Sustainability aspects of flood risk management - interrelations and challenges

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ABSTRACT: Aspects of sustainable development are crucial for Flood Risk Management (FRM). These aspects are relevant for the flood risk analysis, risk evaluation and risk-reduction. Two case studies are used to identify potential conflicts between different values: Lake Vänern and Göta älv River in Sweden and Elbe River in Germany. In both cases there are diverging interests of how to manage the systems, e.g. how to regulate water levels and use floodplains. The conclusion is that the relevant sustainability aspects must be identified, addressed and valued in the risk management process, especially for different risk-reducing measure options.

Keywords: flood risk management, sustainability, Lake Vänern, Elbe River

1. INTRODUCTION

Sustainable development is an overarching vision in many societies. One of the most pronounced characteristics for a sustainable development is the acknowledgement of social and ecologic dimensions of the development, as well as the economic dimension, which gives a broad perspective, including humans, the nature and the society. Another fundamental aspect is the generation perspective, which recognizes future generation's rights to resources to meet their needs.

Water is a key element for sustainable development. It plays an important role for living, health, ecosystems, industry and many other fields. Water-influenced habitats such as wetlands and flood-prone areas are of high ecological value and waterscapes – landscape where water habitats dominate – are important for ecosystem services such as drinking water supply and quality, tourism, flood protection, etc. Water is important as a resource also for urban areas, but urban floods could be devastating.

Also for Flood Risk Management (FRM), the sustainability aspects are crucial. These aspects are relevant for flood risks, including hazards and vulnerabilities. Another important feature of flood risk management is to integrate ecological, economical and social aspects on prevention and mitigation measures. Efforts to protect people's lives and societal infrastructures could potentially be in conflict with the protection of ecosystems or cause conflicts in upstream/downstream socio-economic relations. A special feature of floods, and other natural hazards such as landslides, is that they are important for biodiversity especially in many water and riparian ecosystems, at the same time as they can cause environmental problems due to e.g. release of pollutants (Geertsema and Pojar, 2007; Andersson-Sköld *et al.*, 2008). Natural structures, e.g. wetlands, can also have an exacerbating effect that could prevent or mitigate floods (Srinivas and Nakagawa, 2008). A framework of sustainability is needed to support a wider perspective on flood risk management.

The different components included in FRM have been described by e.g. Schanze (2006): risk analysis (determination of hazards and vulnerability), risk assessment (perception and weighing) and risk-reducing measures (before, during and after events). If a FRM plan is to be produced for a single object, the components are normally processed in a sequence. There are however feedback loops, for example from measures back to vulnerabilities since FRM measures can give unwanted social or ecological effects.

With the EU Flood directive (2007) a shift of paradigm from flood protection towards preventive and sustainable flood risk management can be recognised. It refers to a sustainable development at several places, for instance in the introductory motives: "*This Directive… …seeks to promote the integration into Community policies of a high level of environmental protection in accordance with the principle of sustainable development…*", or in chapter IV, article 7:

“*Flood risk management plans shall address all aspects of flood risk management focusing on prevention, protection, preparedness… …Flood risk management plans may also include the promotion of sustainable land use practices, improvement of water retention as well as the controlled flooding of certain areas in the case of a flood event.*”

2. FLOOD RISK MANAGEMENT AND SUSTAINABILITY

2.1 Hazards

Flood hazards are both a picture of precipitation and runoff, and of land use practices. Variation in precipitation patterns is mainly a natural phenomenon but is also affected by climate change. All of the work related to emission reductions of greenhouse gases does affect flood hazards, especially long-term. IPCC (2007) has predicted more intense precipitation, as one example. Changed relations between rain and snow precipitation, and consequent effects on runoff patterns, are other examples from the climate scenarios. Runoff is also affected by land use, for example in agriculture and forestry, but especially in urban environments. All of these factors influencing precipitation and runoff are related to sustainability aspects in urban and land use planning.

Flood hazards are also strongly related to water regulation. Water can be regulated for several reasons, but in the Northern parts of Europe the main reason is for hydropower production. Another reason to establish dams or is for reduction of flood risks. Regardless of the reason for establishment of dams, there is a strong influence on the runoff and flood risks. Normally, dams decrease peak flows, but there are situations where it could be the opposite, and there is always a risk of dam breaks. Establishment of dams has a negative influence on aquatic ecosystems but if the purpose is hydropower production, that energy is often regarded as more sustainable than from many other energy sources.

2.2 Vulnerability

The modern society has become more vulnerable to natural hazards, due to globalisation, urbanisation, and dependence upon technical systems (Kundzewicz, 2002). International statements, like the Hyogo Framework for Action (ISDR, 2005), point out the necessity to integrate natural risk management into the framework of sustainable development. Vogel and O’Brien (2004) described vulnerabilities as multi-dimensional, scale-dependent and dynamical. The vulnerability can be described in terms of economical, ecological and social vulnerabilities or potential damages. Birkmann (2006) has proposed a model how to integrate the three dimensions into a framework also considering hazards and risk-reduction. One important aspect is the potential for to move vulnerabilities from one sustainability domain to the others. This could also be described as conflicting values, depending on which values to be protected.

2.3 Risk evaluation

One important component of risk evaluation is the weighing of different vulnerabilities or risks. Multi-criteria analysis is one possible approach, where different values are combined into a joint analysis. Meyer *et al*. (2009) used this method for a river in Germany. Social, ecological and economic values were mapped and the total risk was estimated by weighing these three dimensions using a GIS. A sensitivity analysis was made for the used weights. This kind of methods needs a decision-maker (expert, politician, etc) to appoint the weights. The evaluation and the weighing is a normative process which is highly influenced by the risk perception of the decision-makers.

2.4 Risk-reducing measures

Not only flooding but also risk-reducing measures may cause negative impacts, and goal conflicts may be generated. For a sustainable development it is of great importance to assess also the effects of potential measures. A decision-support matrix system has been developed and applied for assessments of different flood risk-reducing options (Andersson-Sköld *et al.*, 2010). The system is designed to incorporate sustainability in a simple manner in a decision-making or planning process. It includes health, environmental, societal and economic aspects and a short and long term perspective. The categories included are global warming (release of greenhouse gases, land use or land-changes that contributes to the global warming), regional and local scale air quality, water quality (drinking water quality, biodiversity, ecosystem, fisheries, marine and limnological properties worthy of protection, eutrophication through leaching), soil quality, land use as a resource, energy consumption, raw material acquisition, well-being/perceived welfare, direct costs (costs for possible risks and cost for measures), socio-economic aspects (infrastructure, cultural, accessibility, business activity, jobs, recreation) and flexibility (how flexible and adaptive measures are for possible changed circumstances) in short and long term. The steps included are based on a classic risk-and vulnerability analysis, i.e. from risk identification to a valuation of measures including risk perception and acceptance versus need of measures. The use of the tool relies on the participation of experts and by decision-makers in an iterative process. The benefit of the matrix process, in addition to a comprehensive assessment of a complex system, is the early thinking and documentation that facilitates identification of where background material are missing, where there are further needs of data to be able to assess and evaluate different aspects.

Kundzewicz (2002) discussed the relation between flood risk management and sustainability. He argues that non-structural measures (~ non-technical) are more sustainable since they to a larger degree are reversible and accepted and cause less impact on ecosystems. The non-structural measures are e.g. legislation, economic instruments, warning-systems and awareness-raising.

The following case study description will illustrate certain aspects of the discussed elements hazard, vulnerability, risk assessments and risk-reducing measures.

3. CASE STUDIES

3.1 Lake Vänern and Göta älv River, Sweden

The system of Lake Vänern and the Göta älv River in SW Sweden was used to analyze different types of opposing interests. Lake Vänern with its area of 5,500 km^2 is the largest lake in Sweden and in the European Union. The Göta älv River runs from the lake outlet 90 km down to the sea at Gothenburg. The total catchment area upstream of the river mouth is 51,000 km^2. Vänern and Göta älv are used for hydropower production, shipping, tourism, fishing, drinking water supply, as waste water recipient, etc. The risk system is complex where flood risks in the lake and in Gothenburg are connected to landslide risks and industrial risks in the river valley, and where the drinking water supply for the Gothenburg region is at stake. This study is focused on differing interests in relation to floods in Lake Vänern: Firstly, the interest to keep a low and steady water level in the lake to reduce flood risks, in relation to nature conservation interest which advocates large water level amplitudes to maintain the natural variations from the unregulated period before 1937. Secondly, the upstream/downstream risk distribution between flood risks around the lake and a downstream system of landslide risks, industrial risks and water quality risks in the river and in Gothenburg, where most of the economic and social values are located. The landslide risks along the river valley are closely related to wet periods and erosion due to high discharge from the lake. Therefore a maximum discharge is decided which, however, increase the flood risks in the lake. Climate scenarios for the 21^{st} century describe substantially increased flood risks for Lake Vänern due to increased amounts of precipitation. The steady sea-level rise cause gradually increasing problems to discharge enough water through Göta älv without causing regular flood problems in the lower part of the river valley and in Gothenburg. One proposed measure to reduce the lake flood risks is to secure the slide-prone areas in the river valley with technical constructions. Another proposed measure, to increase the discharge capacity from the lake, is to construct a tunnel from Lake Vänern directly to the sea (ca 30 km). The flow capacity of the tunnel needs to be ca. 400 m^3/s. The tunnel would have a positive flood-reducing effect but would also most likely have a negative effect on the marine environment in the coastal area. Non-structural measures such as changed urban planning or land use around the lake are also discussed.

3.2 Elbe river, Germany

The second case study is the UNESCO-Biosphere reserve of the Elbe River landscape in Germany. Biosphere reserves serve as model region for sustainable regional development in a worldwide network. The Elbe river reserve is characterized by a riverine and floodplain ecosystem typical for Central Europe. The status as a recognised biosphere reserve is based on the area's singularity, quality and high potential for development as a model region for illustrating aspects of conservation and sustainable development. The UNESCO Biosphere Reserve has an area of around 3,430 km^2 stretching for 400 km on both banks of the Elbe. Characteristic for this area are the biotopes rich in contrasts from aquatic, to wet to very dry (dunes) which is typical for river valleys. Sustainable agricultural land-use plays a vital role in the conservation of this unique environment. Main parts of the floodplain in the biosphere reserve are regularly flooded pastures and meadows which carry nutrients and pollutants. The original floodplain of the middle part of Elbe was reduced by 77 % due to dike constructions (IKSE, 1995). The region faced major floods in 1981, 1988, 2002, 2003 and 2006. The flood in 2002 caused an economic damage of 11,6 Billion € (MunichRe, 2007) of which less than 20% were insured. Important infrastructure was affected, such as train stations, railways and bridges. 38 people died. There were several reasons for this high social and economic damage such as bad conditions of technical measures, flash floods with very high velocity, exposition of infrastructure and developed areas in flood prone areas or even in former river courses such as the railway station in Dresden.

After the 2002 flood a national fund of around 10 Billion € was established which was mainly used for reparation of infrastructure, and building new technical flood protection measures such as dikes. The Land of Lower Saxony developed a flood protection plan where only technical measures were foreseen. There were also vital discussions about the impact of vegetation on the rising of the water level. Some water managers claimed that the changes of the floodplain towards more trees and bushes during the years increased the roughness and therefore the water level in this stretch of the river. An ongoing dispute started on how to develop the land use of floodplains which are the core protected part of the biosphere reserve. The flood risk management plan includes mainly technical measures which are in contrast to goals from ecological perspectives such as revitalization of the floodplain and natural vegetation development. There were very little communication between authorities for water managers and nature protection. The focus for planning was technical definitions for safety levels (such as 100-years flood) and no approach of risk communication was tried.

4. DISCUSSION

The described case studies pointed out the possible differences and varying priorities of sustainable development and flood risk management. There are different philosophies; one is flood protection which focuses on the societal aspects of saving lives and economic aspects of avoiding damages. The other is the model of sustainable development where a broad set of aspects and elements have to be considered such as ecology, economy, health and other social aspects.

Inclusion of ecological aspects in a comprehensive flood risk management approach is crucial but often not (yet) realized in traditional flood risk management. Conflicting societal objectives for floodplain land-use show the need for integrative approaches. Regarding social aspects, saving lives is a very important factor. At the same time there are also negative social aspects of flood protection measures. One example is barrier effects for people in daily life using the waterscape for recreation, tourism etc. From a psychological point of view (physical) barriers such as dams and walls could decrease the contact and influence the relation to water, environment and floods.

Therefore a cross-sectoral and integrated management is needed in order to identify the mosaic of different risks and to develop strategies and adaptive measures, to support important aspects of sustainable development. One appropriate approach to meet this goal is the application of a decision-support matrix system for assessments of different measures for flood-risk reduction. Increased use of non-structural measures could enhance the sustainability in FRM. Participation of experts and decision-makers in an iterative communication process is needed to identify, address and value the different aspects of sustainability. If the full set of sustainability aspects are addressed in the long-term decision-making regarding flood risks, the generation perspective of sustainable development could be satisfied.

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