Spatial information for analyzing changing hydro-meteorological risk

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Short abstract: Environmental changes due to global change and resulting reactions in ecosystems, combined with expected changes in socio-economic development will lead to adjustments in land use in areas that are exposed to hydro-meteorological hazards such as flooding, mass movements, severe erosion, snow avalanches and wind storms. These hazards will also have domino effects (e.g. the effect of land-use change on runoff severe erosion and consequent landslides and river damming leading to flooding) that are still not properly understood. The effects of these changes need to be analyzed and modeled with probabilistic hazard and risk methods that can be used by stakeholders from different sectors. The probabilistic models should incorporate the uncertainties in temporal probability, spatial extend and magnitude of the hazards, as well as the uncertainties of the vulnerability of the exposed elements at risk. The modeled changes in hazard and risk patterns need to be incorporated into disaster risks management strategies and will form an important factor in land use planning activities at stakeholder relevant levels. They also have a large impact on risk governance policies that need to be adapted.

This paper gives an overview of work related to the analysis of changes in hydro-meteorological risk in Europe, focusing on analysis of changing hazards, changing exposure of elements at risk, and their vulnerabilities. The structure and workplan of a recent EU FP7 Marie Curie Initial Training Network called 'CHANGES' is presented. This project (Changing Hydro-meteorological Risks – as Analyzed by a New Generation of European Scientists) intends to develop an advanced understanding of how global changes (related to both environmental and climate change as well as socio-economical developments) will affect the temporal and spatial patterns of hydro-meteorological hazards and associated risks in Europe, how these changes can be assessed, modeled and how these can be incorporated in sustainable risk management strategies, focusing on spatial planning, emergency preparedness and risk communication.

Key words: Risk, climate change, hazard, landuse, vulnerability.

Changing hazards

It is evident that Europe undergoes rapid changes in terms of fast population growth, urbanization, economic development and socio- political structures. On top of that, there is convincing evidence that the emission of greenhouse gasses (GHSs) causes changes in the earth's climate that are expected to lead to an increase in hazardous events with a hydro-meteorological trigger. It is the difficulty of the prediction of the magnitude of these changes and the frequency of the occurrence of extreme events that urges a thorough change in our adaptation management of hydro-meteorological risks (EEA, 2004). According to Intergovernmental Panel on Climate Change (IPCC) reports climate change is expected to cause a rise in temperature ranging from 2.5 – 5.4° C in Europe by 2080 depending on the uncertainty associated with the driving forces of global emissions and the sensitivity of climate models to GHG concentration (Christensen *et al.*, 2007). Several studies are available that evaluate the impacts of climate change in Europe (e.g. Beniston *et al.*, 2007; Alcamo *et al.*, 2007). Several EU project have studied the possible impacts of climate change in Europe (e.g. PRUDENCE, DINAS-COAST, NewExt and CASH); according to recent studies at a European level the projected impact of flooding in Europe would increase dramatically in the coming decades. By 2080

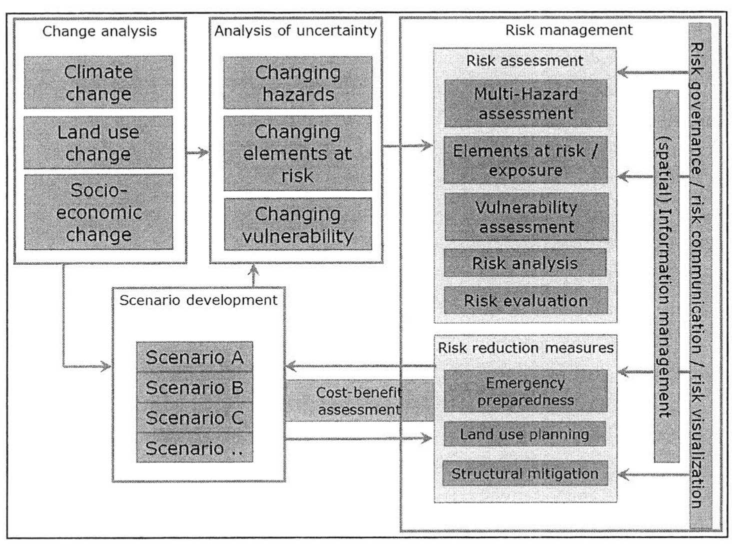

Fig. 1 – Conceptual framework for the analysis of changing hydro-meteorological risk.

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it is estimated that between 250,000 and 400,000 people are affected each year by flooding in Europe, with highest concentration in the British Isles and Central Europe. The total annual expected flood damage in Europe is estimated to range between 7.7 and 15 billion Euros. These values are more than double of those in the period 1961-1990 (Ciscar, 2009). The local effects of flooding have not been taken into account yet, due to the coarse resolution of the model, and there is a need to downscale such models to make them applicable for local risk assessment and management.

For mass movements, such global impact studies have not been carried out so far. Mass movements are one of the major soil threats that are considered within the EU Thematic Strategy for Soil Protection (EC, 2006). The directive indicates that Member States should carry out the identification of risk areas based on empirical evidence or on modeling. However, the focus is more on evaluation of the current situation than on assessing the changes in risk that are likely to occur in the coming decades. Landslide susceptibility studies for some individual countries have been carried out (Malet et al., 2009). Nadim et al. (2006) carried out a general evaluation of landslide susceptibility for the whole of Europe as part of the Global Hotspots study using a scale of 1 x 1 km by combining the triggering factors (precipitation, human activity, seismicity) and susceptibility factors (slope, lithology, soil moisture, vegetation cover) in a qualitative manner. General studies (Beniston & Douglas, 2006) indicate that the number, frequency and intensity of mass movements are likely to change, but the variation in the pattern is not well defined. The impact of climate change on mass movements is being studied in a number of EU research projects (e.g. ClimChAlp in the Alps, SIGMA and GACH2C in France, ESPRC in the UK). So far, the approach to assess the impact of environmental change on landslide risk has been relatively narrow focused on changes in landslide hazard (e.g., van Beek & van Asch, 2004, Dixon & Brook 2007). This distinct weakness can be addressed by including socio-economic change and interactions between climate and land use through scenarios. Very limited work has been carried out up to now to include the cascading or conjoint (also called domino) effects into account in the analysis of future impacts of environmental changes to hydro-meteorological hazards. For instance through changes in vegetation patterns the probability of wild fires may increase leading to more severe run-off, erosion and mass movement problems; also the analysis of landslide dams and consequent dam break flooding is an important topic to be considered.

Changing elements at risk

The exposure of elements at risk also increase and therefore the risk of natural hazards is constantly growing. Land use changes are predicted for Europe as a result of technological, socio-economic and political developments as well as global environmental change. The type and effects of these changes will strongly depend on policy decisions which are governed. The recent EU research project ACCELERATES compared the impact of several scenarios on the prediction of land use changes in Europe in 2050 (Audsley *et al.*, 2006). EEA (2004) concludes that many environmental problems in Europe are caused by rapidly expanding urban areas. By 2020, approximately 80 % of all Europeans will be living in urban areas, while in seven countries the proportion will be 90 % or more. The global economy, cross border transport networks, large scale societal, economic and demographic changes and differences in national planning laws are some of the major drivers of change to the urban environment. Land use changes may have various detrimental effects on the quality of landscape and environment. Studies aiming to predict land use changes are of great use to European policy-makers to anticipate such possible prejudicial effects and to engage adapted actions for their prevention.

Changing vulnerability

The vulnerability to hydro-meteorological hazards of the exposed elements has different components (Birkmann, 2006), including the systems or the community's physical (structural), economic, social and environmental susceptibility to damage. Studies on vulnerability related to environmental change indicate that these have a very high level of uncertainty. Whereas flood vulnerability has been defined in a rather detailed manner (Moel *et al.*, 2009) there are still many uncertainties involved. For mass movement there is much less work done on defining vulnerability (Glade, 2003), partly due to the large variation in physical mass movement processes, the difficulty in expressing landslide intensity versus the degree of damage, and also related to the purely non existence of data. Some approaches exist for single elements (e.g Fuchs *et al.* 2007), but an integrated methodology is still lacking.

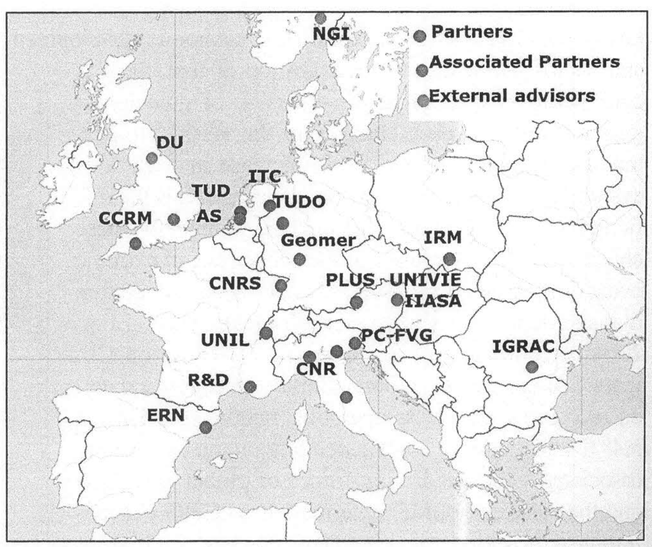

Fig. 2 – Overview of partners in the CHANGES project.

Uncertainty and risk assessment

As the level of uncertainty of the components used in the risk equation (hazard, vulnerability, quantification of the exposed elements at risk) is very high, the analysis of the changes in future risk should incorporate these uncertainties in a probabilistic manner. Methods for probabilistic risk assessment for flooding have been developed (e.g. Moel *et al.*, 2009). The European Parliament adopted a new Flood Directive (2007/60/EC) with the objective to establish a framework for the assessment and management of flood risk in Europe, emphasizing both the frequency and magnitude of a flood as well as its consequences (Lavalle *et al.*, 2005). However, such methodologies should be downscaled for practical use in risk management at local levels. Impacts of natural hazards on the Environment and on the Society are still tackled by mono-disciplinary approaches. The focus is reflected in the domains of scientific research (single approach and tools for each type of threat), in the existing management tools and in the legislative basis of these activities. Management tools, models, and local-to-regional technical solutions have been proposed by numerous projects for single hazards. However only a few of them have tackled the issue of risk assessment and management in a multi-hazard perspective, including possible combined and domino effects. Probabilistic tools for multi-hazard risk assessment are not available to stakeholders at the local level. Insurance companies and specialized risk assessment consultants have developed models but these are not open for public use. Internationally, several initiatives for multi-hazard risk assessment platforms exist, such as HAZUS-MH (FEMA, 2009) and CAPRA (World Bank, 2009). HAZUS-MH is a powerful risk assessment methodology for analyzing potential losses from floods, hurricane winds and earthquakes. CAPRA is a system which utilizes state-of the-art technology in Geographic Information Systems, Web-GIS and catastrophe models, used to generate an open platform for disaster risk assessment. The CHANGES network will further built on these experiences and adapt such an open system for probabilistic risk assessment for hydro-meteorological hazards that can be used by stakeholders at a regional and local level.

Changing risk management

The European Commission has identified the need for adaptations in risk management as a consequence to climate and environmental changes in several documents (e.g. EC 2009). The implementation of risk management measures such as disaster preparedness programmes, land-use planning, regulatory zoning and early warning systems are considered essential. Fleischauer *et al.* (2006) conclude that spatial planning is only one of many aspects in risk management and that it is, in general, not involved in risk assessment. Further, multi-risk assessment approaches are not used in planning practice: risk indicators are hardly used and vulnerability indicators are not at all used. Therefore integrated approaches are needed for integrating spatial planning in disaster risk management. Additionally, scientific advances in hazard and risk assessment and demands of stakeholders/end-users are still not well connected. In many cases, the scientific outcomes remain rooted solely within the scientific community or new knowledge is not fabricated enough to be implemented by stakeholders and end-users (IRGC, 2005). A key cause of the gap between the science community and stakeholders/end-users is in the complexity of human-environment interactions. This has led to the development of a diversity of approaches, often not easy to implement by the end-user community. The CHANGES network recognizes the shared responsibilities of all stakeholders for which shared knowledge is the key element. Therefore, the network aims at a transparency by putting communication via visualization of the whole risk management cycle and scenarios central. There is a need for the development of a harmonised decision-making tool structure for applying hazard and risk mitigation through spatial planning in risk prone areas and development of a guideline on natural hazard mitigation in the context of the EU Environmental Assessment Directive.

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