Wissenschaftliche Zusammenfassung der Dissertation

Dynamics in the Flood Vulnerability of Companies

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River flooding is a constant peril for societies, causing direct economic losses in the order of $100 billion worldwide each year. Under global change, the prolonged concentration of people and assets in floodplains is accompanied by an emerging intensification of flood extremes due to anthropogenic global warming, ultimately exacerbating flood risk in many regions of the world. Flood adaptation plays a key role in the mitigation of impacts, but poor understanding of vulnerability and its dynamics limits the validity of predominant risk assessment methods and impedes effective adaptation strategies. Therefore, this thesis investigates new methods for flood risk assessment that embrace the complexity of flood vulnerability, using the understudied commercial sector as an application example.

Despite its importance for accurate risk evaluation, flood loss modeling has been based on univariable and deterministic stage-damage functions for a long time. However, such simplistic methods only insufficiently describe the large variation in damage processes, which initiated the development of multivariable and probabilistic loss estimation techniques. The first study of this thesis developed flood loss models for companies that are based on emerging statistical and machine learning approaches (i.e., random forest, Bayesian network, Bayesian regression). In a benchmarking experiment on basis of object-level loss survey data, the study showed that all proposed models reproduced the heterogeneity in damage processes and outperformed conventional stage-damage functions with respect to predictive accuracy. Another advantage of the novel methods is that they convey probabilistic information in predictions, which communicates the large remaining uncertainties transparently and, hence, supports well-informed risk assessment.

Flood risk assessment combines vulnerability assessment (e.g., loss estimation) with hazard and exposure analyses. Although all of the three risk drivers interact and change over time, such dependencies and dynamics are usually not explicitly included in flood risk models. Recently, systemic risk assessment that dissolves the isolated consideration of risk drivers has gained traction, but the move to holistic risk assessment comes with limited thoroughness in terms of loss estimation and data limitations. In the second study, I augmented a socio-hydrological system dynamics model for companies in Dresden, Germany, with the multivariable Bayesian regression loss model from the first study. The additional process-detail and calibration data improved the loss estimation in the systemic risk assessment framework and contributed to more accurate and reliable simulations. The model uses Bayesian inference to quantify uncertainty and learn the model parameters from a combination of prior knowledge and diverse data.

The third study demonstrates the potential of the socio-hydrological flood risk model for continuous, long-term risk assessment and management. Using hydroclimatic ad socioeconomic forcing data, I projected a wide range of possible risk trajectories until the end of the century, taking into account the adaptive behavior of companies. The study results underline the necessity

of increased adaptation efforts to counteract the expected intensification of flood risk due to climate change. A sensitivity analysis of the effectiveness of different adaptation measures and strategies revealed that optimized adaptation has the potential to mitigate flood risk by up to 60%, particularly when combining structural and non-structural measures. Additionally, the application shows that systemic risk assessment is capable of capturing adverse long-term feedbacks in the human-flood system such as the levee effect.

Overall, this thesis advances the representation of vulnerability in flood risk modeling by offering modeling solutions that embrace the complexity of human-flood interactions and quantify uncertainties consistently using probabilistic modeling. The studies show how scarce information in data and previous experiments can be integrated in the inference process to provide model predictions and simulations that are reliable and rich in information. Finally, the focus on the flood vulnerability of companies provides new insights into the heterogeneous damage processes and distinct flood coping of this sector.