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COMMENT

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Flood risk management through a resilience lens

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To prevent floods from becoming disasters, social vulnerability must be integrated into flood risk management. We advocate that the welfare of different societal groups should be included by adding recovery capacity, impacts of beyond-design events, and distributional impacts.

Societies have prospered in river valleys, deltas, and coastal areas thanks to effective strategies to cope with flood hazards. However, floods have been increasing in frequency and severity due to climate change and increasing exposure. Governments worldwide aim to develop strategies to reduce flood risks, usually favoring the measures with the largest risk reduction benefits and the lowest costs for a range of sufficiently likely hazard events. Here, the costs conventionally considered are the direct damages.

The high impact of recent extreme but rare events such as the 2022 floods in Pakistan and Malawi, the July 2021 flood in Northwestern Europe, the devastation due to Hurricane Iota in the Central Americas (2020), or the 2017 flooding of Houston, Texas, have brought us to rethink flood risk management. In conventional risk analyses rare, extreme events typically have little importance, because the expected annual damage–the indicator of conventional risk approaches–is often dominated by events that have a high probability but cause relatively low damage. Risk reduction measures conventionally aim to reduce direct impacts and total flood risks while minimizing costs. In contrast, it is rarer for measures to be implemented that enhance the ability to cope with flood hazards and to recover rapidly, to reduce indirect flood effects and to account for the distribution of impacts over wealthier and poorer communities[1] This may result in strategies that amplify existing inequalities, promote already wealthy societal groups[2] and neglect disastrous outliers.

Climate change and the related increase in flood hazards require additional investments into flood risk management. This opens a window of opportunity to ensure new investments contribute to a fairer and more resilient world. We argue that policy makers should adopt a resilience lens that utilises more comprehensive analyses, rooted in societal welfare.

Adopt a resilience lens

To develop flood risk management strategies, governments need to consider what really matters, namely how and over what period floods affect societal welfare. To do so, we advocate the adoption of a resilience lens in flood risk management. Here, resilience is understood as the ability of a society to cope with flood hazards by resisting, absorbing, accommodating, adapting

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to, transforming and recovering from the effects of floods on people's welfare[3,4]. To analyze and enhance resilience, we need to consider how and over what period floods affect societies and how measures could affect flood impacts and society[5]. Questions to consider include whether floods will hamper economic activities; whether people can earn sufficient income or their livelihoods are destroyed and whether their health will be affected.

Adopting a resilience lens means taking societal welfare as our starting point. From there, the interaction with flood hazards and flood risks can be considered[6]. For frequent events resistance may be required to allow societies to continue functioning without facing frequent damage. Damage as a result of rare and extreme events may not be avoidable, but such events must be included in our considerations in order to make sure that those events, although damaging, do not turn into disasters. This requires a deep understanding of what makes people vulnerable to floods and how resilience can be improved. We offer four elements linked to this resilience lens to understand what makes a flood disastrous. We aim to enable an informed discussion on how to arrive at appropriate flood risk management strategies (see Fig. 1).

Impacts on welfare, instead of on asset losses. Floods hit socially vulnerable people harder, because poorer communities often lack the capacity to recover quickly. Vulnerable people or communities have a lower capacity to anticipate, cope with, resist or recover from the impact of hazards[7]. They may be forced to live in hazardous places, have less access to flood warnings, a less effective network to enhance recovery, and fewer resources to protect their homes or livelihoods. Especially people that already live in poverty may need to shift to destructive strategies such as selling land or cattle or consume seeds to meet other short-term needs. Such strategies can lead to a vicious circle.

Using absolute asset-based damages as yardsticks, as is often done in flood risk management, largely underestimates the disproportionally large welfare impact relatively small absolute losses can have on poor people and may lead to biased planning[8]. As one dollar does not count equally for all people, flood risk planning should move beyond asset-based valuations and put the welfare of people at the core of the assessment[9]. This can be done, for example, by considering social impacts such as loss of houses (irrespective of their value), deprivation cost, loss of percentage of income, or considering the effect on income generating ability.

There are further merits to placing welfare upfront. First, it opens the possibility of better aligning flood risk management with the larger development agenda[3], for instance by linking flood risk management to spatial and economic planning. Second, it allows for a better inclusion of non-structural measures in flood risk management strategies, such as adaptive social protection systems that can quickly disburse financial assistance to households when a disaster hits[10]. Such measures may not reduce asset-based damages but can have significant benefits of increasing recovery rate and dampening welfare losses.

Recovery capacity. When recovery from floods takes longer, the impact of the floods is more disastrous because of the many indirect and cascading effects, which often exceed the direct damage[11]. Differences in flood impacts across societal groups

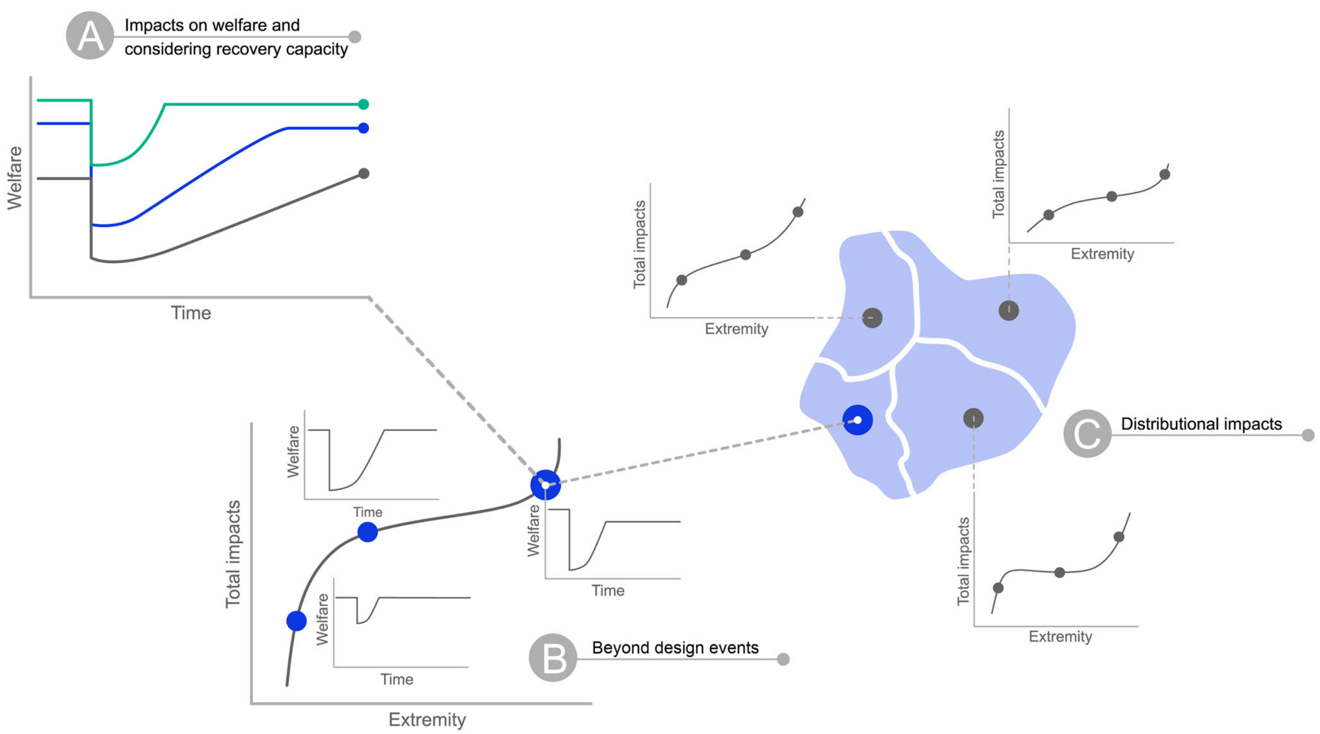

Fig. 1 Adopting a resilience lens by operationalizing the four elements into an integrated flood risk management approach. A welfare and recovery capacity (element 1 and 2): Different effects of floods on different areas or societal groups: some have a larger deterioration of welfare or a slower recovery than others. Both the maximum impact and the recovery together determine the impact of a flood disaster. **B** include beyond-design events (element 3). The grey curve shows the impacts as a function of event extremity. The standard assessment integrates over this curve and uses the resulting expected annual damage as risk measure; this aggregation undermines the role of high-impact but low-probability events. The extreme events must be given attention as well; (**C**) distributional impacts (element 4). Distributional impacts can be considered spatially or for different social groups. Welfare economics principles can be applied to capture the utility of different communities and vulnerable groups. By aggregating the effects, we may not see how some groups benefit from measures while others pay for them, or still face large risks. Therefore, next to total cost and benefits, also distributed impacts must be used and weighted to enhance equity.

often link to differences in their ability to recover from flood impacts. To recover, physical damage must be repaired and income generating options must be restored. Accounting for disruption of services of critical infrastructure, cascading impacts[12] or addressing people's recovery capacity are thus crucial to understand the impact of floods on societal welfare. If we consider recovery as part of flood risk management, the effect of recovery enhancing measures can be included to reduce longer-term welfare loss. Measures such as citizen training, micro-credits, affordable insurance to compensate for flood losses and improving critical infrastructure (enhancing its robustness, redundancy, or flexibility) then become relevant.

Beyond-design events. The July 2021 floods in Europe have shown the devastating impact of beyond-design events, events that exceed the known risks. The flood peak discharge in July 2021 in the Ahr valley was roughly five times higher than the extreme event scenario of the official flood map[13] and its return period was estimated to be around 500 years. Such an event was beyond the imagination of people and authorities, which led to high numbers of fatalities and massive destruction.

The complexity of flood risk systems, limitations of scientific knowledge but also motivational and cognitive biases in perception and decision making contribute to such surprises[14,15]. In many regions, climate change and other drivers of change, such as population growth or increasing vulnerability, lead to more frequent situations where current protection systems are overwhelmed. Our third element targets this blind spot of flood risk management: extreme events beyond current design standards to prevent disastrous surprises.

This can be done for example by using a storyline approach, narrative scenarios or training exercises and simulation games that stimulate decision-makers to think through the full disaster cycle. Such exercises are known to inspire discussion of potentially long-term unexpected or unintended cascading effects across different systems[16]. Outliers in ensemble forecasts may be used as a starting point for such scenarios. These explorations guide dialogues towards achieving the desired level of protection and preparedness for extreme events, to reduce the impact to the most crucial objects, locations, or groups of a society, and provide the basis for training of decision-makers.

Distributional impacts and equity. A resilience lens requires asking the distributional questions of "the five Ws"[17]: for whom, when, what, where, and why? Most flood risk analyses aggregate risks and flood protection benefits and disregard their distribution across people, space and time. The resilience lens requires unpacking this aggregation by assessing the distributional impacts of alternative measures. Making explicit who wins and who loses can support distributive justice and prevent unintended distributional consequences. Additional measures for compensating worse-off groups can also be prepared. It is one option, for example, to target flood risk protection measures[18] at the most socially vulnerable instead of selecting measures based on utilitarian principles. To do so, a risk analysis that shows distributed impacts on a range of social groups and regions must be carried out. These distributional questions also play out between current and future generations (intergenerational justice).

The distributional performance of alternative plans can be assessed through a normative analysis. Various ethical principles drawn from theories of distributive justice can be operationalized to evaluate the fairness of alternative measures[19]. Multiple principles can also be combined. In the Netherlands, the flood protection standard is designed such that every person has at least a minimum level of safety (sufficientarian principle), while additional safety margin is allowed if it is economically sensible (utilitarian principle)[20].

Moving forward

We make a plea for more comprehensive, better-informed and transparent decision-making which allows an open discussion of inherent trade-offs between different values or ambitions, and makes transparent the impact of flood risk management over space, time and population groups. Disparities in flood risk and in effects of risk on people's welfare should be understood and transparently shown to enable decision-makers to take equitable and effective decisions and to prevent increasing inequity due to climate change.

We now have the appropriate tools and methods available to adopt a resilience lens by analyzing distributional impacts, by assessing impacts on welfare, and by including recovery and longer-term consequences for both design and beyond-design events. Using this broader perspective will lead to other flood measures that better serve our joint journey towards a more just and resilient world.

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Competing interests

The authors declare no competing interests.

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