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POLICY BRIEF

Probabilistic Approaches for Improved Flood Risk Assessment and Management under consideration of uncertainties

KEY MESSAGES

- One of the challenges faced by Member States in implementing the Floods Directive is how to factor in uncertainties in flood hazard and flood risk assessments within flood risk management strategies. Tools are needed to support decision-making on appropriate flood measures under consideration of uncertainties.

- Probabilistic methods quantify and visualize uncertainties by providing results as a set of potential values with their corresponding probability of occurrence. The research project IMPREX shows how the implementation of the Floods Directive could benefit from the use of probabilistic approaches in calculations on flood occurrence and flood damage:

  - Probabilistic flood occurrence projections could improve flood hazard maps depicting uncertainties of potential flood scenarios, including climate change impacts

  - Probabilistic flood damage assessments foster a more realistic understanding of potential flood risks and can help identify more efficient risk management measures

  - Probabilistic approaches can improve early warning by extending lead times for water level and river discharge forecasts

  - Probabilistic approaches can bolster more rational decision-making, e.g. in the context of drawing-up flood risk management plans, by factoring in all the possible hazards and risks

→ The potential that probabilistic approaches have with regard to the implementation of the Flood Directive should be explored systematically, e.g. for the development of flood hazard maps, economic damage assessments, and establishing programmes of measures. Research and development of probabilistic approaches ought to be supported.

→ Guidance on the potential of probabilistic approaches and how to include them in the various implementation steps of the Floods Directive should be provided, e.g. through CIS Guidance Documents.

→ Capacity building to support the use of probabilistic approaches should be offered at river basin district level or management unit level. Knowledge exchange across EU Member States should be facilitated.

INTRODUCTION

For decades, floods have been causing tremendous damage across Europe. Better flood forecasts and flood scenarios are needed to improve flood risk management and mitigate the future impact of floods. For years, Europe has been working on improving flood management. The introduction of the Floods Directive has obligated Member States to set up flood hazard and risk maps as well as management plans that will aid flood prevention, protection and preparedness and will serve as a basis for a uniform European approach.

One challenge in implementing the Floods Directive, and flood risk management in general, is the uncertainties associated with flood scenarios and forecasts, which in turn result from uncertainties related to models, the underlying driving forces and the potential effect of climate change. While it is crucial to reduce uncertainties e.g. through improved modelling, forecasting and scenario development will always include inherent uncertainties. It is therefore important to learn how to deal with uncertainties in flood risk management.

Currently, most flood forecasts and scenarios developed in the field of flood hazard and risk assessments make use of deterministic approaches which only provide very limited information on the uncertainty of predicted values. Decisions in flood risk management, e.g. on potential flood measures, therefore tend to not sufficiently reflect the full bandwidth of possible inundation scenarios or potential damage.

The research project IMPREX has explored probabilistic approaches in different fields of water management including the water transport sector, flood damage assessments as well as drought risk management. This approach was also found to offers great potential for improved flood hazard and risk assessments and, consequently, flood risk management, supporting the implementation of the Floods Directive in Member States.

ADVANTAGES OF PROBABILISTIC APPROACHES

Probabilistic approaches visualize and quantify uncertainties

Probabilistic approaches display predictions as a bandwidth of possible values supplemented by the possibility of occurrence of each possible value. This is achieved by calculating distributions instead of fixed values. In comparison, deterministic approaches provide predictions as single static mean values alongside a safety factor, without providing any information on how likely different deviations from the mean actually are. This not only potentially creates a false sense of security in the predicted value but also deprives decision-makers of important information.

Probabilistic flood occurrence projections could improve flood hazard maps depicting uncertainties in potential flood scenarios, including climate change impacts

The Floods Directive requires Member States to compile flood hazard assessments in the form of flood hazard maps for flood scenarios with low, medium and high probability. The review of the Floods Directive has shown that in some Member States uncertainties in flood scenarios are already presented in flood hazard maps as a deviation from the hazard line. However, the likelihood of this deviation is not yet represented. The use of probabilistic approaches for flood hazard maps could add important information by presenting the likelihood of different inundation scenarios. Furthermore, by incorporating different climate projections into hydrological models, the uncertainty of long-term river discharge scenarios was shown in IMPREX allowing for a probabilistic hazard assessment approach. Applying this approach in the context of flood scenario development could help represent future climatic developments in flood hazard assessments and helps keep the focus on the most relevant, rather than on the most likely scenarios. This could support Member States with decision-making over suitable long-term flood prevention measures under consideration of the full bandwidth of potential hazard scenarios.

Probabilistic flood damage assessments foster a more realistic understanding of potential flood risks and can help identify more efficient risk management measures

A realistic assessment of flood risks provides the basis for the implementation of efficient measures. The Floods Directive therefore requires the development of flood risk maps. In various Member States the qualitative approach of flood risk maps are complemented by quantitative, e.g. economic, flood damage assessments. These approaches remain, however, inconsistent. IMPREX has shown that probabilistic flood damage models can present the probability of potential economic flood damage for different inundation scenarios, which helps create awareness of the full range of possible damage. The approach developed is based on models that employ Random Forest methods as well as Bayesian networks and are fed with damage data from various floods in Germany and the Netherlands. This approach was developed on the micro- (house) scale and was up-scaled to a meso- (community) scale in order to make it applicable to all of Europe. While on a local level, detailed building information serves as the input data, on a meso-scale, open-source data are sufficient for the purpose of applying the model. This approach also reduces uncertainty by using more predictor variables such as inundation duration and building characteristics in comparison with depth-damage functions. By providing the model as well as proxy data for all of Europe, the approach can be applied directly in the context of flood risk assessment across Europe.

Probabilistic approaches can improve early warning by extending lead times for water level and discharge forecasts

The Floods Directive requires Member States to improve early warning in order to assure that the necessary preparations can be made in the event of an imminent flood. One challenge faced by Member States is that short to medium term forecasts of river flow or water level become more uncertain with increasing lead times due to the large uncertainties associated with hydrological forecasting. Due to the chaotic-deterministic behaviour of the atmosphere, one of the largest sources of uncertainty in flood forecasting is the future development of the weather. Deterministic forecasts that do not take uncertainties into account are only to be used for short lead times in flood forecasting as they represent only one possibility for the future development of the variable of interest. To extend the lead times of forecasts, we have no option but to quantify the uncertainty. Probabilistic forecasts can improve early warning by providing information on the uncertainty of the forecast of future flows and water levels. Even though the uncertainty of forecasts increases with increasing lead times, they are still an important early warning tool that gives decision-makers useful information, enabling them to prepare for possible flood situations. IMPREX has shown that probabilistic approaches can deliver useful forecasts for large river basins with lead times of up to 10 days for improved transport cost planning in inland waterway transport. This approach could potentially be transferred to applications in flood risk management.

Probabilistic approaches can bolster more rational decision-making, e.g. in the context of drawing-up flood risk management plans, by factoring in all the possible hazards and risks

The Floods Directive requires Member States to draw up flood risk management plans based on flood hazard and risk assessments. Due to the predominant use of deterministic approaches, the extent to which uncertainties are reflected in decisions e.g. on matters such as appropriate flood prevention and protection measures is currently somewhat limited. By using probabilistic approaches, the full bandwidth of potential flood hazards or risks, including their probability, can be derived; helping Member States put more efficient programmes of measures in place with respect to compliance with the Floods Directive. While a proper risk-based decision-making process would require a combination of probabilistic hazard and risk assessments to thoroughly reflect the entire bandwidth of possible flood risks, applying a probabilistic approach in either flood hazard or risk assessments is an important step in the direction of more rational decision-making in the definition of suitable flood measures.

CONCLUSION

In sum, probabilistic approaches have great potential to support flood risk and hazard assessments and can help Member States develop efficient flood risk management plans within the framework of the Floods Directive and prepare for imminent floods in time. IMPREX has showcased some of the possible applications and advantages of probabilistic approaches. The following recommendations can be derived from the work carried out as part of the IMPREX project:

- **The potential of probabilistic approaches for the implementation of the Floods Directive should be explored systematically in all implementation steps, from flood occurrence, hazard, and damage and risk assessments to the development of efficient flood risk management plans. This will require additional research into probabilistic approaches as well as into optimal incorporation of such approaches into the management process. To facilitate this, close cooperation with research institutes is needed alongside increased support for further research in this area.**

- **The CIS Working Group on Floods might consider addressing and promoting the use of probabilistic approaches in CIS Guidance Documents for the Floods Directive**

- **The use of probabilistic approaches as a basis for decision-making is not straightforward. It is therefore important to build up capacities for decision-making under uncertainty at management unit or river basin district level. In addition, dedicated knowledge exchange between Member States is to be encouraged and fostered.**

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IMPREX is designed to help reduce Europe's vulnerability to hydrological extremes by achieving a better understanding of the intensity and frequency of potential disrupting events. Enhancing our forecasting capability will increase the resilience of European society as a whole, while reducing costs for strategic sectors and regions at the same time. The research project brings together 23 partners from 9 countries and has received funding from the European Union's Horizon 2020 Research and Innovation Programme.

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