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Bischiniotis, K.

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E-mail address:
vuresearchportal.ub@vu.nl

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Summary

For many years, flood risk management focused primarily on either long-term risk-reduction strategies or post-disaster response. However, scientific advances in hydro-meteorological forecasting have created a valuable time window between flood warnings and imminent disasters, during which risk reduction measures can be implemented. In response to the growing demand for identifying more effective ways to cope with increasing flood risk, this PhD dissertation investigates important aspects of forecast-based strategies, specifically forecast quality, with the ambition of contributing more effective flood risk management.

First, this thesis focuses on the role of forecast-based strategies in flood risk management. In current practice, temporary measures triggered by forecasts are used to reduce the risk that remains after the application of permanent measures. Chapter 2 presents a methodology that compares permanent and forecast-based flood-prevention measures, investigating the conditions under which forecast-based measures could be used as an alternative to permanent ones. Following the rationale of this methodology, forecast-based measures applied to frequent (high-probability) low-impact events are compared with measures targeting rare (low-probability) high-impact events. Using flood risk indicators for Chikwawa, Malawi, and forecasted discharge time series, the results reveal that the selection of the lowest-cost strategy is a function of the cost of measures, climatological flood risk, and forecast ability in producing accurate flood warnings. Effective temporary measures in combination with skilful forecasts can justify a strategy relying on either forecast-based measures or a mixture of permanent and forecast-based measures, rather than applying permanent measures alone. In addition, the interrelationships between the above-mentioned aspects may prompt a policy of acting against frequent low-impact events instead of rare high-impact events.

Chapter 3 subsequently presents an evaluation framework of a global flood forecast model. Using Peru as a case study, this framework assesses the hydrological performance of the model by comparing observed discharge with the discharge that is produced at a 0-day lead time by the model. The predictive capability of the model is assessed through the comparison of forecasted and modelled discharge, as

well as by validating flood warnings against reported flood events. Raw forecasts are then post-processed to evaluate the degree to which a simple bias-removing technique affects the performance of the model. Results indicate that the model captures the seasonality of the discharge but there are large quantitative differences between observed and modelled discharge. Forecasts at short lead times perform better, and on average forecast performance is higher for grid cells representing major rivers with large upstream areas, in comparison to the short river systems with rapid hydrological response. In general, raw forecasts are characterized by a tendency to overpredict discharge. Post-processed forecast perform better in capturing the modelled discharge, but they provide warnings for less reported flood events in comparison with the raw forecasts. This chapter shows that the selected global forecast model can be valuable in areas where the local forecast systems are either unreliable or only operating at short lead times.

Chapter 4 investigates the influence of the antecedent hydro-meteorological conditions on flood generation. It follows a pragmatic approach, which uses reported historical flood events in sub-Saharan Africa to analyse, both separately and in combination, flood indicators that are representative for timescales ranging from a few days to up to several months prior to the events. Although heavy precipitation is observed shortly before flood generation, it does not always lead to flooding. When heavy precipitation events are preceded by wet hydro-meteorological conditions during the months prior to flood generation, the likelihood of a flood becomes higher. This demonstrates that monitoring and forecasting the seasonal-scale hydro-meteorological conditions can be a useful addition to flood risk management in flood prone areas.

Finally, Chapter 5 presents a methodology that assesses the economic value of a risk-reduction system, in which a forecast triggers an action. The methodology considers budget and time constraints, time-varying forecast ability to provide accurate flood warnings, action costs and effectiveness. These factors permit the exploration of the trade-off between taking effective actions based on low-quality forecast information and taking less effective actions when more reliable forecasts are available. Building upon this methodology, the single-trigger forecast system is compared to a staged system in which a low-quality long-lead-time forecast that triggers a preparatory action is followed by a higher-quality shorter-lead-time forecast that triggers the main risk-reduction action. Using an idealised case study and the forecasted discharge time series for Akokoro, Uganda, results demonstrate that low-quality forecasts at long lead-times coupled with higher-quality forecasts at shorter lead-times can provide additional value to forecast-based systems. Furthermore, this chapter underscores that the characteristics of the forecast-based actions, such as implementation time and time-varying effectiveness, should be examined together with the time-varying forecast reliability to better effectuate the optimal time to trigger the selected action.

This dissertation underlines the complexity of forecast-based strategies. The information presented can aid both policymakers and operational decision-makers in understanding important aspects of these strategies, allowing the development of more effective flood risk management plans. The dissertation concludes with recommendations for further research. First, more empirical data on the effectiveness of forecast-based strategies, as well as long time series of observed and forecasted discharge, are necessary to accurately quantify the value of the forecast-based strategies in the long term. Second, a combination of behavioural and natural sciences is necessary to reliably simulate the actions and interactions of individual and collective actors in forecast-based strategies. Third, future research should focus on the effects of climate change on flood forecasting and on the role of forecast-based systems in a less predictable future.