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Land Policy for Flood Risk Management—Toward a New Working Paradigm

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Key Points:

- Flood risk management needs more focus on processes to plan and implement measures
- Comprehensive and inclusive land policy is crucial for flood retention
- Starting with the local scale is essential throughout the whole process of planning and implementation of flood management measures

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Abstract

Flood risk management (FRM) aims to integrate necessary technical measures with environmental and societal approaches. Focusing on the process and governance of how to plan, implement, and maintain solutions therefore becomes essential. Among the different stakeholders, landowners are a key group to be considered. This contribution elaborates on the interconnections between land policy, FRM and private land ownership. It is based on the European COST Action network LAND4FLOOD, which brings together academics and stakeholders from various disciplines and more than 35 countries. We argue for a less project oriented and more process oriented approach, a focus on land management and more emphasis on small-scale measures. This represents a break with some of the recent working paradigms of FRM.

Plain Language Summary

Flood risks are expected to increase in the future due to the combined effects of climate change, land use change and population growth. New approaches are needed to complement conventional flood risk management (FRM) based on engineering solutions and project-based approaches. In this Commentary we present the findings of the LAND4FLOOD project, which is based on 4 years of research by academics and stakeholders from diverse backgrounds and disciplines: engineering, societal and environmental. We identify three main issues that should be considered to gain support from different stakeholders for the successful implementation of flood risk measures. First, more process orientation in planning and preparing measures is needed. Second, a comprehensive and inclusive land policy is crucial for flood retention. Third, it is important to start at the local scale.

1. Introduction

Flood risks will increase in the future. The intensification of extreme precipitation events, and changes in their spatial distribution, are expected to multiply flood risk by 2050 in some regions (Hettiarachchi et al., 2018; Jongman et al., 2012). In addition to the atmospheric factors mentioned, flood risk is also influenced by the combination of land use changes and socio-economic factors such as population growth (Merz et al., 2021; Pattison & Lane, 2012; Rogger et al., 2017). Conventional flood protection, based on a hydro-engineering approach, is focused on keeping the water away from spaces where it is not wanted. However, this appears to be insufficient to reduce increasing flood risk (Grünewald, 2005; Klijn et al., 2008; Moss & Monstadt, 2008).

Since the late 1990s, flood risk management (FRM) has emerged as the prevalent paradigm in Europe (Patt & Jüpner, 2020) but also in the USA (Thomas, 1995). Flood risk management, starting with an exclusive focus on protection from the hazard of flooding, has evolved to utilizing risk-based approaches, which take vulnerability into account. A main trigger for Europe were the major flood events in 1993 and 1995 along the river Rhine, which revealed the limits of contemporary flood protection at the time (Warner et al., 2012). In the aftermath of the major flood event in 2002 at the river Elbe, the institutionalization of flood risk management was formalized in a European directive (Hartmann & Jüpner, 2014), the Floods Directive (2007/60/EC). From this point on, flood risk management became the state of the art approach to flood risks—in Europe and beyond. FRM questions the institutional separation of water management and spatial planning (Hartmann & Driessen, 2017). This is in line with the academic debate in Europe (Moss, 2004; Wiering & Immink, 2006), and the USA (Calder, 2005; Dyckman & Paulsen, 2012), where the institutional divide seems to be even more

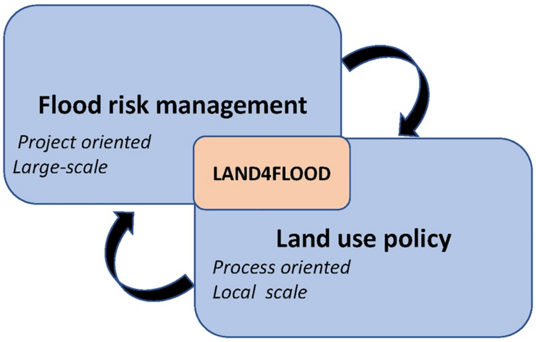

Figure 1. Schematic representation of interactions between land use policy and flood risk management as represented through findings in LAND4FLOOD project. Figure inspired by Hartmann and Spit (2014).

entrenched than in Europe (Suykens et al., 2019; Tarlock, 2012). FRM thus echoes the call for more integrated water management (Gleick, 2000) in flood risk management (Hartmann et al., 2022). FRM is not making flood protection obsolete, but it rather is complementing it. More recently, flood resilience has increasingly been explored as the next evolution in flood risk management (Disse et al., 2020; Fekete et al., 2020). So, ultimately, adaptation and mitigation became highly relevant and generally acknowledged principles not only for fluvial, but also for pluvial floods (Merz et al., 2010). Adaptation as well as mitigation, however, require measures on land. Adaptation involves property-level protection measures (Attems et al., 2020) as well as catchment-wide perspectives on the use of land (Merz et al., 2010; Thaler et al., 2017). Mitigation measures hold a promise for reduction of damages caused by inundations on very small local scales.

The IPCC confirms there is a relation between land management and flood risk (IPCC, 2019). Consequently, a top down support for implementation of Natural Water Retention Measures (NWRM) or nature-based solutions (NBS), into the Floods Directive, has emerged, presenting the concept of Sustainable Flood Management (SFM) or nature-based flood management (Collentine & Futter, 2018; EC, 2007; EC-DGE, 2015; Hartmann et al., 2019; Keesstra et al., 2018; World Bank, 2017). Therefore, nature-based flood risk management additionally incorporates solutions based on NWRM and NBS in FRM, from smaller scales such as urban areas (Ferreira et al., 2021) to large river basins (e.g., natural river retention areas and wetlands; Potočki et al., 2021). In spite of this shift of focus, there are still significant obstacles to overcome in order to coordinate the benefits of risk reduction measures with implementation costs (Calliari et al., 2019; Maes & Jacobs, 2017). FRM measures involve changes in land use, which in turn requires a process and structure for coordination between landowners and beneficiaries (Hartmann et al., 2018; Schanze, 2017). In some cases, the beneficiary and the landowner may be identical (i.e., measures on public land by public flood mitigation authorities) but more commonly the beneficiaries are not organized in a sole purpose institution and the landowners are individual private entities (Collentine & Futter, 2018; Crabbé & Coppens, 2019; Tarlock & Albrecht, 2016).

There is a need to understand and to share experiences, not only of FRM solutions based on water engineering, but also of dedicated nature-based flood risk management measures on private land. This inspired the European COST Action program LAND4FLOOD (https://www.cost.eu/actions/CA16209). Concluding 4 years of sharing experiences in meetings and workshops with representatives from more than 35 countries three key messages have been identified to increase implementation of mitigation measures on private land. The following three messages challenge the existing working flood risk management paradigm which is often very project-oriented, driven by water engineering, and large in scale (Hartmann & Driessen, 2017).

1. Less project orientation and more focus on processes to plan and prepare measures
2. A comprehensive and inclusive land policy is crucial for flood retention
3. Starting from the local scale is vital (Figure 1).

2. From a Project to a Process-Based Approach

Nature-based flood risk management goes beyond merely designing and financing the construction of engineering measures. It aims to integrate necessary technological measures with environmental, traditional, and societal approaches (Jakubínský et al., 2021; Veidemane, 2019). It combines natural features, actively involves a wide range of stakeholders, and incorporates and adapts all relevant regulations and management plans. In this way, a fertile environment is created for the co-creation of integrated management plans. It thus becomes essential to focus on the process (how to plan, implement, and maintain solutions), rather than relying on finding and deciding on the measures alone. An appropriate process will inherently clarify, identify and establish measures (Thaler et al., 2020; Warner & Damm, 2019).

The term Flood Risk Governance (FRG) (Bergsma, 2019; Hegger et al., 2014; Heintz et al., 2012) includes:

1. Describing a complementary approach to FRM as a means to overcome the limitations of structural protection approaches (Kundzewicz & Takeuchi, 1999), by providing general goals, responsibilities and directions—and by facilitating normative debate (Matczak & Hegger, 2021)
2. Preparing FRM measures and engaging with private landowners, requires concerted efforts and dedicated finances to support iterative processes from the initial step to final completion—and beyond
3. Cooperation and coordination, along with communication of flood risks are considered essential to implement solutions in a sustainable way (Kellens et al., 2013; Priest et al., 2016)

Landowners, public authorities, and all other relevant stakeholders must be welcomed and actively engaged into processes of addressing flood risk challenges and into planning cost-effective solutions (Bark & Acreman, 2020). Getting landowners on board is a time-consuming process, due to efforts needed for trust-and consensus-building, mobilization, and co-development (Tempels & Hartmann, 2014). Identifying, mapping and analyzing landowner and stakeholder interests and their potential for commitments are key steps in such processes (Blazquez et al., 2021). However, it is even more important to ensure that the engagement is inclusive, transparent, and persistent over time (Fekete et al., 2021; Zilans et al., 2019).

With regard to stakeholder involvement, FRM should be regarded as an iterative and adaptive process (Pasquier et al., 2020). Although the goal may be the realization of an individual project, this realization will require not only participation in planning and preparation, but continued active governance once measures have been implemented. The experience gathered from each process must be treated as an input to the next one forthcoming, so subsequent quality depends upon what has come before.

3. Comprehensive Land Policy Is Crucial

Access to land is essential for nature-based flood risk management. Space is needed to retain and detain water. Agricultural land is needed—in upstream areas and in the hinterlands (Collentine & Futter, 2018). However, agricultural landowners often resist changes and restrictions to their land use, especially when it comes to changing the use of their land. They do not want to lose control over how they manage their land or to be forced to change farming practices, because their land is the foundation of their income—and often their identity. Flood mitigation policies thus need to incorporate a multifaceted understanding of landowner perspectives, how they influence support for flood mitigation strategies and to identify potential conflict and to develop policies that minimize it (Milman et al., 2018).

Over the last 4 years, LAND4FLOOD found that there is a need for comprehensive and inclusive participatory processes, seeking feasible solutions for reducing flood risk. This is more similar to handling general land use issues, requiring similar representative policy processes (Hartmann & Spit, 2015). Moving to process-based interventions recruits a wider stakeholding public, both upstream and downstream, making it impossible for (public) authorities to implement measures without consultation or involvement.

Several approaches have been proposed in land policy and research—from informal processes or incentives, to top–down command and control solutions (Crabbé & Coppens, 2019; McCarthy et al., 2018; Suykens et al., 2019). Stakeholder participation in processes is often offered as a way to address flooding problems, but when it comes to agricultural land, negotiating such approaches often can be stalled by the issue of land scarcity. Monetary compensation is not the only issue. Keeping and increasing the extent of appropriate land could represent the key value. Further, not all agricultural landowners are farmers and not all farmers own all the land they manage. If alternative solutions to lost production and satisfactory income compensation cannot be guaranteed over the long term, even money cannot circumvent the reluctance of landowners and farmers to engage in a flood risk management program. Experience in the LAND4FLOOD project and presented in case studies shows this (Hartmann et al., 2019). Landowners and farmers represent an important constituency group, so public agencies may be reluctant to use interventionist policy instruments—such as expropriation or direct regulation (Löschner et al., 2021).

One effective way to alleviate the problem of land scarcity is to increase the provisioning of land in the solution. "Land for Land," that is, offering suitable and attractive land in exchange for the constrained land, can be a successful means to alleviate such an impasse (Albrecht & Hartmann, 2021; Crabbé & Coppens, 2019). Promoting multifunctional uses of land represents another strategy. However, these approaches require strategic thinking and long-term land management and governance. This approach requires a shift toward integrated flood policies to address cross-cutting issues, particularly to incorporate the agricultural sector in policy coordination processes (Löschner & Nordbeck, 2020).

4. Starting From the Local Scale Is Vital

Flood risk assessment methodology and application is strongly linked to spatial scale (de Moel et al., 2015) and therefore has impacts on land use management and land owners. A catchment perspective is important to adequately access land for flooding. It has been argued that retention measures should be planned at the large scale to take into account effects throughout the entire river basin (EC, 2007; Hartmann & Spit, 2016; Rouillard et al., 2015). The implementation of water retention measures, however, must be done with direct support from the local level, with reference to perspectives of the involved landowners, who may own small pieces of land or have their land fragmented across the catchment. In addition, upstream farmers and landowners will be asked to provide retention services to downstream settlements (Macháč et al., 2018). All these situations involve cross-scale interactions, therefore cooperative efforts should be taken in order to manage the trade-offs resulting from differing perceptions of scales of environmentally suitable and socially acceptable nature-based flood risk management measures.

Our experiences in the LAND4FLOOD network across Europe brought us several curious findings. In one area comprehensive regional or river basin plans struggle with implementation due to non-cooperative landowners who are afraid of decreased land values and of increased administrative and management duties if the FRM measures are implemented on their land. At other area, active farmers, non-governmental entities or small municipalities acting on their own to retain more water on their properties, are criticized by experts for the lack of hydro-morphological soundness or they face bureaucratic barriers while applying for changes in designation of land in spatial plans. At the same time, we found several successful, local initiatives, where water retention measures were implemented through stakeholder and inter-municipal cooperation. Additionally, we found that the implementation of FRM measures may also generate mismatches in temporal scales related to how we understand persistence of the measures and their effects. While landowners are frequently incentivized by short-term financial instruments to implement measures, the importance of long-term persistence of collaborative efforts and the long-term flood mitigating effects of the measures under climatic uncertainties, are underestimated.

Thus, while starting with locals is essential, the cross-scale effects must be accentuated throughout the whole process of planning and implementation of the measures. Our collective experiences in LAND4FLOOD suggest a need for communicative FRM. Articulating scales that would be effective for bridging the spatial, institutional and temporal variations across stakeholders will help with finding the common understanding of proposed measures and their effects and will support implementation (Raška et al., 2019).

5. Conclusions

LAND4FLOOD has demonstrated the need to create wider and more inclusive FRM processes, which include the active and crucial involvement of local stakeholders in all stages. Examples brought to LAND4FLOOD by participants from member country representatives point both to the limits of a strictly top-down approach or a technical management process, and demonstrate the opportunities made possible by working with local stakeholders, especially land owners. Working together comprehensive FRM policies can be developed which can help mitigate subsequent damage from extreme climate events. The challenges of climate change, and in particular extreme climate events, requires comprehensive responses—from reducing the core causes of the events to building resilience and mitigating their impact. FRM processes which mobilize the wider society to participate in solutions is only one part of this, but it can be a key component of creating security and stability in the face of a changing environment. However, ultimately, the lessons learned from the combined expertise of LAND4FLOOD suggest that it may be time for a break with the current working paradigms in FRM.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

No additional data were used as part of this study.

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References

Albrecht, J., & Hartmann, T. (2021). Land for flood risk management—instruments and strategies of land management for polders and dike relocations in Germany. *Environmental Science & Policy*, *118*, 36–44. https://doi.org/10.1016/j.envsci.2020.12.008

Attems, M.-S., Thaler, T., Genovese, E., & Fuchs, S. (2020). Implementation of property-level flood risk adaptation (PLFRA) measures: Choices and decisions. *WIREs Water*, *7*(1). https://doi.org/10.1002/wat2.1404

Bark, R. H., & Acreman, M. C. (2020). Investigating social processes that underpin local flood risk management action. *Environmental Science & Policy*, *109*, 95–102. https://doi.org/10.1016/j.envsci.2020.04.009

Bergsma, E. (2019). The development of flood risk management in the United States. *Environmental Science & Policy*, *101*, 32–37. https://doi.org/10.1016/j.envsci.2019.07.013

Blázquez, L., García, J. A., & Bodoque, J. M. (2021). Stakeholder analysis: Mapping the river networks for integrated flood risk management. *Environmental Science & Policy*, *124*, 506–516. https://doi.org/10.1016/j.envsci.2021.07.024

Calder, I. R. (2005). *Blue revolution: Integrated land and water resources management*. Earthscan.

Calliari, E., Staccione, A., & Mysiak, J. (2019). An assessment framework for climate-proof nature-based solutions. *Science of the Total Environment*, *656*, 691–700. https://doi.org/10.1016/j.scitotenv.2018.11.341

Collentine, D., & Futter, M. N. (2018). Realising the potential of natural water retention measures in catchment flood management: Trade-offs and matching interests. *Journal of Flood Risk Management*, *11*(1), 76–84. https://doi.org/10.1111/jfr3.12269

Crabbé, A., & Coppens, T. (2019). Swapping development rights in Swampy land: Strategic instruments to prevent floodplain development in flanders. In T. Hartmann, L. Slavíková, & S. McCarthy (Eds.), *Nature-based flood risk management on private land: Disciplinary perspectives on a multidisciplinary challenge* (1st ed., pp. 85–97). Springer International Publishing. https://doi.org/10.1007/978-3-030-23842-1_9

de Moel, H., Jongman, B., Kreibich, H., Merz, B., Penning-Rowsell, E., & Ward, P. J. (2015). Flood risk assessments at different spatial scales. *Mitigation and Adaptation Strategies for Global Change*, *20*(6), 865–890. https://doi.org/10.1007/s11027-015-9654-z

Disse, M., Johnson, T. G., Leandro, J., & Hartmann, T. (2020). Exploring the relation between flood risk management and flood resilience. *Water Security*, *9*, 100059. https://doi.org/10.1016/j.wasec.2020.100059

Dyckman, C. S., & Paulsen, K. (2012). Not in my watershed! Will increased federal supervision really bring better coordination between land use and water planning? *Journal of Planning Education and Research*, *32*(1), 91–106. https://doi.org/10.1177/0739456X11426877

EC-DGE, European Commission Directorate-General Environment. (2015).*The European NWRM platform*. Retrieved from www.nwrm.eu

EC, European Commission. (2007). *Floods directive 2007/60*. EC.

Fekete, A., Aslam, A. B., de Brito, M. M., Dominguez, I., Fernando, N., Illing, C. J., et al. (2021). Increasing flood risk awareness and warning readiness by participation–But who understands what under 'participation'? *International Journal of Disaster Risk Reduction*, *57*, 102157. https://doi.org/10.1016/j.ijdrr.2021.102157

Fekete, A., Hartmann, T., & Jüpner, R. (2020). Resilience: On-going wave or subsiding trend in flood risk research and practice? *WIREs Water*, *7*(1), 121. https://doi.org/10.1002/wat2.1397

Ferreira, C. S. S., Potočki, K., Kapović-Solomun, M., & Kalantari, Z. (2021). Nature-based solutions for flood mitigation and resilience in urban areas. In *The Handbook of environmental chemistry*. Springer. https://doi.org/10.1007/698_2021_758

Gleick, P. H. (2000). A look at twenty-first century water resources development. *Water International*, *25*(1), 127–138. https://doi.org/10.1080/02508060008686804

Grünewald, U. (2005). Vom Hochwasser-'Schutzversprechen' zum 'Hochwasser-Risikomanagement'. In R. Jüpner (Ed.), *Hochwassermanagement* (pp. 5–22). Shaker.

Hartmann, T., & Driessen, P. (2017). The flood risk management plan: Towards spatial water governance. *Journal of Flood Risk Management*, *10*(2), 145–154. https://doi.org/10.1111/jfr3.12077

Hartmann, T., Jílková, J., & Schanze, J. (2018). Land for flood risk management: A catchment-wide and cross-disciplinary perspective. *Journal of Flood Risk Management*, *11*(1), 3–5. https://doi.org/10.1111/jfr3.12344

Hartmann, T., & Jüpner, R. (2014). Editorial: The flood risk management plan between spatial planning and water engineering. *Journal of Flood Risk Management*. Virtual Special Issue.

Hartmann, T., Slavíková, L., & McCarthy, S. (2019). Nature-based solutions in flood risk management. In *Nature-based flood risk management on private land* (pp. 3–8). Springer. https://doi.org/10.1007/978-3-030-23842-1_1

Hartmann, T., Slavíková, L., & Wilkinson, M. E. (Eds.), (2022). *Spatial flood risk management: Implementing catchment-based retention and resilience on private land*. Edgar Elgar.

Hartmann, T., & Spit, T. (2014). Editorial: Frontiers of land and water governance in urban regions. *Water International*, *39*(6), 791–797. https://doi.org/10.1080/02508060.2014.962993

Hartmann, T., & Spit, T. (2015). Towards an integrated water management-Comparing German and Dutch water law from a spatial planning perspective. *International Journal of Water Governance*, *3*(2), 59–78. https://doi.org/10.7564/14-IJWG68

Hartmann, T., & Spit, T. (2016). Implementing the European flood risk management plan. *Journal of Environmental Planning and Management*, *59*(2), 360–377. https://doi.org/10.1080/09640568.2015.1012581

Hegger, D. L., Driessen, P. P., Dieperink, C., Wiering, M., Raadgever, G. T., & van Rijswick, H. F. (2014). Assessing stability and dynamics in flood risk governance. *Water Resources Management*, *28*(12), 4127–4142. https://doi.org/10.1007/s11269-014-0732-x

Heintz, M. D., Hagemeier-Klose, M., & Wagner, K. (2012). Towards a risk governance culture in flood policy—findings from the implementation of the "floods directive" in Germany. *Water*, *4*(1), 135–156. https://doi.org/10.3390/w4010135

Hettiarachchi, S., Wasko, C., & Sharma, A. (2018). Increase in flood risk resulting from climate change in a developed urban watershed–the role of storm temporal patterns. *Hydrology and Earth System Sciences*, *22*(3), 2041–2056. https://doi.org/10.5194/hess-22-2041-2018

IPCC. (2019). Summary for policymakers. In *Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. Retrieved from https://www.ipcc.ch/. (Accessed 13 September 2021).

Jakubínský, J., Prokopová, M., Raška, P., Salvati, L., Bezak, N., Cudlín, O., et al. (2021). Managing floodplains using nature-based solutions to support multiple ecosystem functions and services. *WIREs: Water*, *8*(5), e1545. https://doi.org/10.1002/wat2.1545

Jongman, B., Ward, P. J., & Aerts, J. C. (2012). Global exposure to river and coastal flooding: Long term trends and changes. *Global Environmental Change*, *22*(4), 823–835. https://doi.org/10.1016/j.gloenvcha.2012.07.004

Keesstra, S., Nunes, J., Novara, A., Finger, D., Avelar, D., Kalantari, Z., & Cerdà, A. (2018). The superior effect of nature based solutions in land management for enhancing ecosystem services. *Science of the Total Environment*, *610*, 997–1009. https://doi.org/10.1016/j.scitotenv.2017.08.077

Kellens, W., Terpstra, T., & De Maeyer, P. (2013). Perception and communication of flood risks: A systematic review of empirical research. *Risk Analysis*, *33*(1), 24–49. https://doi.org/10.1111/j.1539-6924.2012.01844.x

Klijn, F., Samuels, P., & van Os, A. (2008). Towards flood risk management in the EU: State of affairs with examples from various European countries. *International Journal of River Basin Management*, *6*(4), 307–321. https://doi.org/10.1080/15715124.2008.9635358

Kundzewicz, Z. W., & Takeuchi, K. (1999). Flood protection and management: Quo vadimus? *Hydrological Sciences Journal*, *44*(3), 417–432. https://doi.org/10.1080/02626669909492237

Löschner, L., Hartmann, T., Priest, S., & Collentine, D. (2021). Strategic use of instruments of land policy for mobilising private land for flood risk management. *Environmental Science & Policy*, *118*, 45–48. https://doi.org/10.1016/j.envsci.2021.01.009

Löschner, L., & Nordbeck, R. (2020). Switzerland's transition from flood defence to flood-adapted land use–A policy coordination perspective. *Land Use Policy*, *95*, 103873. https://doi.org/10.1016/j.landusepol.2019.02.032

Macháč, J., Hartmann, T., & Jilkova, J. (2018). Negotiating land for flood risk management: Upstream-downstream in the light of economic game theory. *Journal of Flood Risk Management*, *11*(1), 66–75. https://doi.org/10.1111/jfr3.12317

Maes, J., & Jacobs, S. (2017). Nature-based solutions for Europe's sustainable development. *Conservation letters*, *10*(1), 121–124. https://doi.org/10.1111/conl.12216

Matczak, P., & Hegger, D. (2021). Improving flood resilience through governance strategies: Gauging the state of the art. *WIREs: Water*, *8*(4), e1532. https://doi.org/10.1002/wat2.1532

McCarthy, S., Viavattene, C., Sheehan, J., & Green, C. (2018). Compensatory approaches and engagement techniques to gain flood storage in England and Wales. *Journal of Flood Risk Management*, *11*(1), 85–94. https://doi.org/10.1111/jfr3.12336

Merz, B., Blöschl, G., Vorogushyn, S., Dottori, F., Aerts, J. C., Bates, P., et al. (2021). Causes, impacts and patterns of disastrous river floods. *Nature Reviews Earth & Environment*, 1–18. https://doi.org/10.1038/s43017-021-00195-3

Merz, B., Hall, J., Disse, M., & Schumann, A. (2010). Fluvial flood risk management in a changing world. *Natural Hazards and Earth System Sciences*, *10*(3), 509–527. https://doi.org/10.5194/nhess-10-509-2010

Milman, A., Warner, B. P., Chapman, D. A., & Short Gianotti, A. G. (2018). Identifying and quantifying landowner perspectives on integrated flood risk management. *Journal of Flood Risk Management*, *11*(1), 34–47. https://doi.org/10.1111/jfr3.12291

Moss, T. (2004). The governance of land use river basins: Prospects for overcoming problems of institutional interplay with the EU water framework directive. *Land Use Policy*, *21*(1), 85–94. https://doi.org/10.1016/j.landusepol.2003.10.001

Moss, T., & Monstadt, J. (2008). *Restoring floodplains in Europe: Policy contexts and project experiences*. IWA Publishing.

Pasquier, U., Few, R., Goulden, M. C., Hooton, S., He, Y., & Hiscock, K. M. (2020). We can't do it on our own!"—integrating stakeholder and scientific knowledge of future flood risk to inform climate change adaptation planning in a coastal region. *Environmental Science & Policy*, *103*, 50–57. https://doi.org/10.1016/j.envsci.2019.10.016

Patt, H., & Jüpner, R. (Eds.), (2020). *Hochwasser-Handbuch: Auswirkungen und Schutz (3., neu bearbeitete Auflage)*.

Pattison, I., & Lane, S. N. (2012). The link between land-use management and fluvial flood risk: A chaotic conception? *Progress in Physical Geography*, *36*(1), 72–92. https://doi.org/10.1177/0309133311425398

Potočki, K., Bekić, D., Bonacci, O., & Kulić, T. (2021). Hydrological aspects of nature-based solutions in flood mitigation in the Danube River Basin in Croatia: Green vs. Grey approach. In *The Handbook of environmental chemistry*. Springer. https://doi.org/10.1007/698_2021_770

Priest, S. J., Suykens, C., van Rijswick, H. F. M. W., Schellenberger, T., Goytia, S., Kundzewicz, Z., et al. (2016). The European Union approach to flood risk management and improving societal resilience: Lessons from the implementation of the floods directive in six European countries. *Ecology and Society*, *21*(4). https://doi.org/10.5751/es-08913-210450

Raška, P., Slavíková, L., & Sheehan, J. (2019). Scale in nature-based solutions for flood risk management. In *Nature-based flood risk management on private land* (pp. 9–20). Springer.

Rogger, M., Agnoletti, M., Alaoui, A., Bathurst, J. C., Bodner, G., Borga, M., et al. (2017). Land use change impacts on floods at the catchment scale: Challenges and opportunities for future research. *Water Resources Research*, *53*(7), 5209–5219. https://doi.org/10.1002/2017wr020723

Rouillard, J. J., Ball, T., Heal, K. V., & Reeves, A. D. (2015). Policy implementation of catchment-scale flood risk management: Learning from Scotland and England. *Environmental Science & Policy*, *50*, 155–165. https://doi.org/10.1016/j.envsci.2015.02.009

Schanze, J. (2017). Nature-based solutions in flood risk management—Buzzword or innovation? *Journal of Flood Risk Management*, *10*(3), 281–282. https://doi.org/10.1111/jfr3.12318

Suykens, C. B. R., Tarlock, D., Priest, S. J., Doorn-Hoekveld, W. J., & van Rijswick, H. F. M. W. (2019). Sticks and carrots for reducing property-level risks from floods: An EU–US comparative perspective. *Water International*, *44*(5), 622–639. https://doi.org/10.1080/02508060.2019.1640957

Tarlock, D. (2012). United States flood control policy: The incomplete transition from the illusion of total protection to risk management. *Duke Environmental Law and Policy Forum*, *23*, 151–183.

Tarlock, D., & Albrecht, J. (2016). Potential constitutional constraints on the regulation of flood plain development: Three case studies. *Journal of Flood Risk Management*, *13*(11), 2379. https://doi.org/10.1111/jfr3.12274

Tempels, B., & Hartmann, T. (2014). A co-evolving Frontier between land and water: Dilemmas of flexibility versus robustness in flood risk management. *Water International*, *39*(6), 872–883. https://doi.org/10.1080/02508060.2014.958797

Thaler, T., Löschner, L., & Hartmann, T. (2017). The introduction of catchment-wide co-operations: Scalar reconstructions and transformation in Austria in flood risk management. *Land Use Policy*, *68*, 563–573. https://doi.org/10.1016/j.landusepol.2017.08.023

Thaler, T., Seebauer, S., & Schindelegger, A. (2020). Patience, persistence and pre-signals: Policy dynamics of planned relocation in Austria. *Global Environmental Change*, *63*, 102122. https://doi.org/10.1016/j.gloenvcha.2020.102122

Thomas, F. H. (1995). United States experience with floodplain management. In J. Gardiner, Ö. Starosolszky, & V. Yevjevich (Eds.), *Defence from floods and floodplain management* (pp. 359–371). Springer. https://doi.org/10.1007/978-94-011-0401-2_22

Veidemane, K. (2019) Reflection on governance challenges in large-scale river restoration actions. In *Nature-based flood risk management on private land* (pp. 187–190). Springer. https://doi.org/10.1007/978-3-030-23842-1_20

Warner, B., & Damm, C. (2019). Relocation of Dikes: Governance challenges in the biosphere reserve "river landscape Elbe-Brandenburg". In T. Hartmann, L. Slavíková, & S. McCarthy (Eds.), *Nature-based flood risk management on private land* (pp. 171–180). Springer International Publishing. https://doi.org/10.1007/978-3-030-23842-1_18

Warner, J. F., van Buuren, A., & Edelenbos, J. (Eds.), (2012). *Making space for the river: Governance experiences with multifunctional river planning in the US and Europe*. IWA Publishing.

Wiering, M., & Immink, I. (2006). When water management meets spatial planning: A policy-arrangement perspective. *Environment and Planning C*, *24*(3), 423–438. https://doi.org/10.1068/c0417j

World Bank. (2017). *Implementing nature based flood protection: Principles and implementation guidance*.

Zilans, A., Schwarz, G., Veidemane, K., Osbeck, M., Tonderski, A., & Olsson, O. (2019). Enabling policy innovations promoting multiple ecosystem benefits: Lessons learnt from case studies in the Baltic Sea region. *Water Policy*, *21*(3), 546–564. https://doi.org/10.2166/wp.2019.054