SYSTEM RISK ETN

Policy Brief

Improving flood risk assessment and management through a systems perspective

Dynamic change, incomplete knowledge and uncertainty in decision-making are among the key challenges of flood risk management.

A systems perspective incorporates the interests of all stakeholders and enables more robust decision-making by taking dynamic change and human behaviour into account. Research from the European Training Network System-Risk shows how advanced approaches and methods for flood risk management allow for a more comprehensive understanding of risk.

KEY MESSAGES

- Considering the diverse drivers of floods creates a more comprehensive understanding of flood risk.
- Understanding and quantifying human behaviour can help to better manage flood risk.
- A new decision support framework allows the quantification of the redistribution of risk across flood-protected areas and enhances decision-making.

This policy brief was compiled by adelphi based on the research work done by the Early Stage Researchers within the context of the European Training Network System-Risk with special contributions by Bruno Merz, Kai Schröter (GFZ German Research Centre for Geosciences), Attilio Castellarin (University of Bologna), Karin de Bruijn (Deltares) and Sally Priest (Middlesex University).

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Introduction

Why have flood risks and related impacts intensified in recent decades? Despite the development of more advanced flood risk management plans, river floods continue to cause major damage all over Europe. Methods for the identification and quantification of the underlying causal mechanisms require further development and improvement, and management strategies require additional refinement. The aggravating climate crisis is likely to increase the number and severity of floods in many regions, making this a pressing issue and adding uncertainties to long-term planning. The dynamic nature of flood risk needs to be recognised, given that the drivers change over time with distinct spatial characteristics, particularly on the large scale.

Adopting a "systems perspective" can help better understand the underlying mechanisms of flood risk. It can therefore create improved management options for flood risk managers. How so? The Marie-Skłodowska-Curie European Training Network "System-Risk" funded 15 doctoral research projects related to "A systems approach to large-scale flood risk assessment and management". One avenue to adopting a systems perspective is to consider the entire flood risk chain and to broaden the selection of included "drivers". Holistically, analysing the drivers of a flood, its space-time dynamics and the diverse impacts on natural and social systems allows for the development of integrated solutions for flood risk management. This requires an improved understanding of the interactions and feedbacks in flood risk systems and a novel consideration of floods and flood impacts.

Policy-makers and flood risk managers are expected to benefit from the adoption of a system perspective, as they are likely to have a more complete understanding of the drivers and dynamics of river floods and are able to include these into flood risk assessment and management.

Adopting a systems perspective: enhancing fluvial flood risk mitigation

Considering the diverse drivers of floods creates a more comprehensive understanding of flood risk

Just as floods and society are dynamic, so is flood risk. It changes over time and is responsive to multiple drivers. Risk assessment and management needs to take this into account, so that flood managers can come up with appropriate risk mitigation strategies. However, the flood risk models in use today often only take into account a few flood drivers, which limits their ability to factor in interactions and feedbacks among these drivers, making them prone to biases. The occurrence of floods and severity of impacts has a number of influencing factors, including, for instance, climatic (e.g. increasing rainfall), human (e.g. land-use change), or river channel processes (e.g. levee construction). Including additional drivers into flood risk assessment therefore helps to gain a better understanding of risk. Two questions are of interest in this context: How does each risk driver contribute to changes in flood risk? How do they interact with each other and change flood risk?

The System-Risk project demonstrated that it is possible to attribute flood changes to drivers by analysing past changes. This is the result of a newly developed, data-based framework for the analysis of long-term records of flood data. The exemplary application to Upper Austria linked the increase of floods to more intense rainfall over the past 50 years (1)[1]. Another approach uses a simulation model of the flood risk chain to examine the sensitivity of flood risk to changes in

[1] With this number, you can find further information about the developed approaches on the last page of the briefing.

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risk drivers. The example application to the Mulde catchment in Germany shows that changes in levee systems or vulnerability could outweigh changes in climate (2).
The application of these frameworks:

- Provides a more complete view to flood risk,
- Helps to prioritise and make robust decisions for long-term investments in risk mitigation measures.

Understanding and quantifying human behaviour can help to better manage flood risk

There is a need to better understand the role of humans in relation to floods. How much damage a flood causes depends strongly on the behaviour of the at-risk population. Flood-aware communities are often inclined to implement structural protection schemes, but paradoxically, effective protection from floods can ultimately lead to even higher levels of damage. How? Before building a levee, few people or industries settle close to the riverbed, due to the frequent occurrence of floods. The "levee effect" encourages building, due to the false perception that the area is safe. If an extreme flood event occurs (exceeding the levee's design level), far more goods are at risk and the damage is much higher. By contrast, a high level of flood risk awareness among the population (e.g. due to frequent flooding), may increase the willingness to take precautionary measures in order to mitigate the impact of floods. The System-Risk project provides a better understanding of such feedbacks through the development of a socio-hydrological flood model (3). It represents feedbacks within the human-flood system, by quantifying the populations' "forgetfulness". The results of a case study of the Elbe River in Dresden, Germany, show that the experience of flood events positively influences the consciousness of flood risk and leads to an uptake in precautionary measures.
At the societal level, the implementation of flood risk management strategies involves numerous sectors with diverse interests and responsibilities divided between many actors. Improving the levels of integration in flood risk management across sectors and between spatial levels can take advantage of synergies and/or create additional opportunities. The System-Risk project proposes a framework for assessing the degree of integration of flood risk management and applies it to the cases of England (4) and Serbia. This identified England as having an intermediate degree of integration. What does this mean? The actors are characterised by strong relationships between key actors (bonding). However, there is still scope to improve the relationships among sector-specific actors (bridging) and across levels (linking). Such findings help identify suitable entry points for the introduction of integrated and participatory flood risk management and thereby improve management and planning practice.
These findings point out that adopting a systems perspective has large potential to reduce flood impacts. To give examples, this potential can be harnessed through:

- Informing awareness-raising campaigns to stimulate actions for private precaution by using insights into human behaviour,
- Analysing levels of integration and targeting entry points for the improvement of flood risk management practice.

A new decision support framework allows the quantification of the redistribution of risk across flood-protected areas and enhances decision-making

The EU Floods Directive requires the provision of risk maps and risk management plans. These plans need to devise risk reduction strategies and specific measures, and have to be drafted despite knowledge of flood risk is incomplete. Adopting a systems perspective paves the way to holistically assessing individual policies, individual policies and risk reduction measures at large scales and in trans-boundary contexts. Upstream-downstream conflicts may arise from local flood protection measures. If during a flood the water level rises and causes flooding in one area, large amounts of water are stored in the hinterlands, lowering the likelihood of flooding downstream. Conversely, embanked rivers channelize

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streamflow, move high water levels downstream, and increase the likelihood of flooding downstream. This redistribution of flood risk only becomes visible if larger regions are considered. This is why System-Risk developed a framework for flood risk assessment, which considers the mentioned effects of system behaviour (5). This decision support framework is widely applicable for any embanked river system. Policy-makers and flood risk managers may benefit from this, as it permits the:

- Quantification of the redistribution of risk due to levees and the discovery of interactions and conflicts among riverine communities,
- Assessment of the robustness of flood risk management strategies through the consideration of levee breaches and the associated uncertainty,
- Assessment of the risk management strategies based on both the equity of distributed risk and risk reduction performance.

Contributions of System-Risk

System-Risk provided new approaches and methods for adopting a systems perspective in flood risk assessment and management. They allow:

- The comprehensive consideration of flood risk drivers to gain a better understanding of flood risk,
- The understanding and factoring in of human behaviour,
- The targeting of entry points to improve the integration of actors in risk management practice,
- The quantification of risk redistribution on a large scale and the assessment of flood risk management strategies both in terms of risk reduction and equity in risk distribution.

Policy-makers and flood risk managers can profit from the System-Risk perspective, as it provides approaches and methods that offer a more comprehensive view to flood risk, reveal the relevant interactions, and quantify feedbacks in flood risk systems. This deepened understanding of risk enables the improved management of flood risk.

Related links:

(1) Bertola, M., Viglione, A. and Blöschl, G.: *Informed attribution of flood changes to decadal variation of atmospheric, catchment and river drivers in Upper Austria*, Journal of Hydrology, 577, 123919, doi:10.1016/j.jhydrol.2019.123919, 2019

(2) Metin, A. D., Dung, N. V., Schröter, K., Guse, B., Apel, H., Kreibich, H., Vorogushyn, S. and Merz, B.: *How do changes along the risk chain affect flood risk*?, Natural Hazards and Earth System Sciences, 18(11), 3089–3108, doi:https://doi.org/10.5194/nhess-18-3089-2018, 2018.

(3) Barendrecht, M. H., Viglione, A., Kreibich, H., Merz, B., Vorogushyn, S. and Blöschl, G.: *The Value of Empirical Data for Estimating the Parameters of a Sociohydrological Flood Risk Model*, Water Resources Research, 55(2), 1312–1336, doi:10.1029/2018WR024128, 2019. & Barendrecht, M. H., Viglione, A. and Blöschl, G.: A dynamic framework for flood risk, Water Security, 1, 3–11, doi:10.1016/j.wasec.2017.02.001, 2017.

(4) Cumiskey, L., Priest, S., Klijn, F. and Juntti, M.: *A framework to assess integration in flood risk management: implications for governance, policy, and practice*, Ecology and Society, 24(4), doi: 10.5751/ES-11298-240417, 2019.

(5) Ciullo, A., de Bruijn, K. M., Kwakkel, J. H. and Klijn, F.: *Accounting for the uncertain effects of hydraulic interactions in optimising embankments heights: Proof of principle for the IJssel River*, Journal of Flood Risk Management, 0(0), e12532, doi:10.1111/jfr3.12532, 2019.

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