations, communities and researchers to participate and contribute to its development.

This innovative, integrated, open standards based whole-systems disaster management platform will draw on vast amounts of geospatial and infrastructure information, bring these together, facilitate discovery, integrate, and analyze the data to create real-time, practical information streams on disaster events and to develop simulation and optimization models. This practical information will then be communicated at appropriate levels of detail, to the wide spectrum of people involved in making emergency decisions – from the central coordinating agencies who are charged with directing activities, to on-ground emergency services personnel, through to the local community members trying to decide whether to evacuate and if so how.

ADMP Capabilities & Delivery Layers 3D Visualization and Interaction

- Optimization and Decision Support
- Simulation and Forecasting
- Behavioural Modelling
- Data Acquisition and Fusion
- Sensing and Monitoring
- Infrastructure & Geospatial Modelling

AUSTRALIA DISASTER MANAGEMENT PLATFORM

www.admp.org.au

EYE ON DISASTER MANAGEMENT

GSDI is a member of, and contributes to global disaster management initiatives such as 'Eye on Disaster Management', which is part of the activities of 'Eye on Earth' under support of UNEP. Eye on Disaster Management is a Public-Private Partnership (PPP) to strengthen existing networks and support GIS technology and SDI capacity building.

www.gsdi.org

Information Technology for Humanitarian Assistance, Cooperation and Action

Luciana Dequal

The non-profit association ITHACA, based in Torino, Italy, is a center of applied research devoted to support humanitarian activities in response to natural disasters by means of remote sensing techniques.

ITHACA has built strong competences in the field of acquisition, management and elaboration of geographic and cartographic data for emergency response purposes, delivering methodologies, analytical services and technical tools to improve the capacity of the international humanitarian community in early warning, early impact assessment and other risk management related areas.

The association was founded in November 2006 in a joint initiative of Politecnico di Torino and SiTI (Higher Institute on Innovation Territorial Systems) and in cooperation with other partners such as public and private research centers, companies operating in the aerospace and telecommunications fields and other territorial data providers. Therefore, ITHACA's operational team is composed of experts from the academic, industrial and scientific environments with deep experience in several of the domains concerning geomatics, such as remote sensing, photogrammetry and Geographic Information Systems (GIS).

Emergency mapping for post-event early impact assessment

The rapid production of geo-referenced information on the impact of disasters, especially data on affected areas and damage grading, is proving to be highly effective in enhancing the operational efficiency of emergency response activities and post disaster needs assessments, especially for events hitting developing countries, more vulnerable to calamities and less prepared to face them.

ITHACA is a 24/7/365 service provider for the on-demand and fast production of geospatial information in support of emergency management activities immediately following an emergency event. Satellite and aerial image sensor data and other geospatial raster and vector data sources are processed and analyzed in order to provide cartographic products in support of humanitarian operations. The emergency mapping activities cover all types of environmental disasters, from forest fires, landslides and floods, to earthquakes and volcanic eruptions, also including industrial accidents and humanitarian crises.

Extreme Rainfall Detection System

ERDS is a service for the monitoring and forecasting of exceptional rainfall events, with a nearly global geographic coverage, been conceived to be used by humanitarian assistance organizations to evaluate the events and to understand the potentially floodable areas in places where their assistance is needed.

The application follows a multi-scale approach for the monitoring and forecasting of extreme rainfall events and potential flood events, with the capability of integrating a large number of data-sets for the assessment of the social and economic impacts of disasters. This methodology strongly contributes to the improvement of public services and citizens' resilience to natural hazards, through an effective dissemination of warnings.

ERDS provides scientific community with relevant data related to heavy rain monitoring and forecasting, on a regular basis and relatively inexpensively.

Water bodies automatic extraction for flood vulnerability assessment

Among the various natural disasters human population is vulnerable to, floods are the most common and amongst the deadliest; furthermore, flood event recurrence seems to show an increasing trend, possibly related to climate change. The identification of flood prone areas and related vulnerability analysis are therefore extremely useful for specific stakeholders, helping them in prioritizing the investments and in being guided during the decision making process.

The automatic extraction of information on both the actual extent of water bodies and the historically flooded areas represents a powerful tool for flood vulnerability analysis as well as for assessing the evolution of an ongoing flooding. ITHACA has developed an automated procedure to allow the extraction of water bodies by means of satellite data processing, suitable both for actual flooding monitoring and for the creation of an archive that will allow the production of customized analyses for the evaluation of flood vulnerability.

Detection and monitoring of drought events

ITHACA has developed a global drought early warning system as support to emergency management activities. The system is based on the monitoring and integration of a series of drought-related variables and indices, such as NDVI and SPI, obtained mostly from satellite data, in order to define thresholds and triggers suitable for early warnings.

Technical training in remote sensing and data management for emergency

Ithaca provides specific technical training to field practitioners to improve their capacity in GIS and remote sensing data processing; those actions are particularly important in order to allow local and international relief organizations to know in advance the characteristics and benefits they can expect from a specific emergency mapping product in a specific disaster management phase.

Being closely linked to the Politecnico di Torino, ITHACA can rely on the solid expertise of one of the most prestigious technical universities in Europe and worldwide. Its management and operational staff consists of professors, assistants, scholars and researchers with a long experience in the domain of geomatics, who collaborate with a growing network of technical and non technical partners in order to develop and deliver the Association's services.

ITHACA has already provided training to technical personnel of humanitarian agencies, multilateral development agencies, as well as scientific research institutions and private companies.

The focus of the training sessions is on the emergency response activities, providing lectures on remote sensing technologies in real case studies and basic principles of a Spatial Data Infrastructure (SDI) design, implementation, management and exploitation. The training normally includes sessions of practical laboratories, where real early impact activations are simulated and the attendees perform all the steps required to produce a map (by means of a SDI) showing the affected areas, the possible affected population, road accessibility and infrastructures damages.

www.ithacaweb.org

Figure 1: ITHACA facilities in Torino, Italy

Figure 2: Mapping and analyzing emergency situations

The role of modern cartography for disaster management

Georg Gartner and Milan Konecny

Today maps can be created and used by any individual with only modest computing skills for virtually any location on Earth and for almost any purpose. In this new mapmaking paradigm users are often present at the location of interest and produce maps that address needs that arise instantaneously. Cartographic data may be digitally and wirelessly delivered in final form to the device in the hands of the user or he/she may download requested visualization data in situ. Rapid advances in technologies have enabled this revolution in map making to be achieved by anyone. One such prominent advance in technology includes the possibility to derive maps immediately after data has been acquired by accessing and disseminating maps through the internet. Other significant developments include location-based services, mobile cartography and augmented reality.

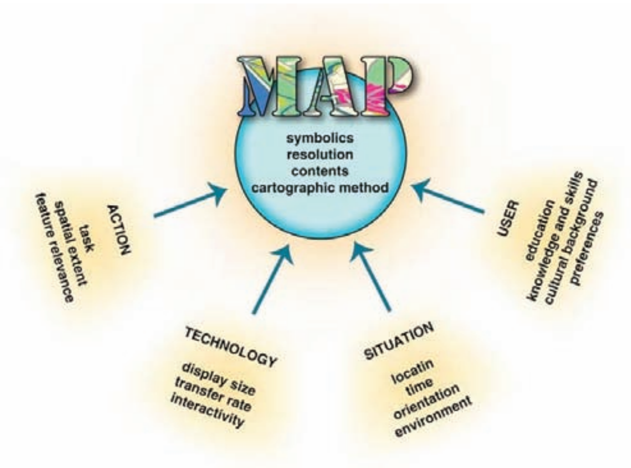


Figure 1: Contexts in adaptabile cartography

While the above advances have enabled significant progress in the design and implementation of new ways of map production over the past decade, many cartographic principles remain unchanged, the most important one being that maps are an abstraction of reality. Visualization of selected information means that some features present in reality are depicted more prominently than others, while many features might not even be depicted at all. Abstracting reality makes a map powerful, as it helps to efficiently understand and interpret very complex situations .

Abstraction is essential in all stages of the disaster management cycle. In the recovery phase quick production of imagery of the affected area is required using depictions which allow the emergency teams to understand the situation on ground from a glance at the maps. Important on-going developments supporting the rescue work in the recovery phase are map derivation technologies, crowd sourcing, neo-cartography techniques and location-based services. The role of cartography in the protection phase of the disaster management cycle has always been crucial. In this phase risk maps are produced which enable governors, decision makers, experts and the general public alike to understand the kind and levels of risk present in the surrounding areas. Modern cartography enables the general public on a voluntary basis to participate in modelling and visualizing the risks in their neighbourhood. Modern cartography also helps to quickly disseminate crucial information.

In this sense cartography is most relevant. Without maps we would be "spatially blind". Knowledge about spatial relations and location of objects is most important for handling disasters and crisis situations or simply to be able to make good decisions. Cartography is also most contemporary, as new and innovative technologies have an impact on how maps are produced. Maps can be derived automatically from geodata acquisition methods such as laser scanning, remote sensing or sensor-networks. Smart models of geodata can be built allowing in-depth analysis of structures and patterns.

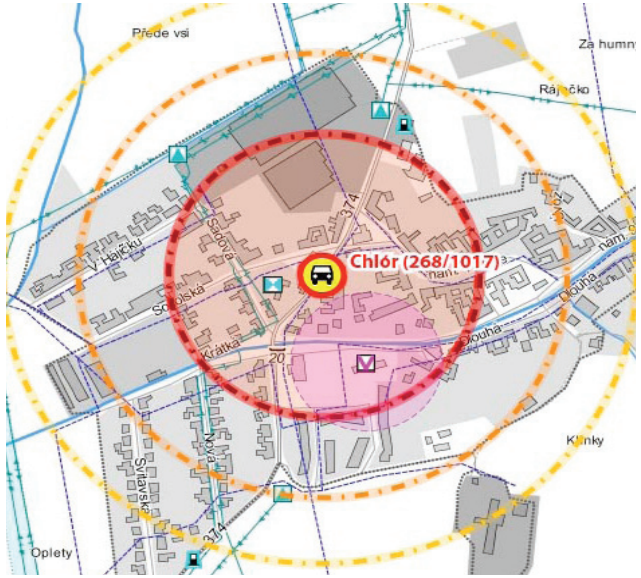


Figure 2: Example of visualization of theoretical danger zone generated around the location of accident

A whole range of presentation forms are available nowadays, from maps on mobile phones all the way to geoinformation presented as Augmented Reality presentations. In this situation it is important that those who are interested in maps, mapping and cartography work together at an international level. This is the role of the International Cartographic Association (ICA). ICA is a world authoritative body for cartography and GI Science. It consists of national and affiliate members. Every nation is encouraged to join ICA's large family of cartography and GI science, which provides a stronger voice for ICA. Companies, Universities and other bodies involved in Cartography and GIScience join ICA as affiliate members, and their numbers are growing.

The Association has several instruments. The most important ones are Conferences and Commissions, where particular topics are discussed and worked through. ICA runs 28 commissions, ranging from Generalisation Aspects to Map Projections as listed at http://icaci.org/commissions/.

Within the cartographic communities dedicated research, projects and applications in the context of disaster management are under development. A focus point of those activities is the ICA's Commission on Cartography in Early Warning and Crisis Management (CEW&CM). This commission especially deals with the following research targets:

- leadership in the development of concepts, ontologisation and standardization for early warning (EW), hazard, risk and vulnerability mapping;
- promote the cartographic use of remotely sensed and other geospatial data for EW and crisis management (CM) through scientific conferences, seminars and workshops;
- investigate the psychological condition of end users revealed by their personal character and situation and psychological condition of rescued persons (with support of ubiquitous, context adaptive mapping);
- foster quality mapping and cartographic modeling, including state-of-the-art visualization technologies, geospatial processing and publishing tools, for EW and CM through topic related publication activities;
- participate and contribute to global initiatives in EW and CM;
- promote the development of dynamic and real-time cartographic visualization concepts and techniques for enhanced operational EW activities through active collaboration with governmental authorities;
- establish and cultivate professional networks for exchange of information among stakeholders in the domains of CM and EW;
- develop mechanisms of command and control systems integration as well as improve real-time data-centric intelligence based on field sensors for purposes of CM;
- develop mapping methodologies and technologies for EW&CM from children's perspectives. Promote the process of teaching, understanding and using maps for EW&CM in children aspects.

In order to achieve its goals the Commission is actively organizing workshops and seminars, including in Bulgaria (Borovets, Nessebar, Albena), in USA (AutoCarto), in Russia (Inter Expo Geosiberia) and China (Wuhan, Beijing). As the topic of crisis management and early warning is interdisciplinary, the commission also participates in joint efforts with sister organizations such as ISPRS, FIG or ISDE. As a result of such a cooperation ICA and ISPRS specialists published the book „Geographic Information and Cartography for Risk and Crisis Management", edited by Milan Konecny, Sisi Zlatanova and Temenoujka Bandrova, Springer, 2010.

The Commission is also represented at the highest political levels and in different parts of the World, e.g. in the EU-China Disaster Risk Management project, allowing for informing decision and policy makers to be informed about contemporary cartography in early warning and crisis management.

www.icaci.org

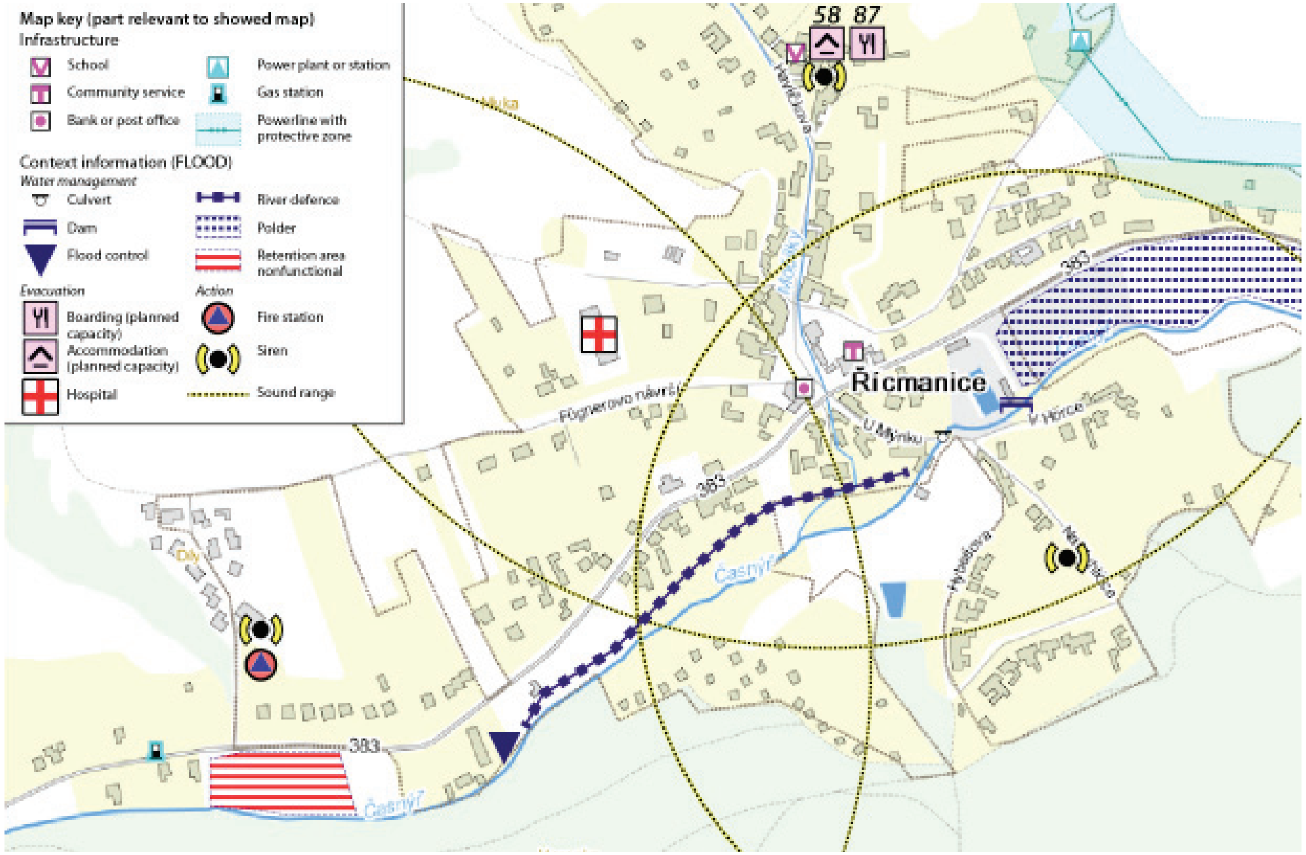


Figure 3: Example of visualization of the context FLOOD

The International Federation of Surveyors

Yerach Doytsher

What is FIG?

The International Federation of Surveyors is an international, non-government organization whose purpose is to support international collaboration for the progress of surveying in all fields and applications.

FIG is the premier international organization representing the interests of surveyors worldwide. It is a federation of the national member associations and covers the whole range of professional fields within the global surveying community. FIG provides an international forum for discussion and development aiming to promote professional practices and standards.

As a UN-recognized non-government organization (NGO), representing more than 120 countries around the world, FIG aims to ensure that the disciplines of surveying and all who practice them meet the needs of the markets and the communities that they serve.

The FIG Vision

A profession, armed with knowledge and best practices, extending the usefulness of surveying for the benefit of society, environment and economy, increasingly positioned in significance and relevance to mankind.

Who are the members of FIG?

FIG draws its membership from practitioners working in the public and private sectors; from the scientific, research and academic community; and, from the spatial technologies and services community. The formal members of FIG include:

Member associations – national associations representing one or more of the disciplines of surveying;

Affiliates – groups of surveyors or surveying organizations undertaking professional activities but not fulfilling the criteria for member associations;

Corporate members – organizations, institutions, or agencies which provide commercial services related to the surveying profession;

Academic members – organizations, institutions, or agencies which promote education or research in one or more of the disciplines of surveying.

Commissions‘ Activity

Ten commissions lead FIG's technical work. Their terms of reference are as follows:

Commission 1 - Professional Practice

Perception of surveying profession; professional practice, legal aspects and organizational structures; standards and certification; code of ethics and applications; under-represented groups in surveying; information technology management and professional practice; project management, quality and best practices.

Commission 2 - Professional Education

Curriculum development; learning and teaching methods and technologies; educational management and marketing; continuous professional development; networking in education and training.

Commission 3 - Spatial Information Management

Management of spatial information about land, property and marine data; spatial data infrastructure – data collection, analysis, visualization, standardization, dissemination, and support of good governance; knowledge management for SIM; business models, public-private-partnerships, professional practice and administration.

Commission 4 - Hydrography

Hydrographic surveying; hydrographic education, training and CPD; marine environment and coastal zone management; data processing and management; nautical charting and bathymetric maps – analogue and digital, including electronic navigational charts.

Commission 5 - Positioning and Measurement

The science of measurement including instrumentation, methodology and guidelines; the acquisition of accurate and reliable survey data related to the position, size and shape of natural and artificial features of the earth and its environment and including variation with time.

Commission 6 - Engineering Surveys

Acquisition, processing and management of topometric data; quality control and validation for civil engineering construction and manufacturing; modern concepts for setting-out and machine guidance; deformation monitoring systems; automatic measuring systems, multi-sensor measuring systems; terrestrial laser systems.

Commission 7 - Cadastre and Land Management

Cadastre, land administration and land management; development of pro poor land management and land administration; development of sustainable land administration as an infrastructure for sustainable development to underpin economic growth; applications of innovative and advanced technology in cadastre and land administration.

Commission 8 - Spatial Planning and Development

Regional and local structure planning; urban and rural land use planning and implementation; planning policies and environmental management for sustainable development; public-private partnerships; informal settlement issues in spatial development, planning and governance.

Commission 9 - Valuation and the Management of Real Estate

Valuation; investment in real estate and investment planning; real estate, development finance and land use feasibility planning; real estate economics and markets and market analyses; management of property and property systems; management of public sector property.

Commission 10 - Construction Economics and Management

Construction economics, including quantity surveying, building surveying, cost engineering and management; estimating and tendering; commercial management including procurement, risk management and contracts; project management including planning and scheduling.

Disaster and Risk Management within FIG

As geo-information technology and products are important components for risk and disaster management, FIG is actively involved in different aspects on the topic through several of its commissions. In this context, sub-topics such as risk maps, damage maps, integration of datasets from different sources, and early warning, should be based on assessing and processing of geospatial data. The mapping and surveying community within FIG is integrating the knowledge and experience of its members – professionals as well as researchers – in order to positively impact on emergency response, disaster preparedness, and risk reduction activities, at the operational as well as strategic levels.

Major FIG activities on disaster and risk management are:

Commission 3 (Spatial Information Management) is focusing on the technical aspects of 2D, 3D, and 4D spatial data recording and management to support legal, accurate, and relevant integration of geospatial data, inter alia, for decision making, risk-assessment, and disaster management in general and in areas with informal settlements in particular.

Commission 5 (Positioning and Measurement) and **Commission 6** (Engineering Surveys) are working jointly to respond to global warming and disaster management from the geodetic and measurement viewpoint.

Commission 7 (Cadastre and Land Management) is focusing on land administration, natural disasters and climate change. In this context, the commission is targeting better preparedness and response to natural disaster and climate change, and specifically handling topics such as: land issues in disaster preparedness and mitigation; land policies in disaster mitigation; and the use of risk maps in land use planning and land development.

Commission 8 (Spatial Planning and Development) is focusing on land use planning while taking into consideration disaster risk management effect. In particular, analyzing the role and collective responsibility of surveyors and other experts on the built environments for well-functioning urban regions and mega cities, including integrated disaster risk management as a discipline.

www.fig.net

Figure 1: Examples of FIG Commissions' Activities

Figure 2: More Examples of FIG Commissions' Activities

International Geographical Union

S. Haruyama and M. Meadows

Geography and the IGU

Geography is the discipline that attempts to explore how environments emerge by natural processes, how societies produce, organize, use and misuse environments, and how societies themselves are influenced by the environments in which they are located. Thus, geography aims to study both natural and human realms and their interactions, focusing on space, places, and regions, addressing both short-term and longer-term processes and their resultant patterns. The purposes of the International Geographical Union are primarily to promote the discipline of geography through initiating and coordinating geographical research that is international in scope and effected through the instruments of its various Commissions and Task Forces. There are currently 41 Commissions within the IGU, each run by a steering committee of internationally respected scientists, and several of these commissions engage in projects that have strong relevance to the field of disaster mitigation and management, most especially Commission C12.18 'Hazard and Risk'.

The IGU Commission on Hazard and Risk

The Commission on Hazard and Risk plays an important role in promoting the disaster risk science and disaster risk reduction. There are a number of approaches, for example, from the perspective of human geography that may focus on comparing the impact of historical disasters with more recent ones. Human geographers also study land use and land cover change (another IGU Commission topic) as a major factor in disasters and their impacts, while there are also key initiatives dealing with community structure and disaster risk, risk communication and disaster resilience. Physical geographers explore the structure of the natural environment and processes that promote disasters in fields such as climatology, geomorphology, biogeography and hydrology using, for example, remote sensing technology and GIS through observation, measuring, recording and analysis.

What is the mission of the IGU Commission on Hazard and Risk?

The Commission identifies its mission as follows:

- To construct networks with related agencies working in a geographical approach to hazard and risk with the aim of promoting further collective engagement in research projects with these organizations. The objective is to conduct and publish research for hazard and risk mitigation employing GIS technology with remote sensing and landscape studies.
- To continue to develop close links with several international disaster prevention associations and the IRDR especially through engaging younger researchers. The objective is to promote round tables for discussions on risk management and to contribute to social interchange.
- To extend its work on the role of geography in coping with disaster through education. The objective is to assess the uptake of the concept of sustainable development in curriculum materials and promote these ideas through the meetings of the Commission and through participation in IGU Regional Conferences and Congresses.
- To continue to develop statistical approaches to evaluate regional risks from the knowledge of atmosphere-related and lithosphere-related hazards statistics.
- To explore the issue of desertification and land degradation and the way these processes increase disaster risk with the objective of developing sustainable solutions to desertification.

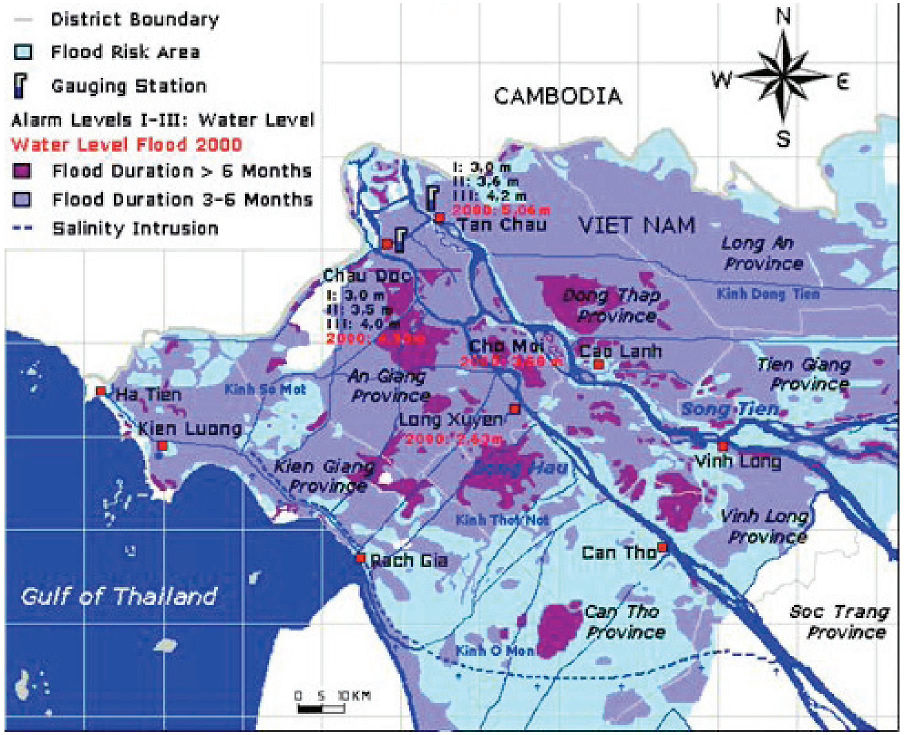


Figure 1: The largest flood on record in the Mekong region of Vietnam occurred in the year 2000 and several areas flooded experienced inundation for more than six months. Geomorphological analysis of the delta suggests that that the back-swamps are most likely to experience extended periods of inundation. Mitigation efforts can thus be targeted especially at such areas.

The Organization and Activities of the IGU Commission on Hazard and Risk

The scientific and technical programme of the Commission is led by the chair, Professor Shigeko Haruyama, and ten members of the Steering Committee who are responsible for particular topics. For example, the working group on disaster assessment and mitigation was formed to investigate, from a scientific and technical point of view, the role of remote sensing in managing the consequences of 'natural' and 'man-made' disasters and aims at informing and activating people involved in disaster monitoring, mitigation and damage assessment from both public institutions and private companies. The main goals include the development of appropriate tools and methodologies in relation to the human dimension of disaster risk assessment, and management of the generation of vulnerability and hazard risk maps for different types of geohazards, such as typhoons and cyclones, floods, droughts, earthquakes, landslides etc.. Further objectives of the group include the identification and assessment of geomorphological risk, integration of remote sensing, and early warning, monitoring, and damage assessment in collaboration with engineers as well as the development of risk communication.

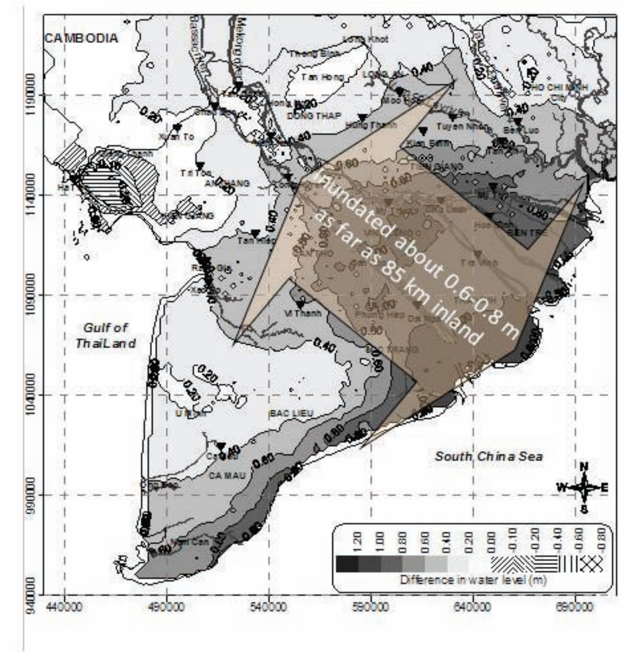


Figure 2: Flood assessment in the Mekong Delta under scenarios of sea level rise. Flood inundation was calculated for several future scenarios of flooding in the delta and the resultant flood assessment illustrates the expansion of inundation areas given projected sea level rise.

For further information on the IGU Commission on Hazard and Risk contact the chairperson, Professor Shigeko Haruyama: haruyama@bio.mie-u.ac.jp; www.bio.mie-u.ac.jp/~haruyama/igu/

LANDSCAPE-LAC: Landslide Networking for Disaster Studies, Capacity Building, Partnership and Engagement in Latin America and the Caribbean

The International Council for Science (ICSU) has recently funded an important IGU initiative that aims to develop networking around disaster studies in Latin America and the Caribbean. Landslide disasters have major impacts in developing countries due to the social vulnerability of communities and the absence of integrated risk research. This project recognizes the importance of integrated landslide research for disaster risk, and particularly the necessity to promote capacity building for young scientists in Latin America by shifting the disaster paradigm to recognize the "unnaturalness" of disasters. In recent decades landslide disasters in Latin America, triggered by both precipitation and earthquakes, have increased considerably. Therefore, scientific contributions towards reducing the vulnerability of exposed communities to landslides are urgently needed. LANDSCAPE-LAC focuses on the need to develop and implement integrated landslide research for disaster risk from a multi- and trans-disciplinary approach recognising that scientific achievements must be visibly useful for societies. Understanding risk and investigating the natural and social dimensions of disasters are critical processes for disaster risk reduction. Consequently, integrated risk research is regarded as a key factor for sustainable development, since disasters have increasingly become an obstacle to development, particularly in vulnerable countries exposed to such hazards. As such, strengthening capacity building and promoting disaster risk research on landslides would help to increase resilience and awareness in the Latin-American region.

For further information contact the project leader, Professor Irasema Alcántara Ayala: irasema@igg.unam.mx

www.igu-online.org

Figure 3: Risk communication and regional planning for mitigation in the Mekong delta. Photo shows a meeting between officers of the local government and geographers discussing possible mitigation interventions.

The International Society for Photogrammetry and Remote Sensing (ISPRS)

Christian Heipke

The International Society for Photogrammetry and Remote Sensing (ISPRS) is a non-governmental organisation devoted to the development of international cooperation for the advancement of photogrammetry, remote sensing and spatial information sciences and their applications. The Society operates without any discrimination on grounds of race, religion, nationality, or political philosophy. Established in 1910 by Professor Doležal from the Technical University of Vienna, Austria, ISPRS is the oldest international umbrella organisation in its fields, which may be summarized as addressing "information from imagery."

Role of ISPRS

The principal activities of ISPRS are:

1. Stimulating the formation of national or regional Societies of Photogrammetry, Remote Sensing and Spatial Information Sciences.
2. Initiating and coordinating research in photogrammetry and remote sensing and spatial information sciences.
3. Holding international Symposia and Congresses at regular intervals.
4. Ensuring worldwide circulation of the records of discussion and the results of research by publication of the International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences and the newly established peer-reviewed International Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences.
5. Encouraging the publication and exchange of scientific papers and journals dealing with photogrammetry and remote sensing and spatial sciences, in particular in the ISPRS Journals on Photogrammetry and Remote Sensing and the ISPRS International Journal of Geo-Information.

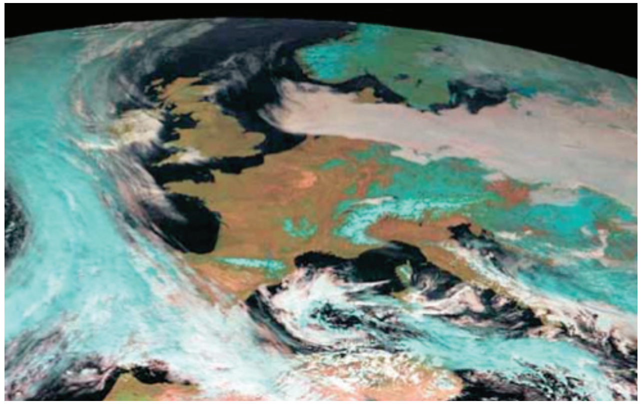
The scientific and technical programme of ISPRS

The scientific and technical programme of ISPRS is organized by eight Technical Commissions. Each Commission is comprised of a number of Working Groups which are responsible for particular topics within the Commissions' areas of responsibility. The ISPRS conference programme includes a quadrennial Congress, Technical Commission Symposia held in the even numbered year between the Congresses and workshops organized by the Working Groups at regular intervals.

What are Photogrammetry, Remote Sensing and the Spatial Information Sciences?

Photogrammetry is used for the derivation of 3D information of points, lines and areas on the terrain from aerial and satellite images for the development of geospatial databases and spatial information systems (SIS). The data can be used in digital, graphical and orthophoto forms as maps, charts and overlays. Photogrammetry is also used for the general measurement and interpretation of objects from images, image sequences, and other non-contact techniques, by providing precise 3D point coordinates and other geometric and semantic object information for populating spatial databases and for creating virtual reality 3D scenes with real-life textured models.

By observing the Earth from air- and space-borne platforms remote sensing provides the basis for mapping of human



Figures 1 and 2: Examples of remote sensing and spatial information analysis and natural activities; for monitoring change; for assessing and mitigating disasters; for identifying and assessing non-renewable resources; for monitoring temporal changes in weather, land and sea cover; and for many other applications. Spatial and semantic descriptions of objects and features are derived from 3D measurements of imagery, and the interpretation of their spectral and semantic attributes from panchromatic, multispectral and other remotely sensed data.

The description and location of objects and features obtained from images, as well as temporal relationships between physical objects and processes, can be integrated with other data using approaches from Spatial Information Science for analysis, simulation, prediction and visualization independent of scale. Spatial Information Science is being applied in urban and infrastructure planning, land and resource management, monitoring the environment, and understanding many other natural and man-made processes and phenomena.

Current activities of the ISPRS in Disaster Management and Response

Within ISPRS the main activities in disaster management and response are pooled in Commission VIII and more specifically in Working Group VIII/1 entitled „Disaster and risk reduction“. The working group is chaired by T. Srinivasa Kumar from the Indian National Centre for Ocean Information Services (INCOIS) in Hyderabad, Cees van Westen from ITC, University of Twente, the Netherlands, and Fabio Giulio Tonolo from the Information Technology for Humanitarian Assistance, Cooperation and Action (ITHACA) in Torino, Italy serve as co-chairs.

The tasks of the working group are the generation of vulnerability and hazard zone maps for different type of disasters, such as forest fire, cyclone, floods, drought, volcano eruptions, earthquakes, landslides etc. and the identification and assessment of potential risk zones, the integration of remotely sensed observations and communication strategies with enhanced predictive modelling capabilities for disaster detection, early warning, monitoring, damage assessment and response, and the development of disaster management plans for pre, during and post disaster situations to enhance support for early warning systems, emergency events mitigation and decision making.

In this way the working group aims to promote the development of tools and methodologies that support disaster risk reduction by using remote sensing, GIS and enhanced predictive modelling capabilities in support of risk assessment, detection, early warning, monitoring, damage assessment and response. Towards this goal, the working group is engaged in organising workshops and other scientific and technical meetings to exchange latest developments as well as to provide links to publicly available resources to support disaster risk reduction. Further, the working group collaborates with ISPRS Technical Commission I and other relevant working groups as well as international bodies such as the Group on Earth Observation (GEO), the Committee on Earth Observation Satellites (CEOS), the International Global Observing Strategy (IGOS) and the International Charter on Space and Major Disasters (ICSMD) to enhance remote observing capabilities.

Besides the activities at the working group level, ISPRS is the main contributor to the Geo-information for Disaster management (Gi4DM) conference series. Gi4DM is an annual conference devoted to the use and application of geo-information technology in disaster management. The fundamental goal of the conference is to provide a forum where disaster managers, stakeholders, researchers, data providers and system developers can discuss challenges, share experience, discuss new ideas, demonstrate technology and analyse future research toward better support of risk and disaster management activities.

Eight editions of these conferences have taken place in Delft, The Netherlands, (March 2005), Goa, India, (September 2006), Toronto, Canada, (May 2007), Harbin, China (August, 2008), Prague, Czech Republic (January 2009), Turin, Italy (February 2010), Antalya, Turkey (May, 2011) and Enschede, the Netherlands (December, 2012). The 9th Gi4DM meeting will take place in Hanoi, Vietnam in December 2013.

Gi4DM has been organised in cooperation with different international bodies such as ISPRS, OOSA, ICA, ISCRAM FIG, IAG, OGC, WFP and supported by national organisations such as GIN (Netherlands) and CIG (Canada). Since 2008, Gi4DM is coordinated by the Joint Board of Geospatial Information Societies (JB GIS) ad-hoc Committee on Risk and Disaster Management.

www.isprs.org

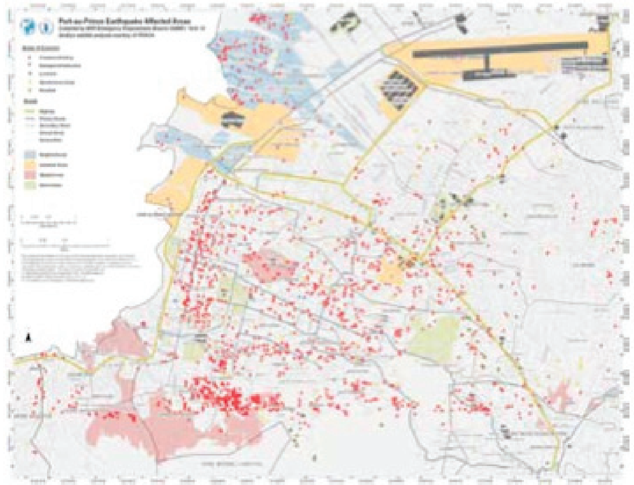


Figure 3: Crowd sourcing for the Haiti earthquake response

International Union of Geodesy and Geophysics (IUGG)

Alik Ismail-Zadeh

The International Union of Geodesy and Geophysics (IUGG) is an international, non-governmental, non-profit organization established in Brussels, Belgium, on 28 July 1919. IUGG is dedicated to the scientific study of the Earth and its environment in space and the application of knowledge gained by such studies to benefit society. IUGG promotes and coordinates physical, chemical, and mathematical studies of the Earth including the shape of the Earth; the nature of its gravitational and magnetic fields; the dynamics of the Earth as a whole and of its component parts; the Earth‘s internal structure, composition, and tectonics; the generation of magmas; volcanism and rock formation; the hydrological cycle including snow and ice; the physics and chemistry of the oceans; the atmosphere, ionosphere, magnetosphere and solar-terrestrial relations; and analogous problems associated with the Moon and other planets. Today, IUGG is comprised of eight semi-autonomous International Associations, each responsible for a specific range of topics within the overall scope of Union activities:

- cryospheric sciences (IACS; www.cryosphericsciences.org),
- geodesy (IAG; www.iag-aig.org),
- geomagnetism and aeronomy (IAGA; www.iugg.org/IAGA),
- hydrological sciences (IAHS; iahs.info),
- meteorology and atmospheric sciences (IAMAS; www.iamas.org),
- physical sciences of the oceans (IAPSO; iapso.iugg.org),
- seismology and physics of the Earth's interior (IASPEI; www.iaspei.org), and
- volcanology and chemistry of the Earth's interior (IAVCEI; www.iavcei.org).

Each International Association operates via its scientific divisions, commissions, working groups, services, and committees. Owing to the interactive nature of the subject fields managed by the Associations, five Union Commissions have been established, which serve the Union and the international geophysical community by promoting the study of particular interdisciplinary problems: Climatic and Environmental Change; Data and Information; Geophysical Risk and Sustainability; Mathematical Geophysics; and Study of the Earth‘s Deep Interior. The Union includes 70 countries of Africa, America, Asia, Europe, and Oceania, giving scientists from across the world the advantage of close cooperation, the opportunity to share data and to engage in open scientific discussion.

Activities of IUGG in Natural Hazard, Disaster Risk Research and Management

IUGG is one of the major players in the international scientific community dealing with natural hazards and some aspects of disaster risk research and management. Several divisions and commissions of the Union Associations deal with specific natural hazard and risk problems and assist in disaster risk management relevant bodies, for example,

- IACS's Division on Snow and Avalanches,
- IAG's Global Geodetic Observing System,
- IAGA's expertise in space weather research,
- IAHS's expertise in hydrological hazards and risk management,
- IAMAS's expertise in meteorological risks,
- IAPSO-IASPEI-IAVCEI Commission on Tsunami,
- IASPEI Commission on Earthquake Hazard, Risk, and Strong Ground Motion, and
- IAVCEI's expertise in volcanic risks.

To coordinate the activities of the International Associations in the field of natural hazards and disaster risk research, the IUGG Union Commission on Geophysical Risk and Sustainability (GRC; http://www.iugg-georisk.org) was established in 2000 to promote studies on the interaction between hazards, their likelihood and their wider social consequences as a result of the vulnerability of societies. GRC focuses on the scientific studies aimed at the reduction of risk from natural hazards in an increasingly urbanized world and at enhancing resilience of societies and sustainable development, reducing death and destruction from natural hazards by providing hazards data and information to emergency managers, policy-makers, scientists and the general public in the most timely and effective manner. One of the recent activities of GRC was the trans-disciplinary ENHANS project (http://www.enhans.org).

IUGG cooperates closely with the Scientific Committee "Integrated Research on Disaster Risk" (IRDR) co-sponsored by the International Council for Science (ICSU), the International Social Sciences Council (ISSC), and the United Nations International Strategy for Disaster Risk Reduction (UNISDR). IUGG via its Associations and GRC also cooperates with the World Meteorological Organization (WHO) and the International Civil Aviation Organization (ICAO) in the area of volcanic ash risk and established in 2010 a joint IUGG-WMO Volcanic Ash Scientific Advisory Group; with UNESCO through the Intergovernmental Oceanographic Commission (IOC) on tsunami hazards and risks, the International Hydrological Program on water risk management, and and the Disaster Preparedness and Mitigation Program on geohazards risks.

The following section presents specific activities of the International Association of Geodesy, in natural hazards and disaster risk management.

www.iugg.org

International Association of Geodesy

Hermann Drewes

Geodetic techniques enable us to monitor continuously and in nearly real time the preliminary, coincidental and subsequent phenomena and processes of Earth disasters. Currently the most important techniques are precise point positioning at the solid Earth surface, global gravity field determination, and remote sensing over continents and oceans.

The International Association of Geodesy (IAG) concentrates on these activities by means of its Commissions and Services and the Global Geodetic Observing System (GGOS). There are four Commissions on “Reference Frames”, “Gravity Field”, “Earth Rotation and Geodynamics”, and “Positioning and Applications” studying observation techniques and data analysis methods. Fifteen International Scientific Services deal with the practical realization of the geometric and gravimetric observations, and the generation of products for a myriad of applications. The GGOS combines the results of the Commissions and outputs of the Services. Some examples of such products are discussed below.

Point positioning is predominately done by satellite and space techniques, mainly Satellite Laser Ranging (SLR), Global Navigation Satellite Systems (GNSS), Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS), and astronomic Very Long Baseline Interferometry (VLBI). Global and regional station networks of these techniques are monitoring continuously their precise geometric positions, and hence are capable of detecting any deformation of the Earth's surface. Figure 1 shows the deformation of the central zone of South America after the 2010 Maule earthquake in Chile, with displacements up to 4 m (Sanchez et al., 2013).

Figure 1: GPS station displacements after the Maule earthquake, Chile, 27 February 2010

Mass displacements produce changes in the Earth gravity field. These changes are monitored by computing global epoch gravity models from repeated orbits of satellite gravity missions, such as the Gravity Recovery and Climate Experiment (GRACE) and the Gravity field and steady-state Ocean Circulation Explorer (GOCE), before and after an event. Figure 2 shows the gravity signal produced by the mass displacements of the 2011 Tohoku earthquake in Japan (Fuchs et al., 2013).

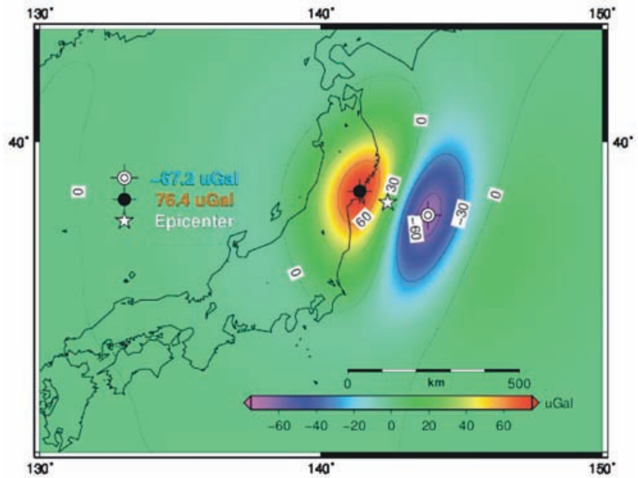


Figure 2: Signal of mass displacements in the Earth gravity field from the Tohoku earthquake, Japan, 11 March 2011

We clearly see an increase of the gravity acceleration by more than 76 · 10-8 ms-2 in the continental fault side and less than -67 · 10-8 ms-2 in the oceanic side (1 μGal = 10-8 ms-2). The gravity changes may be transformed into mass transport during the seismic event.

One of the most common remote sensing techniques over oceans is satellite radar altimetry. Several missions are continuously monitoring the global ocean surface with cm-precision, the most precise being TOPEX/Poseidon and Jason-1. Figure 3 shows the comparison of sea surface heights from tracks 10 days before the Indian Ocean Tsunami 2004 (black lines) and from the flyovers during the Tsunami (blue and red lines). We see the Tsunami wave with heights greater than 1 m in the open sea. These signals are today transmitted to an early warning system in the Indian Ocean in order to alert vulnerable cities and islands in the region.

www.iag-aig.org

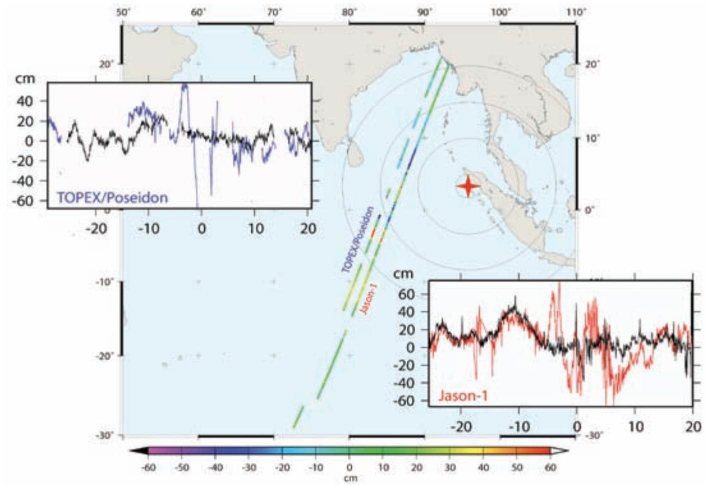


Figure 3: Sea surface heights from TOPEX/Poseidon and Jason-1 tracks before and during the Indian Ocean Tsunami, 26 December 2004 (Bosch, 2013).

The International Union of Geological Sciences

Ian Lambert and Roland Oberhänsli

The IUGS is the world largest geoscientific union representing over 1 million geoscientists through its 121 Adhering Members and 53 Affiliated Organisations. The Union is an international non-governmental organization devoted to international cooperation in the field of geology. It aims to promote development of the Earth sciences through the support of broad-based scientific studies relevant to the entire Earth system; to apply the results of these and other studies to preserving the Earth's natural environment, using all natural resources wisely and improving the prosperity of nations and the quality of human life; and to strengthen public awareness of geology and advance geological education in the widest sense.

IUGS fosters dialogue and communication among the various specialists in Earth sciences around the world. It achieves this by organizing international projects and meetings, sponsoring symposia and scientific field trips, and producing publications. Topics addressed span the gamut from fundamental research to its economic and industrial applications, and from scientific, environmental and social issues to educational and developmental problems.

IUGS works through its Commissions, Task Groups and Initiatives, plus joint programs with other Geoscience unions, such as the International Union of Geodesy and Geophysics (IUGG). One of the major tasks of IUGS is providing standards - for example for geoinformation systems and stratigraphy.

The union is building on its second strategic plan (2012). While mineral resources, water and energy will be central topics, associated risks and conflicting interests will be included.

IUGS' Disaster and Risk research

Scientific inputs to disaster and risk research from IUGS members and scientists are focused in the Commissions on Geoscience for Environment Management (GEM) and Geoscience Information (CGI); and the IUGS-UNESCO Geological Applications of Remote Sensing (GARS) program. Additionally, some other disaster risk reduction activities are covered by the Task Group Tectonics and Structural Geology (TECTASK) and the joint IUGS-IUGG International Lithosphere Program (ILP). Outlines of some important the activities follow.

Geoscience for Environmental Management

GEM is now comprised of seven individual working groups: Dust, Gold and Mercury, Land Subsidence and Groundwater, Climate Change Adaptation, Man Made Strata and Geopollution, Drinking Water, and Geological Hazards and Territorial Sustainability. Its former Working Group on Forensic Geology became a separate IUGS Initiative in 2010.

Working Group on Dust

This is concerned with the improvement of investigation and understanding of both dust and other particulates (PM10s and finer emissions). Dust performs an important function in the atmosphere, with individual particles acting as nucleation centers for droplets that become precipitation essential to life and geomorphological processes. Impacts on people, agriculture, livestock and the natural environment are major study objects of this group.

Climate Change Adaptation

The main focus is to improve understanding of the need for, and nature of, adaptation to climate change. The field of adaptation seeks to reduce human vulnerabilities to the impacts of a changing climate. The intention is to inform about best practice examples of planned or implemented adaptation measures and to make these available.

Man-made Strata

Man-made strata are widely distributed in urbanised and adjacent areas as a result of anthropogenic activities especially during intensive industrial development. These strata comprise cultural layers, landfills, waste management sites, abandoned industrial land, mine tailings, non-remediated pollution sites and other formations accumulated without proper environmental management, monitoring and treatment. IUGS seeks developing standards regarding hazard threats from man made strata.

Land Subsidence and Ground Water

Extraction of groundwater can lead to significant subsidence, including depression of the ground surface or fissuring of the ground. Damage to property and infrastructure and increased flood potential, particularly in coastal plains and deltas, result from these ground movements. This working group aims to examine the nature, extent and mechanisms of subsidence associated with groundwater withdrawal and methods for recharging aquifers to reduce the impacts of these ground movements.

Forensic Geology Initiative

The aim of this initiative is to develop forensic geology internationally and promote its applications by collating and disseminating data and information on forensic geology applied to policing and law enforcement, criminal and civil investigations, and disasters.

Management and Application of Geoscience Information

The mission of CGI is to enable the global exchange of knowledge about geoscience information and systems, which is vital as applications of IT are the key to the future exploitation of geological knowledge for the benefit of society.

Specifically CGI major task however is supporting and developing standards. It aims to provide the means for transferring knowledge on geoscience information and systems. It stimulates international dissemination of best practice in geoscience information.

Geological Application of Remote Sensing

The GARS Program - a partnership between IUGS and UNESCO -contributes to advancement of geological research and developing understanding of the Earth system, in order to address problems of relevance to the welfare of the Earth's population. Since 2005, there has been a dual focus on geohazards and groundwater issues. Building on previous GARS studies into landslide hazards in Latin America and volcanic hazards in Asia, GARS has been an important sponsor for development and implementation of the Integrated Global Observing Strategy (IGOS) for Geohazards.

Tsunami Risk

IUGS has initiated evaluation of information gaps that are limiting predictions of where major tsunami are likely to occur in the future – in particular, an important gap appears to be systematic studies of the presence and ages of paleotsunami deposits in the recent geological record in coastal areas adjacent to subduction zones.

www.iugs.org

Figure 1: Aiguille de Tsa, Dent Blanche nappe, Swiss Alps (R. Oberhänsli)

Figure 2: Convolute bedding, S of Van, Eastern Anatolia (R. Oberhänsli)

International Union of Radio Science

François Lefeuvre and Tullio Joseph Tanzi

What is Radio Science?

Electromagnetic (EM) waves carry energy through space. In empty space, they propagate at the speed of light. The basic properties, defined by Maxwell's equations, are identical throughout the electromagnetic spectrum, i.e. from milli-Hertz to 10^{24} Hz, but radio science stops slightly above 10^{14} Hz (optical communications). Radio science covers studies in many fields including the ones relevant to remote sensing, navigation, telecommunication and electronic science.

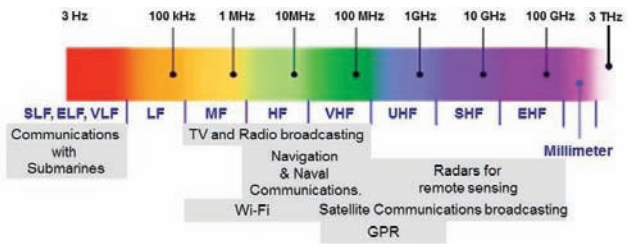


Figure 1: Radio spectrum (civilian GPS frequencies: ~1.5 GHz)

Role of URSI

The International Union of Radio Science (URSI) was founded in 1919 and is a non-governmental and not profit organization under the auspices of the International Council for Science.

URSI seeks to stimulate and to coordinate, on an international basis, studies in the fields of radio science through scientific and technical symposia and publications and by organizing and participating in international scientific committees on radio science. One of its main activities is to strengthen the understanding of – and to develop engineering solutions for - measuring, monitoring and controlling naturally occurring and man-made electromagnetic emissions.

In response to an increasing vulnerability to global disasters, the 2008 URSI General Assembly created a working group (WG) on Natural and Human Induced Hazards with terms of reference that includes methods and strategies to combat the impact of such events using techniques which derive from radio science.

Disaster Communications

When a disaster strikes, communication facilities can be totally destroyed. A critical early requirement is, therefore, the setting up emergency communication systems to support the rescue teams, and for disseminating information and instructions to the survivors. One of the first actions is to set up a disaster management cell for coordination. For major risks the cells include national ministries, civil defence, regional and local administrations, non-governmental organizations involved in disaster management, etc.

Access to observational data are facilitated by the international charter "Space and Major Disasters" signed by various space agencies. When available, optical or/and radio images from radio sensing satellites are the best sources of information. They can be quickly acquired and cover large geographical regions. Photo-interpreters use them to provide maps summarizing the relevant information. Data handling services can typically provide reliable information in 8 hours.

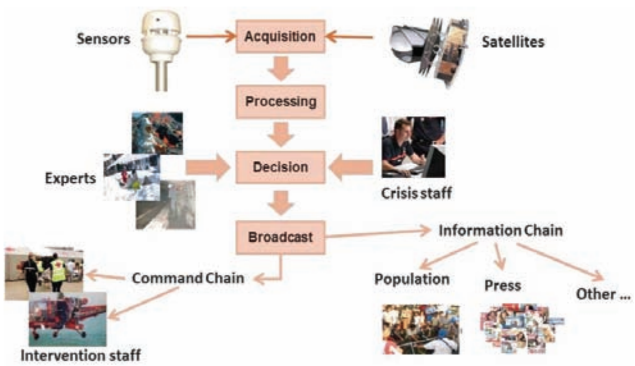


Figure 2: Disaster Information Cell

Risk prevention and crisis management may include the following which are all dependent on radio science:

- a high capacity communication sub-system,
- a Geographic Information System (GIS) providing spatio-temporal locations based on GPS data and imagery,
- a radio and optical data acquisition sub-system,
- a sub-system for synthesis of the information.

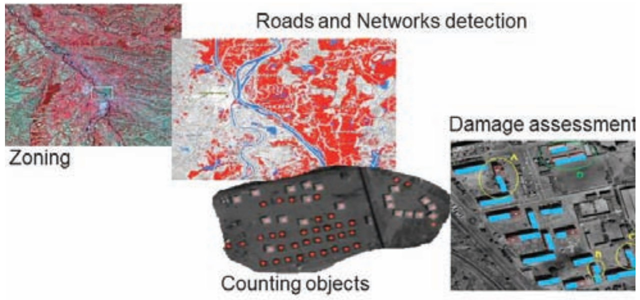


Figure 3: Example of image processing used by Risk Manager

Radio wave remote sensing

Remote sensing by air-borne or space-borne sensors can be used to detect, identify and monitor the impact and effects of natural disasters. Radio imagery provided by satellite-based synthetic aperture radars (SAR) should ideally be available 24/7, and should operate at frequencies capable of dealing with the prevailing and atmospheric conditions.

SAR observations of Earth have a wide range of practical applications (eg detection of flooded areas, drought monitoring, damage detection in an area affected by a major disaster, social and economic vulnerability analysis, search-and-rescue operations). Fusion of SAR images and optical images bring together complementary information.

Figure 4: SAR Image (X band 8-12 GHz)

InSAR — DinSAR

Interferometric synthetic aperture radar (InSAR) is a radar technique used in geodesy and remote sensing. It calculates the interference pattern caused by the difference in phase between two images acquired by a spaceborne synthetic aperture radar at two distinct times. The resulting interferogram is a contour map of the change in distance between the ground and the radar instrument. It may be used to generate maps of surface deformation.

The SAR interferometry differential (DInSAR) technique relies on the processing of the same portion of two SAR images of Earth's surface. In the repeat pass interferometry method, the detection and the quantification of the ground displacement that occurred between the two is measured.

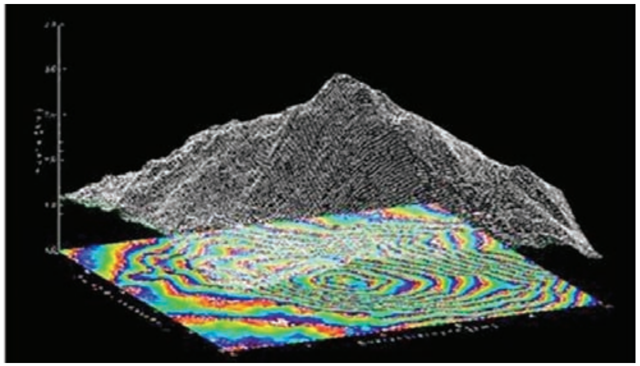


Figure 5: Fringes & Terrain model of the Etna Volcano Sicilia, Italy, obtained by SAR Interferometry

Ground Penetrating Radar

Ground-penetrating radar (GPR) is a geophysical method that uses radar pulses to image the subsurface. This non destructive method uses electromagnetic radiation in the microwave band (UHF/VHF frequencies) of the radio spectrum, and detects the reflected signals from subsurface structures.

GPR can be used in a variety of media, including rock, soil, ice, fresh water, pavements and structures. It can detect objects, changes in material, and voids and cracks. Studies are in progress to assess the ability of GPR to detect damages inside of buildings, bridges, concrete roads…. and Humanitarian Demining.

Communications during Space Weather events

Space Weather can be defined as conditions on the Sun and in solar wind, magnetosphere, ionosphere and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems. Solar electromagnetic and particle radiation cause:

- communications, navigation and remote sensing satellite anomalies and aging of solar cells.
- perturbations to the ionosphere which in turn cause a variety of effects including: loss of lock in GNSS navigation systems, degradation in space-borne geo-location, satellite communications systems operating below 2 GHz and degradations of HF communications.
- noise and interference on satellite ground stations, mainly at K band (~20 GHz) and C band (~4 GHz).

Disturbances of the ionosphere, caused by X-ray emissions from the Sun, produce HF radio blackouts (http://www.spc.noaa.gov/NOAAscales). Moderate space weather causes, HF radio blackouts on the sunlit side of the earth for tens of minutes on ~300 days per solar cycle. Extreme events occur less than one day per solar cycle, but produce HF radio blackouts on the entire sunlit side of the Earth for a number of hours.

Ionization density irregularities in the auroral regions and the equatorial regions cause fast random fluctuations of phase and amplitude on radio signals up to a few GHz and degrade and disrupt satellite-based navigation and communication systems.

When crossing a magneto-plasma, the polarization of the signal is rotated (Faraday rotation). This can affect synthetic aperture images, at L band (1.5 GHz) and lower frequencies.

In conclusion, on time periods running from a few minutes to several days, space based navigation, remote sensing and communications systems can all be affected by space weather. This may render more difficult rescue and recovery efforts after disasters such as earthquake and flood.

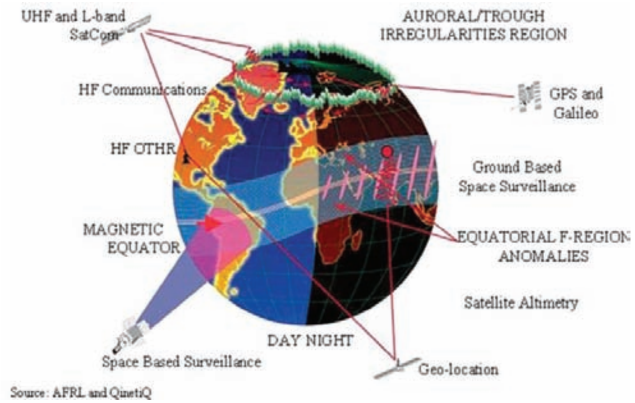


Figure 6: Radio systems affected by Space weather events

Note: On the 1 September 1859 Richard Carrington observed a white light solar flare that was followed by the largest super solar-storm recorded to date. If an event of this size occurred today it would certainly cause expensive damage to our technological infrastructure including our power networks.

United Nations Office for Outer Space Affairs

Anne Knauer

The overall purpose of the United Nations Office for Outer Space Affairs (OOSA) is the promotion of international co-operation in the peaceful uses of outer space for economic, social and scientific development, in particular for the bene-fit of developing countries.

About OOSA

The United Nations Office for Outer Space Affairs imple-ments the decisions of the General Assembly and of the Committee on the Peaceful Uses of Outer Space. The office has the dual objective of supporting the intergovernmental discussions in the Committee and its Scientific and Techni-cal Subcommittee and Legal Subcommittee, and of assisting developing countries in using space technology for develop-ment. In addition, it follows legal, scientific and technical developments relating to space activities, technology and applications in order to provide technical information and advice to Member States, international organizations and other United Nations offices.

The Office has two sections: the Space Applications Section (SAS), which organizes and carries out the United Nations Programme on Space Applications, and the Committee, Policy and Legal Affairs Section (CPLA), which provides substantive secretariat services to the Committee, its two subcommittees and its working groups. CPLA also prepa-res and distributes reports and publications on international space activities and on international space law.

OOSA's mandate

The Office has been mandated to:

- Service the intergovernmental process;
- Discharge the responsibilities of the Secretary-General under the United Nations Treaties and Principles on Outer Space;
- Implement the United Nations Programme on Space Applications;
- Coordinate space-related activities within the United Nations system; and
- Implement the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER).

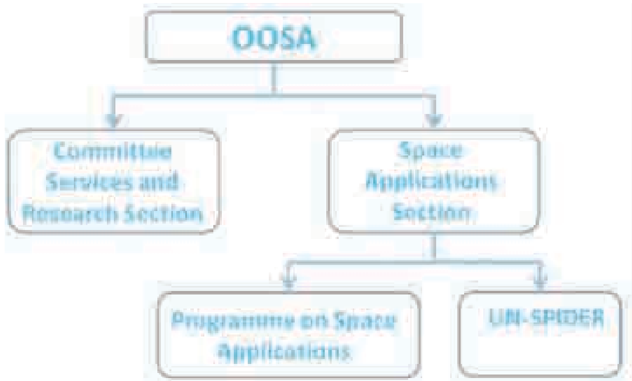


Figure 1: Organizational chart of OOSA

www.oosa.unvienna.org

Figure 2: Committee on the Peaceful Uses of Outer Space in session

UN-SPIDER

UN-SPIDER was established through the General Assembly in 2006 and aims at ensuring that all countries and international and regional organizations have access to and develop the capacity to use all types of space-based information to support the full disaster management cycle. UN-SPIDER's work focuses on knowledge management, technical advisory support, capacity building and fostering cooperation.

Knowledge Management

In order to provide a common platform to all its stakeholders, the Programme operates the UN-SPIDER Knowledge Portal (www.un-spider.org). This portal serves as a gateway to a variety of scientific and technical articles, proceedings, documents, news, events, contact data and other useful information concerning the use of space-based information to support in all phases of the disaster management cycle.

Figure 3: UN-SPIDER Technical Advisory Mission to Myanmar in March 2012

Technical Advisory Support

UN-SPIDER carries out Technical Advisory Support to requesting Member States. This has included, since 2011, conducting more than 10 Technical Advisory Missions to Member States in Asia, Latin America and Africa. The goal of these mission is to identify lessons learned and to outline recommendations that, when implemented, will allow government agencies, academia and the private sector within these Member States to take advantage of the opportunities offered by space-based information in order to respond more effectively to disasters, to improve disaster risk assessments or to reduce disaster risks.

Capacity Building

Complementary to its technical advisory services, the Programme carries out training activities to increase the skills and the knowledge of staff members in government agencies responsible for disaster-risk management efforts. Regional training courses have been organized among others in Burkina Faso, Cameroon, Dominican Republic , India, Mexico, Myanmar, Sri Lanka, and Sudan. In addition, UN-SPIDER supports training efforts organized by partner organizations either through the provision of experts or through the mobilization of participants to such training activities.

Fostering Cooperation

UN-SPIDER's network include National Focal Points (NFPs) nominated by their respective government to strengthen national disaster management planning and policies and the implementation of specific national activities that incorporate space-based technology solutions to support disaster management.

In addition, UN-SPIDER builds partnerships for the implementation of its work programme with a network of 16 Regional Support Offices (RSO) which are existing national or regional entities from the Earth observation sector or with authority in disaster management.

Through the organisation of international workshops, conferences and expert meetings, UN-SPIDER furthermore provides platforms for disaster and disaster risk managers, decision-makers, space application expert, academia and the private sector to exchange experiences, discuss novel methods and form partnerships.

www.un-spider.org

Sponsors

DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center

IEEE GRSS Geoscience and Remote Sensing Society

GSDI Global Spatial Data Infrastructure Association

ITHACA Information Technology for Humanitarian Assistance, Cooperation and Action

ICA ACI

FIG

IGU UGI

isprs information from imagery

IAG

IUGS

U.R.S.I.

UNITED NATIONS Office for Outer Space Affairs

Printed by Cenkler Matbaacılık, Istanbul, Turkey