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Natural Hazards and Earth System Sciences

Preface: Damage of natural hazards: assessment and mitigation

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1 Introduction

Hundreds of thousands of people are killed each year by natural hazards, and economic damage is significantly increasing, which was shown for instance based on inflation-adjusted, non-normalized losses of natural hazards in the period 1980–2009 (ICSU, 2008; Neumayer and Barthel, 2011). An in-depth understanding and assessment of the risks of natural hazards is necessary in order to develop sustainable risk management strategies including efficient damage mitigation approaches (Kreibich et al., 2014, 2015; Evers et al., 2016). Risk analyses combine hazard with damage modelling, which provides quantitative estimates of expected damage. Such information is key to optimize risk mitigation on the basis of cost–benefit analyses. Risk analyses are carried out at different spatial scales including the macro-scale (global, continental), mesoscale (national, regional) and micro-scale (local) (de Moel et al., 2015; Falter et al., 2016). System approaches are necessary to tackle the challenge of assessing interactions of physical and socio-economic processes that determine the consequences of natural hazards (Vorogushyn et al., 2018; Kreibich et al., 2017b, 2019). Additionally, there is general agreement that risks, as well as their components hazard, exposure and vulnerability, are dynamic and need to be treated as such (Hufschmidt et al., 2005; Sairam et al., 2019).

The special issue "Damage of natural hazards: assessment and mitigation" was inspired by the annual EGU session "Costs of Natural Hazards", which was organized in 2012 for the first time. This special issue presents 12 studies on advancements in the field of damage assessment and mitigation related to droughts (Bachmair et al., 2017; Peichl et al., 2018; Markantonis et al., 2018), extreme rainfall (Cortès et al., 2018; Spekkers et al., 2017), different types of floods (Markantonis et al., 2018; Cortès et al., 2018; Laudan et al., 2017; Bernet et al., 2017; Wagenaar et al., 2017) and earthquakes (Livaoğlu et al., 2018; Yılmaz et al., 2018; Altunışık et al., 2017; Zhang et al., 2017). A common challenge tackled by many of the studies in this special issue is the lack of impact and damage data. Unfortunately, there are very few standardized methods or routines to collect and update damage data after events. Utilizing new data sources such as satellite data, social media and open data provides promising possibilities (Fohringer et al., 2015, Schröter et al., 2018). In this preface to the special issue we focus in the next section on each study's main findings and common themes.

2 Damage assessment and mitigation

Two studies undertook on-site data collection to gain more insight into which building or community characteristics determine the amount of damage during flash-flood or earthquake events. On-site data collection was undertaken by Laudan et al. (2017) to gain a better understanding of damage caused by flash floods. They assessed all affected houses 8 to 10 days after the flash-flood event in May 2016 in Braunsbach, Germany. The results revealed that the damage-determining factors of flash floods differ from those of riverine floods to a certain extent. The exposition of a building in flow direction shows an especially strong correlation with the damage grade. Additionally, the results suggest that building materials as well as various building aspects, such as the existence of a shop window and the surroundings, might have an effect on the resulting damage. Livaoğlu et al. (2018) combined on-site observations with a survey to investigate the damage caused by the Ayvacık earthquake swarm in February 2017 in Turkey. Distribution maps showed that damage ratios are higher in villages closer to the epicentre, except for the town of Gülpınar, where past experiences and development level had increased the construction quality. Construction failure was additionally explained by the influence of pre-existing cracks on the performance of buildings due to many earthquakes occurring in a short period of time.

Post-event surveys of affected households were undertaken by Markantonis et al. (2018) and Spekkers et al. (2017) to gain knowledge about private risk mitigation actions to cope with droughts and/or floods. Markantonis et al. (2018) used an integrated approach to assess floods and droughts in the transboundary Mékrou River basin, West Africa. They utilize climatic trend analysis, a household survey and two econometric models to combine information on climate variability and flood and drought occurrence with information on household mitigation measures and impacts of floods and droughts. As such, a per-household cost estimation of floods and droughts that occurred over a 2-year period is provided. Spekkers et al. (2017) investigated the impacts of extreme rainfall on residential buildings and how affected households coped with these impacts in terms of precautionary and emergency actions. Analyses are based on damage data, collected through computer-aided telephone interviews and an online survey in the cities of Münster (Germany) and Amsterdam (the Netherlands). The difference in event severity is probably the most important cause for the differences between the cities in terms of the suffered financial damage. Factors that significantly influence damage are water contamination, the presence of a basement in the building and people's awareness of the upcoming event. The study confirms conclusions by previous studies that people's experience with damaging events positively correlates with precautionary behaviour.

Flood-related insurance damage claims can provide a proxy for flood impacts. Based on such data for the last 20 years, Cortès et al. (2018) developed and evaluated a methodology to estimate surface water flood damage from heavy precipitation in the Mediterranean region. Results show that logistic regression models are able to simulate the probability of a damaging event as a function of precipitation. Bernet et al. (2017) introduce a large ($n = 63\,117$), long (10–33 years) and representative (48 % of all Swiss buildings covered) data set of spatially explicit Swiss insurance flood claims, which they separated into damage caused by surface water floods and fluvial floods. The data analyses revealed that surface water floods are responsible for at least 45 % of the flood damage to buildings and 23 % of the associated direct tangible damage. Damage caused by surface water floods occurs by far most frequently in summer in almost all regions. The normalized surface water flood damage of all regions shows no significant upward trend between 1993 and 2013.

Enriching a data set of residential building and contents damage from the Meuse flood of 1993 in the Netherlands to make it suitable for multivariable flood damage assessment is the strategy of Wagenaar et al. (2017). Results from 2-D flood simulations are used to add information on flow velocity, flood duration and the return period to the data set, and cadastre data are used to add information on building characteristics. Validation of various multivariable flood damage models showed that the enriched data set in combination with the supervised learning techniques delivers a 20 % reduction in the mean absolute error, compared to a simple model only based on the water depth.

The challenge of lacking data on ecological and socioeconomic consequences of droughts is tackled by Bachmair et al. (2017) in analysing reports on drought impacts. They develop empirical drought impact functions based on hydrometeorological drought indicators as predictors and text-based reports on drought impacts as a surrogate variable for drought damage. Three data-driven approaches for predicting drought impacts were tested, namely logistic regression, zero-altered negative binomial regression and random forest, of which random forests seemed to perform best. Different ways of defining the impact counts based on text reports had little influence on the prediction skill.

The following modelling-based studies partly use empirical data for model refinement and validation. Yılmaz et al. (2018) employed an analytical method to generate fragility curves for the Alasehir bridge with respect to earthquakes. The bridge model was refined using field measurements and impact data of 60 selected earthquakes. The results show that velocity has important effects on the fragility curves and truss pier elements are the most vulnerable elements in the system. Altunışık et al. (2017) investigate the restoration effect on the earthquake response of a historical masonry mosque in the old city of Van, Turkey. A finite element model of the mosque was constructed and structural analyses were performed under dead load and earthquake load. The results show that reduction of the window openings affected the structural behaviour of the mosque positively. Zhang et al. (2017) analyse the ripple effects of indirect economic damage and spatial heterogeneity of both direct and indirect economic damage caused by a hypothetical earthquake in the region of Beijing, China. Spatial heterogeneity of damage is analysed at the scale of streets, villages and towns. The results indicate that the most severe indirect economic damage is expected to the finance and insurance industry located in the Chaowai Street in the Chaoyang District. There, indirect damage is estimated to be 1.46 times that of the direct damage. Damage can be efficiently mitigated by increasing rescue effort and by supporting the industries in the high-risk areas. Thus, the results may help the government to better allocate rescue funds. Peichl et al. (2018) investigated the intra-seasonal predictability of maize yield using soil moisture information in Germany. The effects of soil moisture dominate those of temperature and are time dependent. Soil moisture anomalies have predictive skills that vary in magnitude and direction depending on the month; e.g. dry soil moisture anomalies in August and September reduce maize yield by more than 10 %, and dry anomalies in May increase crop yield by up to 7 % because absolute soil water content is higher in May compared to August due to its seasonality.

3 Concluding remarks

Trends in the discourse of natural hazards and risk science are well reflected and underpinned by this special issue. Increasingly, aspects of social justice and equity are included in risk assessments to support the selection of optimal damage mitigation measures (Thaler et al., 2018). Two studies included in this special issue underpin this aspect by highlighting the importance of comprehensive event and risk assessments as well as integrated approaches to investigate the interaction of physical and socio-economic processes (Zhang et al., 2017; Markantonis et al., 2018). Additionally, cost assessments may include costs of the recovery phase as households may face enormous difficulties in recovering from events, as shown by Markantonis et al. (2018) in this special issue. Thus, there is growing interest in various socio-economic aspects, types of damage and exposed elements (Thieken et al., 2016). For the development of new approaches for damage assessments, new data and tools are utilized. More and more studies, also the following two studies included in the special issue, use multivariate statistics or data-mining methods for data analyses and damage modelling (Figueiredo et al., 2018; Bachmair et al., 2017). Their main advantages are the ability to capture nonlinear, threshold, or nonmonotonic dependencies between predictor and response variables, to take interactions between the predictors into account and the possibility of being trained from data sets of various sizes (Rözer et al., 2016; Kreibich et al., 2017a; Wagenaar et al., 2017, 2018).

By providing new insights and novel methodological approaches, this special issue contributes to advancements in the field of damage assessment and mitigation of natural hazards. The contributions also provide an overview of the variety of research initiatives, which may indicate future research directions in this field.

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