

Supporting authorities by digital earth services for preventing risk; assessing damages and monitoring critical assets.

Dr. N. Stephenne

Eurosense Belfotop

Project Manager

Avenue des Nerviens 54 / Nervierslaan 54

1780 WEMMEL, Brussels

Phone : +32 (0) 24607000 Fax +32 (0) 24604958

nathalie.stephenne@eurosense.com

<http://www.eurosense.com/>

Abstract

In the “human security” paradigm, risks refer to the survival of people to be assured from natural hazards and environmental degradation (UNDP, 1994). Only a close dialogue between Earth Observation developers and responsible authorities can enable timely responses to global security challenges. Support to decision makers at the different stages of the emergency cycle is the major concern of EUROSENSE products in flood risk mapping, in spatial industrial risk management or in monitoring of elements at risk (critical assets) after a crisis.

Keywords

Human security, Risk cycle, Spatial technologies, Earth Observation,

1. Introduction

During the past half decade, perceptions of regional and international security have changed dramatically (Burnley et al. 2009). In parallel of these changes, the European Commission (EC) together with the European Space Agency (ESA) initiated Global Monitoring for Environment and Security (GMES). As the “S” of this acronym states for “Security”, one of the purposes of this project is to provide information to address some of the security related concerns.. EUROSENSE has been part of several GMES projects to provide security related information to respective local and regional authorities. This paper refers to the evolution in security definitions, in Earth Observation (EO) services and specifically in geo-spatial products to address users’ needs.

In the “human security” paradigm, risks refer to the survival of people, their livelihood and dignity. Human security is also inseparable from development and poverty. Daily safety and survival need to be assured from natural hazards and environmental degradation; the issues related to climate change are increasingly relevant for human security (UNDP, 1994). Only a close dialogue between Earth Observation developers and responsible authorities can enable timely

research responses to global security challenges, which in themselves lead to modification of human security research policy. In such a dialogue, geospatial concepts and earth observation techniques have to be integrated into technologies to address policy makers' needs and to test scenarios of political changes (Burnley et al. 2009).

No technology can prevent natural hazards. However, the disaster situation can be mitigated by prevention measures, early warning tools and adequate monitoring of past experiences and coordination of relief efforts. The support to the responsible authorities at the different stages of the emergency cycle (Figure 1) is the major concern of EUROSENSE products. One important task of this paper is to promote coordinated collaboration between the demands for information by decision makers with that supplied by geospatial technology using earth observation.

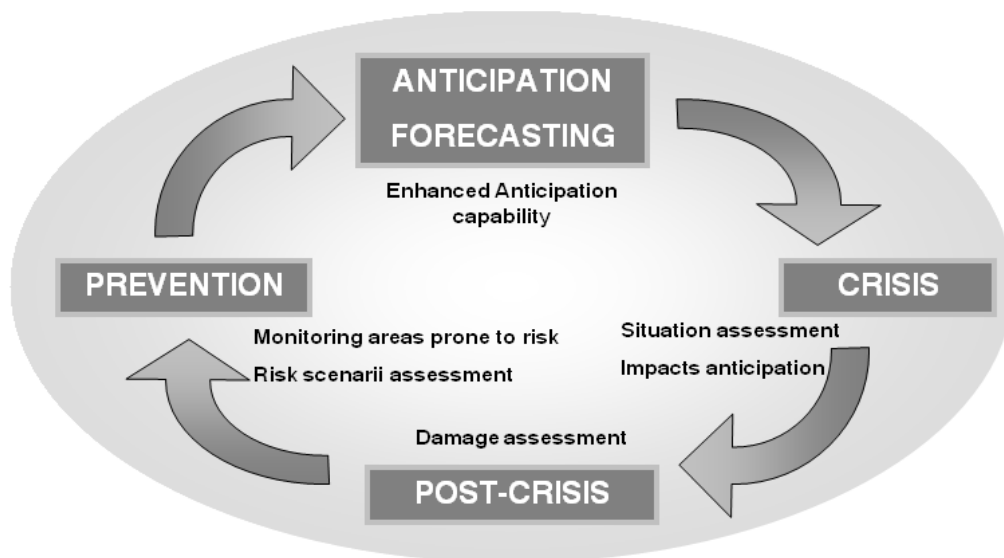


Figure 1 Emergency cycle

Section 2 will discuss theoretical concepts surrounding the two definitions of security. We highlight the focus to human security definition on risk to the state or to the individual and mention the consequences for scientific responses in spatial technologies. In this section, the challenges to Remote Sensing technology will be reminded. Section 3 presents the involvement of EUROSENSE in several thematic projects (Geoland, G-Mosaic, Globe, Safer) through the GMES evolution. Section 4 focus on the emergency cycle to propose three applications of remote Sensing techniques in: flood risk mapping, in spatial data support for industrial risk management and monitoring of elements at risk (critical assets) after a crisis. These products take advantage of newly developing capabilities in Earth Observation (EO), Navigation and Geographical Information Systems (GIS) in the context of both research and operational products.

2. Security Definitions and Spatial technologies

A wide body of literature has developed around the concept of security, from state security to human security. It has commonly been defined in relative terms, by reference to an object at risk, threats to that object and measures which may be taken to safeguard the object. These security definitions and their shifting and disputed understandings of risk, threats, objects at risk and safeguard measures are described in details in Burnley et al. (2009). As review by these

authors, “Security” has been defined negatively as, the absence of threats and the perception of threats to survival, or positively as, the fulfillment of human needs, aspirations and potential (Sen 1999). The two main schools of thought in international relations, can be distinguished by the weight given to states, groups and individuals as both as actors and objects at risk, and on the importance placed on cooperation within the international system.

After World War II, security concepts were framed by the Cold War. The object at risk was automatically the state, which was the primary international actor. In an anarchic international environment the exclusive and primary responsibility of the state was the protection by military means of state borders, territory and citizens. Maximisation of power was seen as the best defence for states against the “other” beyond the state border (Lynn-Jones and Miller 1995).

The Post-Cold War era has witnessed a shift in focus from security of the state, conceived in terms of power, autonomy, territorial integrity and sovereignty to one which relies on concepts of universal, indivisible, interdependent human rights, recognised and protected by international law enforced by states and international institutions. The nuclear stalemate, the increasing weight of shared threats to states and to the global environment, as well as the increased focus on people and their needs have led to a shift towards conceptualisation of security as multi-scale, inter-dependent and requiring a multilevel response not only by states, but by international institutions like the UN and by regional organisations like the EU, NATO and OSCE. The United Nations definition of human security is a rights-based definition, addressing well-being of people (UNDP 1994).

Spatial studies have historically addressed security in these two different paradigms. Firstly, geographers have been involved in “international relations” where geographical knowledge has been used to support military expansion, to foster peace and provide advice to policy makers (Mamadouh 2005). The most notable example is the use of “geopolitics” in the Darwinian theories largely exploited by colonial powers to rationalize the foreign policy of imperialism expansion before and during World War II (Foster 2006). In the second half of the 20th century geographers have started to conceptualize and analyse the causes and developments of conflict and peace but also the general well-being of population and the link to environmental factors.

2.1. Spatial concepts related to State and Human Security definitions

The spatial dimension of security issues has been theoretically addressed in socio-political studies whether security is defined as state security or as human security. In the state security definition, boundary refers to the line separating two states while the border is the area surrounding a boundary (Pace and Setter 2003). In the globalization and regionalization processes, state boundaries are becoming more and more permeable to trans-boundary collaboration, borderland initiatives, and open-ness (Blake 2000).

2.2. Geospatial technologies for human security

The quantitative analysis of human security benefits from geospatial technologies. Earth Observation (EO) and Navigation provide high precision measures of spatial entities and events. Geographical Information Systems (GIS) allow to quantitatively process geospatial information. The production of security information in the form of images is

still shaping politics even if not as evidently as during the second war. For example, satellite imagery and digital elevation models (DEM) were used operationally during the negotiations for the delineation of the international border between Bosnia and Herzegovina and Serbia (Wood and Smith 1997). Earth Observation data has progressively become a source of updated geospatial data that when combined with field information can be used as a visual tool for the decision makers in negotiations (Starr 2002).

Satellite imagery is extensively integrated in creating grid-based/raster dataset of the spatial socio-environmental indicators. Datasets of physical factors like topography, elevation, land cover, natural resources and population can be built or improved using these remote data. The new generation of globally available digital elevation models allow representing more realistically landscapes, a feature that can be used also in addressing security issues. The frequent revisit time of Earth Observation can be used to monitor spatial issues in time including illegal timber (i.e. in G-Mosaic see below) or flood (i.e. in Risk Eos see below). On a more general level remote sensing is providing geospatial features – often from archive datasets - that are used in a number of geospatial products used in security research that include natural land resource assessment and population density estimations (i.e. in 3WSA see below).

GIS offers 3 invaluable opportunities in the analysis of geospatial data: (i) improved cartographic output capability for visualization, (ii) efficient tools and techniques to integrate different data sources, and (iii) ability to quantitatively analyze geospatial data.

The cartographic functions of GIS's can be used to make decision-making more transparent, analysis of options more thorough and the presentation of results more convincing. However, to harness the potential of GIS, the issues of data completeness and data quality need to be addressed. For example, datasets need to have associated appropriate geographical information that allow them to be geo-referenced.

GIS tools possibly combined with satellite imagery can provide a continuous spatial representation of variables such as density of roads, density of population, distribution or ethnicity, land cover or natural resources, among different layers. The GIS tools built to support industrial crisis prevention include road and river networks information to precisely locate the civil population needs or the accessibility to potentially damaged regions (i.e. in 3WSA see below). The Digital elevation model (DEM) derived from EO or radar, laser imagery can be used to derive slopes aspect and elevation that for example can provide physical characteristics along rivers or borders (see 4.1). Gridded datasets of rainfall, as well as other environmental variables as land cover or extraction of natural resources are built using remote sensing data and can be used as spatial indicators in several geospatial model related to human well-being (i.e. in Geoland).

GIS tools not only provide the structure to build grid based dataset but also some tools to integrate and overlay the different datasets and to provide spatial indicators such as proximity, shape, size, buffering, accessibility, vulnerability or border permeability. The GIS allows to model different spatial characteristics in a whole system based on the conceptual interactions existing between these characteristics. The model is a tool to predict and simulate “What if” scenario that helps to better understand the system. The border permeability models the sustainability of crossing the border for an illegal migrant (Stephene and Pesaresi 2006). This permeability concept has been applied in EC projects

such as GMOSS and LIMES (see below). The modelling of spatial and temporal alternatives of human security issues is an important challenge in the overall goal of the political geography, geopolitics and international relations.

3. Involvement of EUROSENSE in GMES evolution

The European project aims to political stabilization and integration of former Mediterranean dictatorships and most recently to the ambitious attempt of stabilization of the whole of Europe. The shift in threat perception that occurred in Europe after the end of the Cold War, had some consequences for the pace of European integration. Existing transboundary challenges such as globalisation and environmental problems were brought to greater attention within the emerging human security concept.

In recent years, there has been a growing consensus that the EU must address issues of political, economic and human security, internally and externally. On this basis, notable elements of European security relevant policy have been developed in the last fifteen years. In the meantime, GMES was established to support the following (Jasani et al., 2009):

- Europe's environmental commitments, within the EU and globally by contributing to the formulation, implementation and verification of the EC environmental policies, national regulations and international conventions
- Other policy areas, such as agriculture, regional development, fisheries and transport are also considered
- Common Foreign and Security Policy (CFSP),
- Policies relevant to European citizens' security at EC and national levels (border surveillance).

These aims were carried out with the following general principles:

- Production and dissemination of information in support of EU policies for Environment and Security
- The mechanisms needed to ensure a permanent dialogue between all stakeholders and in particular between providers and users and
- The legal, financial, organisational and institutional frame to ensure the functioning of the system and its evolution

EUROSENSE is involved in a wide range of GMES services. The evolution in time illustrates the trends and objectives of EC initiatives to respond to human security principles. The line of services related to urban land use/ land cover, change detection, soil sealing and urban environment have been initiated in the GMES/GUS first phase of GSE projects, then the GSE land (GMES Service Element-Land financed by ESA). Geoland EC consortium aims at developing operational products to better represent the urban environment to support urban planners. The Security services, defined in the frame of the Global Monitoring for Security and Stability (GMOSS) Network of Excellence, were specified, developed and tested at the European level in the SABOCO (Satellites in Border Cooperation, ESA contract) and LIMES (Land /Sea Integrated Monitoring for European Security, EC FP6) projects. The G-Mosaic (GMES services for Management of Operations, Situations Awareness and Intelligence for regional Crises) project adapts these services to the international context by identifying and developing products, methodologies and pilot services for the provision of geo-spatial information in support of EU external relation policies. The development of early warning systems that was

the main stream of GeoCrew (GEO Crisis Early Warning) has been pursued by two EC projects: WIMAAS (Wide Maritime Area Airborne Surveillance) and Globe (Global Border Environment). The RISK-EOS – Risk-Earth Observation Services. GMES Service Element (funded by ESA) has been followed by the SAFER (Services and Applications For Emergency Response).

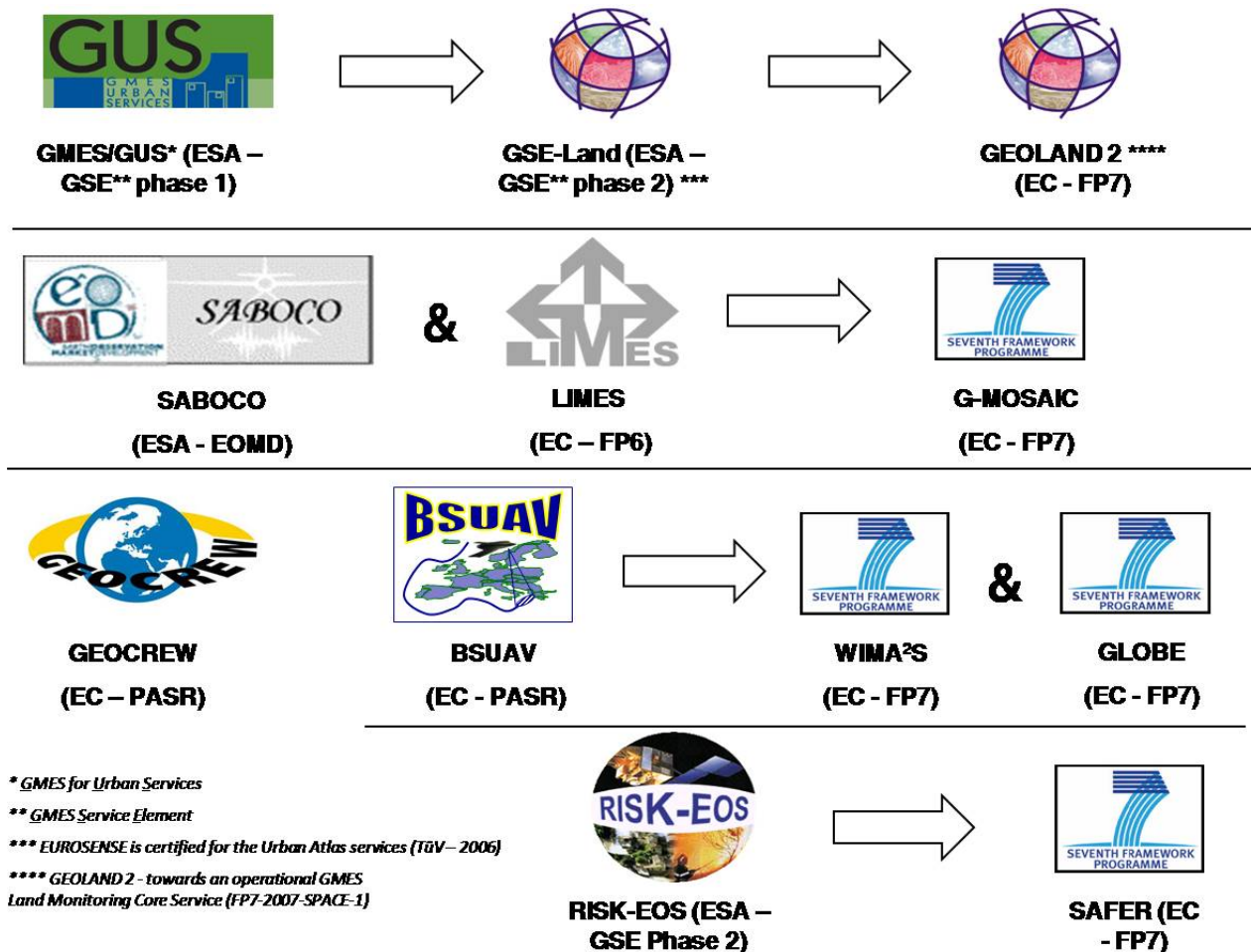


Figure2 : EUROSENSE involvement in GMES projects

The applications developed in EUROSENSE using EO and GIS technologies are distinguished in eight different segments (Figure 3). EUROSENSE provides specific satellite images in close discussion with the users about their real needs and technological capacities. The Land monitoring segment of the society is one on its strength, developed in the GMES/GUS and the GSE-land providing mapping tools for different political and private users. Some of the main risk analysis services will be discussed in this paper (see chapter 4). The environmental segment and mainly the maps produced with thermographic camera are recently intensively requested by urban planners. The vitality of trees and the monitoring of the urban greenness is a regular product of the company to support urban planners with aerial photos derived information. The company has developed a large expertise in agricultural control in several projects in support to the EC Agricultural Policy. In the all branch of projects issued after the GMOSS Network of Excellence, including LIMES and G-Mosaic, EUROSENSE have developed specific geo-spatial tools in support to land border management or control of illegal movements.

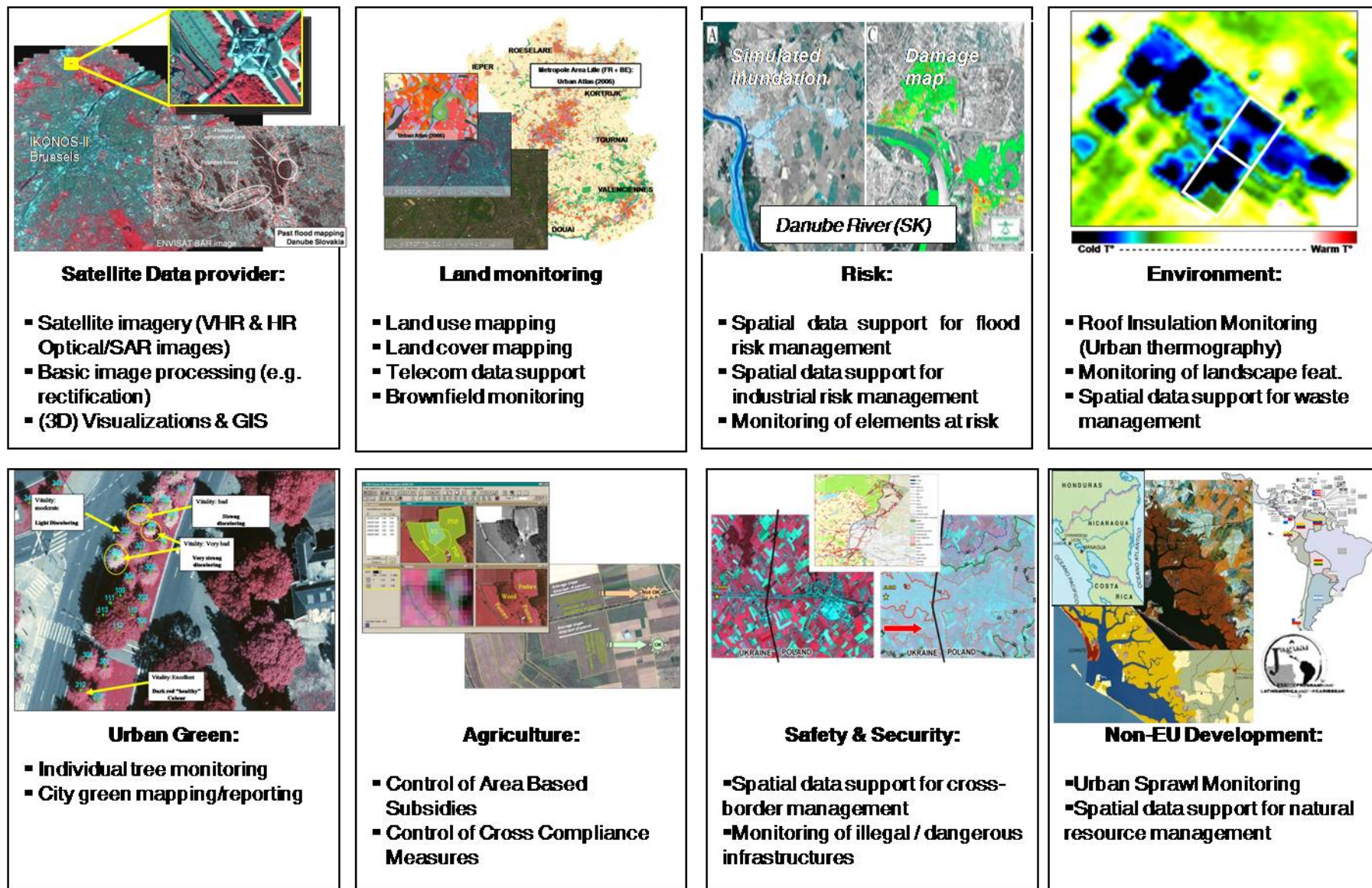


Figure 3: Main segments and themes in remote sensing development in EUROSENSE

4. Three products in the crisis cycle

The effective handling of a crisis is central not only to the EU's security responsibilities. It requires an exact understanding of the different crisis situations, their possible impacts, mechanisms and actors (Voigt et al. 2009). For these authors, there are four classes of crisis: (i) technological crisis refer mainly to the breakdown of utility networks (electricity, water gas, oil, ..) and communication networks (telephone, internet), which include also technical process failures and accidents that lead to large scale contamination and endangerment of the population, (ii) natural crisis situations include all types of fast onset natural disasters like earthquakes and tsunamis, floods, storms, or large fires. Additionally, also slow onset crisis like droughts and effects of global warming are summarized in that category, (iii) the term "complex crisis" describes the often interrelated conglomerate of riots and civil commotion, terrorism, civil wars and coups d'états, which may be induced by strong democratic changes or supply shortage, (iv) economic, financial crises which cover stock exchange crashes, resource shortages, market failure or bankruptcies.

Much practical experience of the gathering, processing and dissemination of information in a crisis management situation is available from recent operations and GMES projects (Cragg et al. 2009). According to these authors, the demands for Earth Observation support can be envisaged:

- **Pre-crisis:** *broadly-based routine observation in the context of the European Security Strategy (ESS). Useful areas for pre-crisis or conflict prevention include the monitoring of resources in developing countries which are potential focal points for crises (including, for example, diamond, timber and water) (tackled in the G-Mosaic project) as well as applications for humanitarian purposes such as the monitoring of crops for food security.*
- **Developing crisis:** *flexibility to facilitate rapid focus on emerging problem and crisis management planning. This might include on the one hand assessing the impact of natural disasters or of indicators of potential crisis, such as movement of troops and refugees and on the other supporting the preparation of humanitarian or military operations.*
- **Crisis situation:** *contribution to political management of crisis including humanitarian interventions and any military or police involvement in crisis management to support to the Situation Center and other bodies as required. (See G-mosaic critical assessment below). All will require high quality information in near real time.*
- **Post-crisis:** *contribution to management of post-crisis phase will require flexibility, accuracy and precision. This will include supporting damage assessment and tracking post-crisis humanitarian aid, recovery and reconstruction programmes, the monitoring of military disengagement, including disarmament and demobilisation and possibly specific observation tasks linked to the implementation of peace building agreements, such as the monitoring of large-scale movements of displaced persons and refugees, borders or other disputed areas, critical infrastructures, ...*

EUROSENSE mainly developed products in the natural (see 4.1. and 4.3.) and industrial crisis (see 4.2.) situations. These products illustrated the type of EO and GIS developments that could be proposed to responsible authorities at the different stages in the crisis cycle: while the flood management portfolio and 3WSA tools are two pre-crisis geo-information services, the flood portfolio uses previous crisis information and can then be characterised as a post-crisis output, the Chile critical assessment is clearly a crisis situation tool.

4.1. Flood management

Over the last decades, severe transnational floods occurred in Europe. In the context of global warming, intensity and frequency of extreme rainfall will probably increase. The EC directive addresses the need for pan-European flood policy. Designed with and for the responsible authorities, EUROSENSE's mapping products help in preventing risks and deaths related to flood events and in setting up responsible policies. The large river systems of central and Eastern Europe make these areas vulnerable to floods. By combining EO data with exogenous data and modelling techniques, EUROSENSE developed three customized products in Bulgaria and Slovakia in support of flood risk management. These are replicable in all Europe.

The Directive refers to inland and coastal waters across the whole territory of the EU. Member States must (i) assess flooding risks in water courses and coast lines, (ii) map potential flood extent, and humans and assets at risk in these areas and (iii) take adequate and coordinated measures to reduce risks. Flood risk maps need to be prepared by 2013. EUROSENSE services support the responsive authorities in the three dimensions of prevention, protection and preparedness.

Past Flood Maps are based on archive optical (e.g. SPOT, IRS, Ikonos) and radar (e.g. Envisat, Terrasar-X) earth observation data. These maps identify the flood extent of former events, the flood memory. Duration and max extent of the event can be derived from semi-automatic classification (flooded and potentially flooded areas) method and statistical analysis.

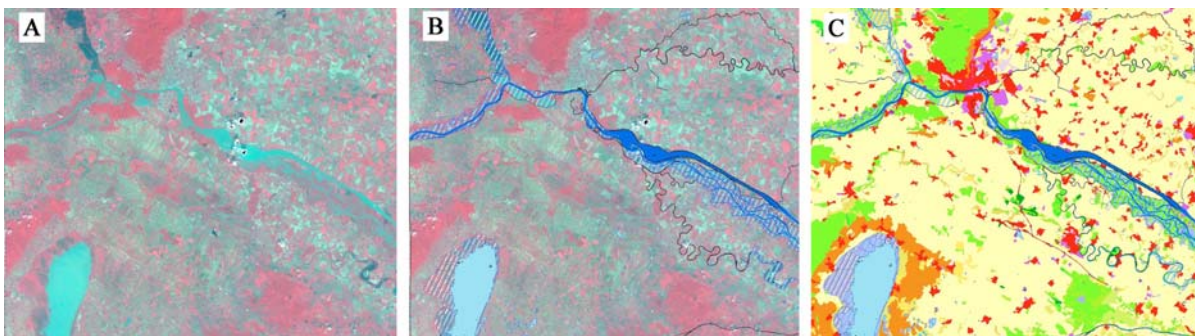


Figure 4: Danube river at the borders of Austria – Slovakia – Hungary on the 17/08/2002 (A) overlaid with past flood vector (B), CorineLandcover2000 with same vectors (C) (background imagery © spotimage)

Simulation techniques provide essential information for Flood Risk Management. FloodArea (Geomer ArcGis © extension) software uses EO-based information to identify flood risk zones and impact of specific flooding scenarios (e.g. extreme events, dam failure). Water depth, flowing velocity and flow direction are derived.

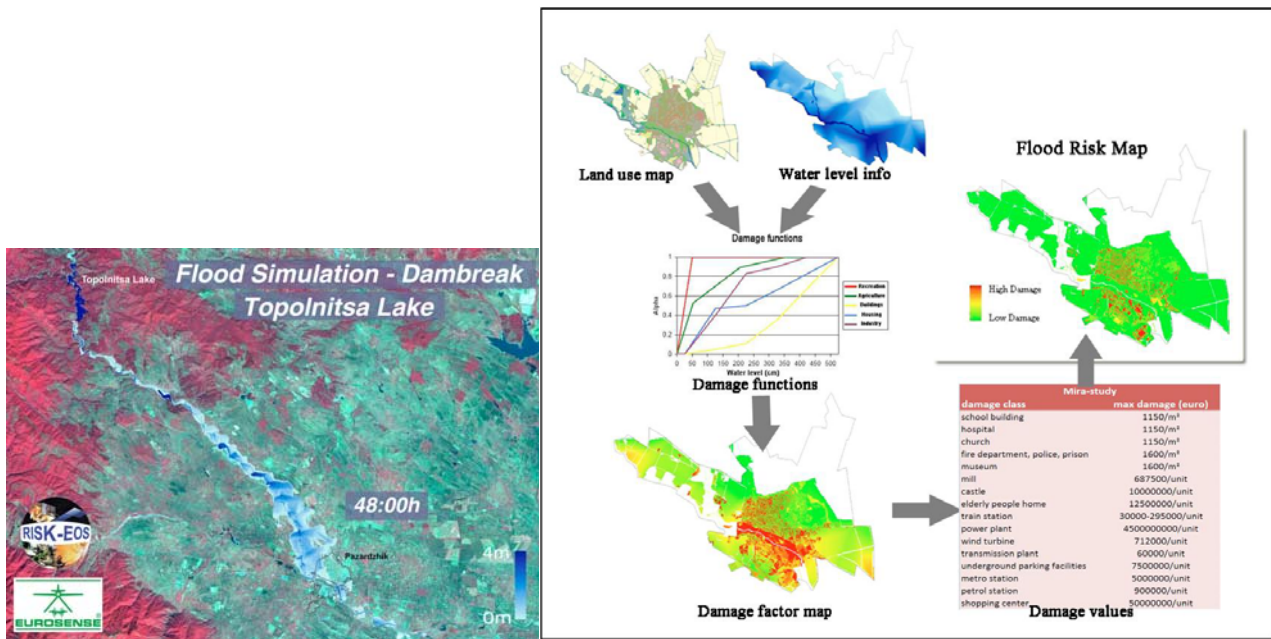


Figure 5a: Dike break of the Topolnitsa lake after 48 hours, in Bulgaria, water depth in blue (imagery ©IRS), and b: Workflow of the Flood Risk mapping procedure

The third service provides an assessment of estimated losses/damages during the flood event. Damage calculation is performed using well-established model algorithms and ancillary data (e.g. socio-economic). Strict quality check protocol and accordance to the EC directive makes the operability of these flood risk portfolio. These services are replicable and appropriate for responsible authorities.

4.2. 3WSA – industrial prevention

The Belgian project 3WSA, “Wallonia World Wide Space Applications”, aims to develop and the implement technical means combining new tools coming from Information and communication technology with existing and future space technology (in particular Galileo and GMES) to meet needs of safety policymakers. The specific focus of 3WSA is the prevention and management of industrial crisis. In that objective, 3WSA refers to the first EU Directive 82/501/EEC – so-called Seveso Directive. The Seveso II Directive applies to some thousands of industrial establishments where dangerous substances are present in quantities exceeding the thresholds in the directive (source: European Civil Protection, Environment, European Commission). This directive focuses on the prevention of major accidents with hazardous substances and the consequences of such accidents for man and also for the environment.

The establishment of a legal framework urged operators of industries as well as public emergency services to use models in both emergency planning and the response phase in order to support decisions. Clearly, there is a need for information on potential adverse impacts of accidents based on both pre-planned scenarios and pollutant transport models. This information must be available to responders in real time in order to facilitate rapid response. In the framework of the 3WSA project, EUROSENSE aims at developing a number of EO products/services enabling pre-crisis and rapid post-crisis mapping of Seveso-sites in particular.

Even for small industries, local physical/environmental damage, pollution and potential victims could be much higher than expected because of the vicinity of distribution channels (rivers, railways, airports ...) and high density of population. The consideration of these parameters surrounding a Seveso-site enables operators to define risk zones and perimeters of vulnerabilities. By integrating this local information with geographic information derived amongst other form remote sensing data a valuable GIS tool is developed. A Web application rapid mapping tool aims to support decision making before and during technological accidents, to assess the impact of the accident on the local environment (fauna and flora) and to indicate the areas at risk for early warning in case of a future event.

The EO services and products identified and developed will support the respective authorities, “Agence Prévention et Sécurité (APS)” (Marche-en-Famenne, Belgium) in the specific case, in achieving this challenge. EUROSENSE provides a list of services: (i) a number of layers and prototypes of airborne/spaceborne geographic data information layers that could be used for crises response, (ii) a set of image (airborne or satellite data) processing and customizing tools that could be further integrated in a web interface, (iii) these services will be demonstrated in a geospatial information based rapid mapping tool

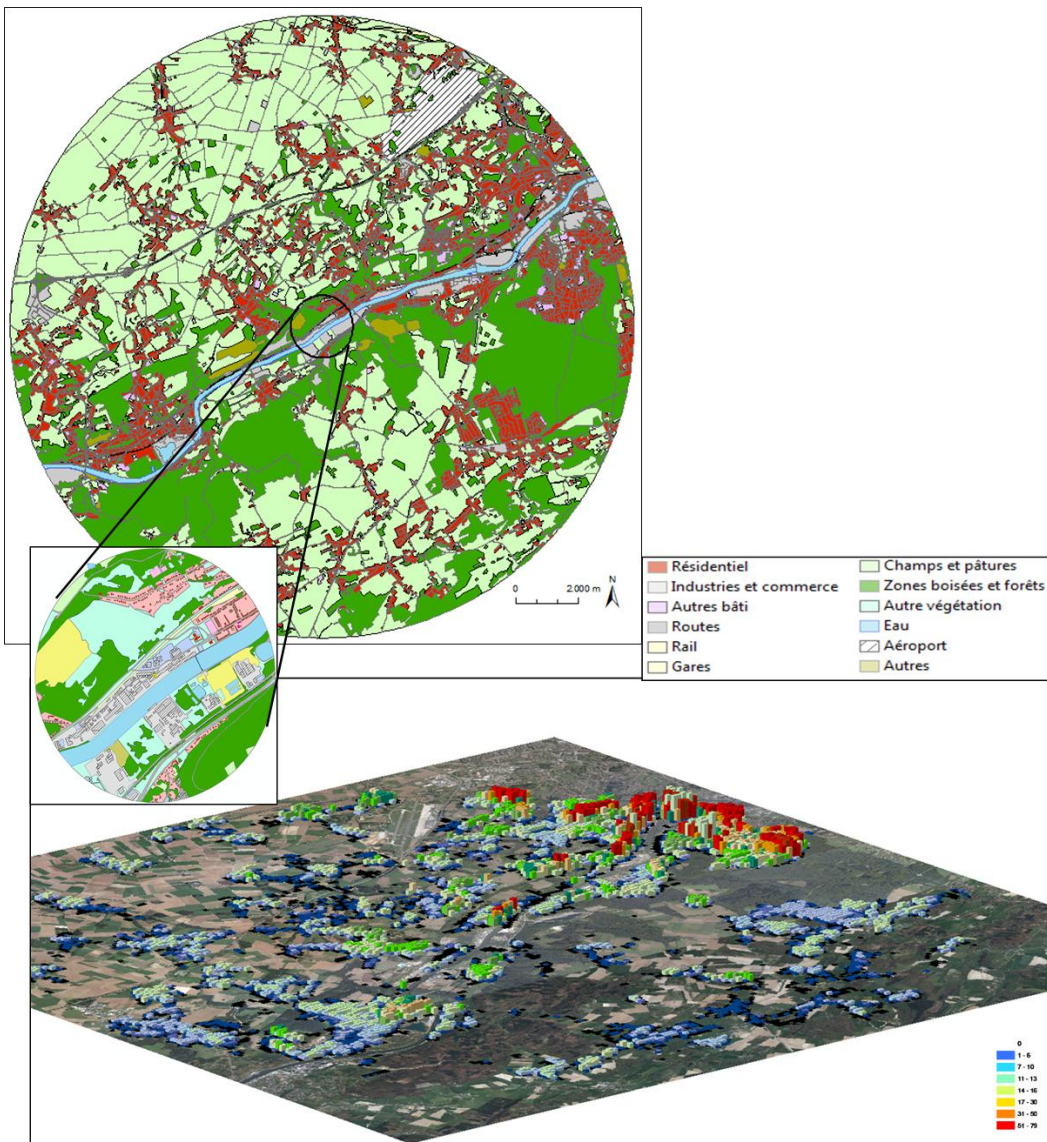


Figure 6: geospatial information tools illustrated the land cover and population in the neighbourhood of the Seveso site

4.3. Post-crisis critical assets in Chile

In only 2 months time, devastating earthquakes hit Port-au-Prince, Haiti (12 January 2010) and Concepción, Chile (27 February 2010). For both emergencies, the G-MOSAIC consortium was activated to provide geo-spatial products supporting the emergency decision makers in the crisis and post-crisis phase. One day after the earthquake hit Chile, the United Nations asked G-MOSAIC for the production of maps and data in support of the emergency workers in the field. The 'Rapid mapping service' from G-MOSAIC, led by the European Union Satellite Center (EUSC), was activated.

In 2009, EUROSENSE already produced a detailed Urban Atlas of Concepción and the surrounding area to illustrate the potential of Earth Observation for Urban applications (Coóperacion Urban Services (CUBS) project for JAGUAR-initiative funded by ESA). The Urban Atlas was made available immediately after the crisis. The product proved to be very useful to the emergency decision makers, mainly to rebuild the affected areas (source: personal email correspondence with 'Servicio del Sector Vivienda' from the Chile government.). Following its involvement in the Critical Assets Monitoring Service and its previous mapping experience in Concepción, EUROSENSE was also asked by EUSC to analyze the damage of 2 water treatment plants and 1 oil refinery in the neighborhood of Concepción.

Based on the pre-event analysis during which the main components of these critical assets were identified, the available post-event imagery and the available open source information, vector files and digital maps were produced (see figure). The current risk, damage and impact of the damage were analyzed and all the collected information was summarized in accompanying briefing reports. New relevant information was used to update the report several times after the crisis.

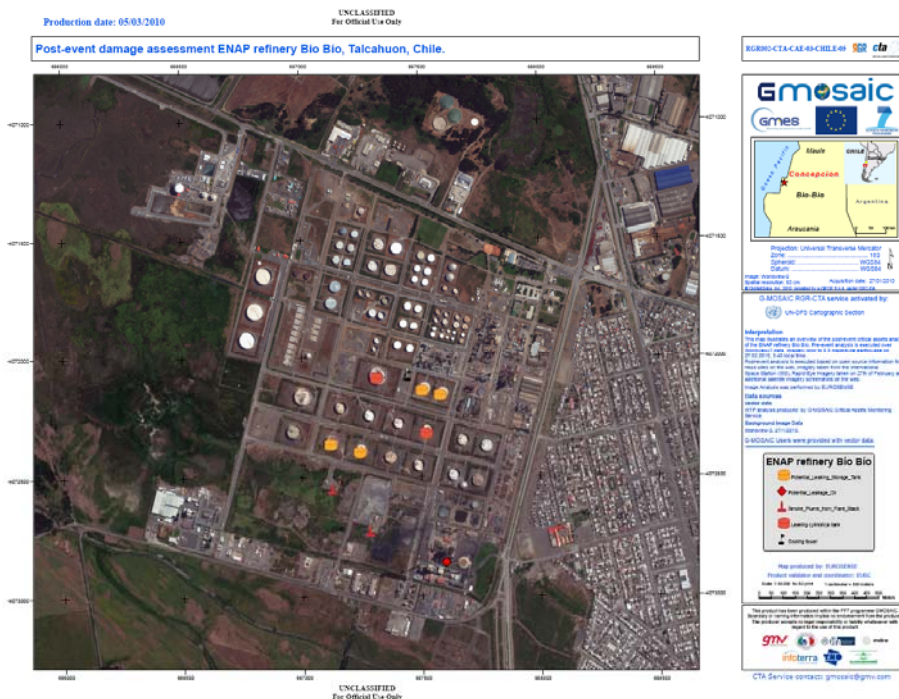


Figure 7: Post-event damage assessment of the ENAP refinery in Talcahuon, Chile. The symbols indicate the potential damage. The satellite in the background is taken before the earthquake: World View-2, 27.01.2010, 50 cm resolution (© DigitalGlobe, Inc.. 2010, provided by e-GEOS SpA under GSC-DA).

5. Conclusions: Geospatial concepts and Tools to support EU security policy

At the level of research, ongoing changes to the map of Europe caused changes to the European security research strategy. A specific geospatial security research strategy is part of the current FP7 (EC Frame Program 7, and related projects). All this contribute to a more coherent definition by the EU of its security interests, of a coherent EU security concept and of instruments to implement such a concept.

This paper claims that geospatial technology and geospatial concepts can help in monitoring European human security. In fact, the cartographic representation and threat scenarios produced by geospatial scientists are requested by decision makers to improve their information. Earth Observation and complementary geospatial technologies that include navigation and geospatial information systems complement the current information flow to decision makers. Researchers have the responsibility to both use geospatial concepts and methods and communicate these concepts and the results of the analysis in a suitable way to decision makers. The use of GIS with its user friendly interface and tools provide information products in the form of maps help in this coordination process.

Several existing links between security policies such as the “Flood directive”, the “Seveso directive” and geospatial analysis have been highlighted in this paper in some particular examples. Evidence-based theories that explain security threats require models and qualitative and quantitative data on their causes. If operational products are developed, number of challenges is still posed to the research community.

6. Acknowledgement

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6. Biography

Nathalie Stephene obtained a degree in Geography followed by a Master degree in Development Studies from the University of Louvain-la-Neuve (UCL), Belgium. In the private I-mage consult company, she had experience in database management and mapping in EU projects. She presented her PhD thesis untitled dynamic simulation model to understand land-use change processes in the Sudano-sahelian region (SALU – Sahelian Land Use) in 2002, supervised by Pr E. Lambin. Laureate of ARSOM in 2000, this foundation published her PhD thesis in 2003. In collaboration with the CEH Wallingford, UK, the integration of SALU results in GCM simulations estimated the impact of these changes on climate. She joined the IGEAT, University of Brussels, on a Belgian Science Policy funded and user-oriented project with very-high-resolution satellite imagery. Engaged at the Joint Research Center, Italy, in 2005 with a post-doctoral position, she has been involved in the JRC institutional research activity related to modelling of EU Border Permeability and EU Neighbourhood Stability. She is currently project manager in EUROSENSE Belfotop, Belgium.