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Event tree analysis for flood protection—An exploratory study in Finland

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ABSTRACT

Decision-making for the purpose of adaptation to climate change typically involves several stakeholders, regions and sectors, as well as multiple objectives related to the use of resources and benefits. In the case of adapting to extreme events, modelling of the impact pathways and consequences need to be conducted in some way. We explore the role of event tree analysis of extreme events in the context of flood protection of critical infrastructure. Experts representing potentially affected infrastructure services are consulted on the usability of the ETA method for providing structured information on flood scenarios, system impacts and consequences, risks and counter measures. The main users of the analysis results are the asset owners and the local public decision-makers whose joint efforts are usually required to fund and prioritize such measures of adaptation.

1. Introduction

In Finland, the most general floods are spring floods when the snow melts rapidly because of rain and warm spring days. The phenomenon occurs mainly in western coastal areas where there are several rivers without any larger lakes which could balance the runoff [1]. Extreme weather conditions, such as heat wave or heavy precipitation, might strengthen the phenomenon.

Even though spring floods are a frequently occurring event in various river systems (e.g., downstream the Kemijoki river) the damage of these floods is usually quite limited due to the very low population densities in the concerned areas. Also, the combination of land uplift and the absence of tides prevent storm surge in coastal areas from getting a significant issue. As a consequence river flood control received fairly little attention in the past decades, with the exception of Pori. Pori is the only larger urban settlement in Finland with significant river flooding risks. Climate change is, however, changing this view as the sea level rises more quickly than the land uplift phenomenon takes place [2].

Our case study relates to the coastal city, Pori, through which the Kokemäki river runs and where flooding is a recurrent problem. The catchment area of Kokemäki river includes several lake areas but they exist only in the uppermost part of the catchment area. During the spring, the lake reservoirs fill up early, and finally they feed the Kokemäki river with masses of water, all at the same time. In particular, a flood whose return time is 50 years have a huge negative impact on city life and physical assets such as infrastructure [3].

Based on simulation studies the change of the runoff of the Kokemäki river in future climate 2020–2050 compared to current climate 1970–2000 is approximately 8% for floods with the return period[1] of 100 years and 9% for floods with the return period of 250 years [3]. The percentages are averages over several climate simulation models under the SRES emission scenario A1B [4].

In the paper the usefulness of the event tree analysis (ETA) method for impact assessment and decision-support for the risk management of public sectors against floods is demonstrated to experts and civil servants responsible for taking into account possible climate change effects in their respective sectors. Direct consequences will be the focus of a broad range of impacts that, in principle, can be categorized according to economic, humanitarian and ecological consequences [5]. The application of the ETA method is, however, extendable to indirect economic and other impacts. Related work on flood risk assessment, where ETA has been applied, is presented in [6].

The work was conducted in the IRTORISKI[2] -project, funded by the Finland's Climate Change Adaptation Research Programme (ISTO). ISTO was running in 2006–2010 as part of the implementation of the National Strategy for Adaptation to Climate Change, aiming to produce information that will facilitate the planning of practical adaptation measures.

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[1] A flood has a return period, for example, R100, which refers to the average time between two at least as serious flood events in static conditions.

[2] Cost-benefit analysis of climate change induced extreme events as part of public decision making (IRTORISKI).

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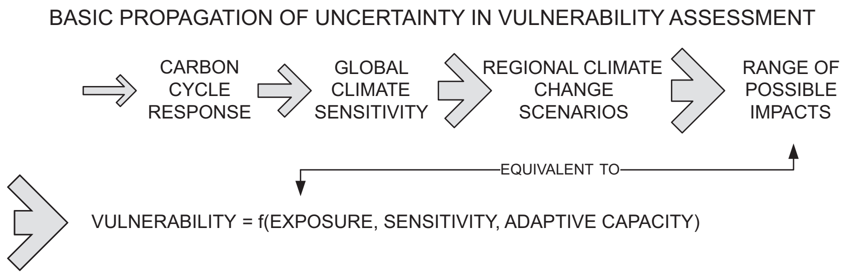

Fig. 1. Illustration of the growing uncertainty along the chain of inference from emission scenarios to a range of possible impacts and the vulnerability of a man-made system (adapted from Adger and Vincent [7]). Vulnerability is a function of exposure (=range of impacts), sensitivity and adaptive capacity.

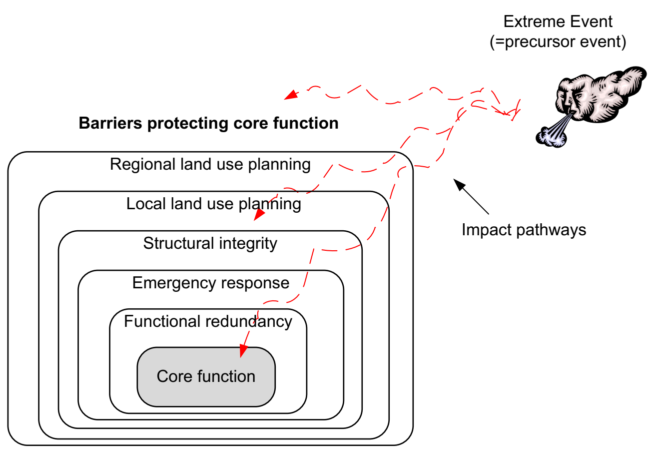

Fig. 2. Generic countermeasures or barriers against extreme events.

2. Impact scenarios and vulnerability

The reference model we have adopted for understanding the causal chain of events related to climate change is the diagram in Fig. 1 [7]. Basically, the more exposure and sensitivity can be attributed to a system which has limited adaptive capacity, the more vulnerable it is and, hence, also the severity of the consequences will be higher. The diagram is generic in the sense that it is applicable for both climate change trends and extreme events. In this paper, the event tree analysis method [8] is explored for the quantitative assessment of the vulnerability in the case of flood.

Another reference model is shown in Fig. 2 depicting impact scenarios or pathways. It was developed in the IRTORISKI-project in order to illustrate the impact pathways of an extreme event such as a flood. It indicates the sensitivity and the adaptive capacity of the system to the potential adverse consequences on the core function that should be kept protected as much as possible. The core function is related to e.g., an infrastructure service such as a hospital. The adaptive capacity of the hospital depend on the technical and institutional preparedness of the asset operator and owner to install, and in cooperation with the first responders, to maintain the performance of different barriers that obstruct the adverse impacts on the core function, which, in this case, is to treat patients even when a flood event has occurred. The key point in Fig. 2 is to show the wide range of barrier functions that can be leaned on in order to stop the adverse impact before it hits the core function, disrupting or destroying it.

The vulnerability assessment is bottom-up in the sense that we look at the core function of the (physical) asset first and then identify technical and organizatorial barriers to protect it. This is line with notes in several reports that adaptation is a locally driven process in which the distribution of costs and benefits among stakeholders, their risk perceptions and the local risk governance influencing the process [9].

In the next section the ETA method is explored for assessing the vulnerability of a flood prone area near the city of Pori. As mentioned above, only direct costs are the consequences addressed. Thus, the ETA method will directly support a cost–benefit assessment of introducing optional flood protection measures. This will also be demonstrated in the next section.

3. Impact modelling of floods in the city of Pori

3.1. Event tree analysis of Pori area floods

The aim of the IRTORISKI-project was to demonstrate and evaluate the event tree analysis method for supporting flood protection decision-making in the public sector. The flood prone area along Kokemäki river of the city of Pori was selected as the case for demonstration [10]. Three flood scenarios, with return periods of 50 and 30 years, were defined as:

Sc1: $R=50$ in current climate with current flood protection.
Sc2: $R=30$ in future climate 2020–2050 with current flood protection.
Sc3: $R=30$ in future climate 2020–2050 with new flood protection.

One assumption made for the ETA was that the current expected direct costs to sectors from a R50 flood will in the future climate (2020–2050) correspond to R30 floods [3]. This would mean a change of the annual probability from $1/50=0.02$ to $1/30=0.03$ of the given R50 flood of today. Another assumption is that the character of the current R50 flood and the built stock in the flood prone area do not significantly change, i.e., the direct costs of a single flood are approximately the same in the future as today.

Following the basic method of ETA (see Appendix A), the event tree model for floods was developed according to Fig. 3. It was presented to flood experts and sector managers in the areas of buildings/real estate, water management, electrical and telecommunication networks. The role of the experts was to give expert feedback on the ETA approach and provide information for the model specification, in particular, the barrier functions and the related success/failure probabilities. The following barriers (B) were modelled by the generic event tree (Fig. 3):

(1) Flood containment.
(2) Location of infrastructure.
(3) Structural engineering.
(4) Emergency response.
(5) Core process redundancies.