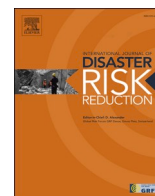


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Multidimensional resilience - flood recovery on private land

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ABSTRACT

Flood damages are increasing and thus flood resilience is gaining importance. Various definitions of resilience and the identification of different resilience dimensions have been the focus of past research, but there is a lack of understanding how these dimensions systemically interrelate. Using an exploratory research design, this study examines multidimensional resilience in the context of flood recovery on private land. The results show that physical, social and financial resilience dimensions are part of the recovery process. The dimensions can have conflicting impacts on each other, meaning that a trade-off has to take place between two dimensions. Further, dependencies have been detected, the increase of one resilience dimension depends on others. In the case study there are also projects being implemented that create synergies between different resilience dimensions. This requires coordination between the involved stakeholders. Only limited attention has been put on the interrelations between different resilience dimensions, increased coordination is therefore necessary. Applying a multidimensional resilience understanding allows the inclusion of different perspectives, which helps to reach an understanding on flood resilience of a whole system.

1. Introduction

Increasing flood damages are a challenge for society. Growing wealth, population development, settlement expansion, and climate change influence the rise in flood damages [1–4]. This development and its uncertainty pose a challenge to flood risk management [5]. Against this background, flood resilience has gained importance [6–9].

There are different understandings of resilience. The understanding of engineering resilience describes a system that can absorb the impact of a shock and return to its original state [10,11]. Applying this concept to flood risks would see the recovery process as a way of returning to normal. However, returning to the original post-flood condition could result in past vulnerabilities remaining [12]. The ecological and evolutionary understanding of resilience includes the ability of a system to adapt [10,13]. This underlines the chance of the recovery processes to increase resilience [14,15]. Within this research, resilience describes the ability of a system to absorb a shock and adapt to it.

Resilience is especially relevant during recovery processes, as a shock, such as the impact of a flood event can offer a ‘window of opportunity’. After a flood event, “[...] damage and destruction open the possibility of rebuilding otherwise [...]” [14]. However, disasters don’t necessarily lead to change [16]. For example, due to time constraints and the wish to rebuild quickly, the recovery

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process can lead to bouncing back rather than forward [16,17]. Recovery is not a detached process simply focusing on restoring; an overarching approach is essential [15,18]. The recovery process should, therefore, also include reducing flood risk via “building back better” [19]. Building back better entails bouncing forward (referring to structural and non-structural measures) after a shock in order not to recreate past vulnerabilities [19,20]. This understanding is inclined with the ecological and evolutionary resilience understanding. The recovery process is not only about rebuilding, but also adaptation.

Increasing flood resilience during the recover process includes measures taken on private and on public land. There is a broad selection of research focusing on flood resilience and the public sector; it discusses infrastructure damages [21], nature-based solutions [22] and policy learning [23] among others. However, private land is also considered essential in the debate on flood resilience [24]. While flood risk management has long been considered the responsibility of public authorities with a focus on flood defense, this has shifted towards a distribution of responsibility [25]. Measures taken by homeowners are important considering this debate on shared responsibility [26]. Mitigation measures on private land can significantly reduce the damage potential [27,28]. Further, flood risk management often needs private land, for example, for nature-based solutions [29]. In this context, it is also especially relevant to understand the motivation for homeowners to implement private adaptation measures [30] and how to communicate flood risk advice [31]. Private land and homeowners are vital to increase flood resilience.

There are different measures in connection to private land that can increase resilience during recovery. Building back better can, for example, include waterproofing windows or paying attention to the location of oil tanks [32]. Further, financial support can help recover after a flooding event [17]. Financial support can include public funds, insurance, investments, and private household savings [33]. Besides physical and financial measures, social networks can enhance the adaptive capacities of a community [34]. The involvement of citizens in flood risk management depends among other things on risk awareness, motivation and knowledge [35]. Increasing the resilience of a system can therefore also include creating a sense of community [36]. Consequently, a system can apply physical, social and financial measures to increase resilience.

While there is research looking at physical [32], financial [17] and social resilience [37] within flood risk, we don't know how these dimensions interrelate. Identifying the interrelations between physical, social and financial resilience within a system is therefore the aim of this paper. This is relevant, because a system, such as a community or city consists of built, natural, social and economic environments influencing each other [38]. And “[...] some of the most crucial and interesting research challenges concern the interfaces among these different environments.” [39]. Increasing flood resilience within such a complex system relies on understanding the influences and interfaces between the different dimensions. Research for example shows, that the social context can impact the physical recovery [40] and the financial dimension can depend on the social [34]. If the increase of one dimension can lead to the decrease of another, this trade-off needs to be acknowledged during recovery processes. Finding a balance between the dimensions depends on the context, which shows that resilience is a dynamic concept. This underlines the fact, that resilience is a political concept [41]. Our research will help to explain how the dimensions are interrelated, which will support a better understanding of the complexity of resilience.

This explorative study investigates each dimension in connection to private land and their interrelations. Because the recovery process offers the possibility to increase resilience, a respective case study will be examined. The following research questions will guide the research: (1) How are physical, financial and social resilience dimensions (referring to private land) part of the recovery process? (2) How are these resilience dimensions interrelated? The first part of the research will look at measures taken that help to absorb or adapt to the flooding. The second part will look at the interrelations. To answer the research questions a qualitative research approach was chosen. This includes non-participatory observations, a document analysis and 12 expert interviews with stakeholders involved in flood risk management, the public sector, planners and civil society. The material was analysed according to an analytical framework using a qualitative content analysis. Researching the interrelation of different dimensions will help to better understand how resilience can increase in order to meet the current and future challenges of flood risk. The results will add to research on flood resilience on private land by looking at it from a multidimensional perspective.

After the introduction, the subsequent chapter will define multidimensional resilience and present the analytical framework. Then the description of the methods and case study area will follow. Afterwards, in the results section each dimension will be discussed, before going into the interrelations. The topic will then be further deliberated in the discussion chapter and a conclusion will sum up the key findings.

2. Multidimensional resilience

There are different understandings of resilience [6,40,42]. Multidimensional resilience builds upon the understanding that a system can apply measures within the social, physical or financial dimensions to absorb a shock and adapt to it. Absorbing a shock can be understood as maintaining essential functions [13] and therefore limiting the impact of a shock. Adaptation describes system changes oriented toward future developments [43,44], which helps to be better prepared for future flood events. A resilient system is therefore constantly evolving.

‘System’ is a frequently used term in the resilience debate, however referring to different concepts. It can describe different scales, from individual people to communities or whole socio-ecological systems [37]. The definition of the system boundaries opens up the question of ‘resilience for whom?’ [45] or ‘whose resilience?’ ([10,46]). Within this research the focus is on measures on private land and actions taken by individuals. However, this does not limit the system to individual building plots. It is rather acknowledging the role private property (owners) play to increase the resilience of a city or region.

Based on this understanding, multidimensional resilience includes measures that help affected regions and cities maintain or restore essential functions. Further, changes that are implemented in order to adapt to future flooding are of relevance.

2.1. Social dimension

Social resilience includes social cohesion within a community, connection and trust towards governmental organizations and the networks between communities [47]. In addition, individual skills, knowledge and awareness are also part of social resilience, especially in connection to private flood adaptation [27,48]. Social resilience is an essential part of flood resilience, as it is considered necessary to move beyond engineering resilience (to adaptive resilience) [49]. For example, existing social networks can offer the possibility for affected people to find short-term accommodation with neighbours. This supports the basic need for shelter. The social network, therefore, helps to absorb the shock. Flooding can increase awareness and knowledge on how to act during flooding. This can help to be better prepared in the future, influencing the adaptation to flooding. There is a link between resilience and social capital, which is more discussed by Carmen et al. (2022) [50]. Social resilience during the recovery process focuses on the diverse abilities and connections of a community and on individual skills in order to absorb a shock and adapt to it.

2.2. Physical dimension

Private land offers a lot of possibilities to increase physical resilience. The responsibility for private adaptation is even referred to in the German Water Legislation (§5 WHG), stating that possible mitigation measures have to be taken by homeowners. This adaptation can, for example, be the location of the fuse box on the first floor or an emergency power generator [32]. These adaptation measures can be taken during recovery process by private homeowners, which would help in the case of future flooding. The physical resilience dimensions is however not only focused on the built environment, but also on the natural environment [22,47,51], which can for example include nature-based-solutions. Private land is especially relevant within the physical resilience, as it often is the space where adaptation measures can take place.

2.3. Financial dimension

A diversity of financial resources can support a system to absorb and adapt to a shock. This includes private household savings, support from public administration and insurance [17,33,52]. For example, public funds such as emergency disaster funds are often needed to help homeowners to absorb a shock. Further, flood insurance for private homes is a means to adapt to flooding and be better prepared financially. A diverse range of financial support and savings increases flood resilience.

2.4. Interrelations

Only limited attention has been put on the interrelations between flood resilience dimensions. Various authors have identified resilience as multidimensional, using the dimensions to measure resilience based on a collection of indicators [48,53,54]. Almutairi et al. (2020) for example identified indicators within different resilience dimensions such as social and economic to measure coastal community resilience [55]. While there is a common understanding, that resilience can be described through different dimensions, there is lack of in-depth focus on how these dimensions interrelate. However, “communities are composed of built, natural, social, and economic environments that influence one another in complex ways.” [38]. Increasing resilience of a community, therefore needs to include the different environments and how they influence each other. To get a better insight into this complexity, this research studies the way the dimensions interrelate. It produces a framework that focusses on describing the interrelations to support a better understanding of resilience (see Fig. 1).

The framework also has practical relevance. One the one hand, by considering the different dimensions it acknowledges the broad spectrum of stakeholders involved in the recovery process. Different stakeholders focus on different resilience dimensions,

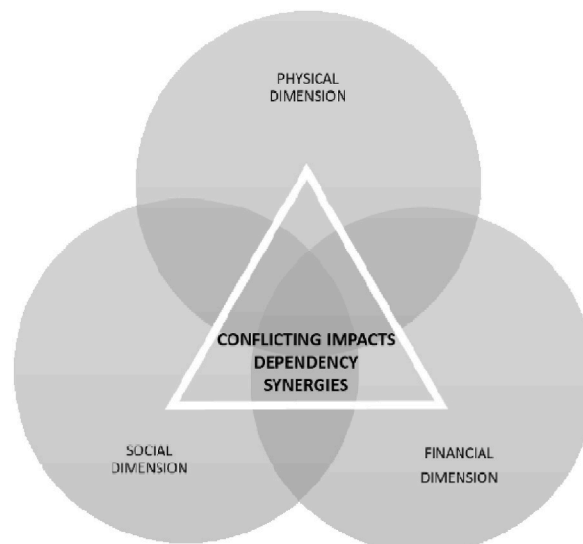


Fig. 1. Multidimensional resilience framework.

understanding the interrelations can help to consider the variety of perspectives and how they connect. On the other hand, flood risk management and recovery strategies have to be aware of these interrelations, in order to find a balance between different resilience dimensions. Or to at least be aware of the impacts, that decisions to focus on one dimension can have on a resilient development. A multidimensional approach to recovery considers all three resilience dimensions and their interrelations.

Case studies and other empirical evidence reveal that different resilience measures can impact each other. A case study shows, that high financial resilience prevailed against physical resilience. After the destruction of train tracks during a flooding, they were reconstructed at the same place. The argument made by the company was that it was less effort to rebuild it at the same spot than to move it somewhere due to "property rights and planning issues" [41]. Besides conflicting impacts, there can also be a dependency of the financial resilience on the social dimension. Individual economic preparation increases when social relations and trust within the community and towards public authority exist [34]. In addition, research shows complementary interests between the physical and the financial dimension. During the recovery process there could be possible synergies between financial resources available and flood-adaptive rebuilding, which is however lacking in practice [17]. Different measures impact each other, showing that interrelations can be observed between different dimensions.

Interrelations are therefore not simply the connection between the dimensions, but the impact they have on each other. There is research using different indicators to measure resilience (ex.: [53]), however there is a lack of qualitative understanding of how different resilience dimensions interrelate [56]. Research shows that there can be trade-offs and synergies between ecosystem services [57]. Similarly within the sustainability research the interactions between different goals or systems are separated into conflicts and synergies [58]. Within our research, multidimensional resilience includes conflicting impacts and synergies as well as dependencies, which were detected in other case studies.

3. Methodology

Due to a lack of research into the interrelations of resilience dimensions an exploratory case study approach according to Yin (2008) [59] was chosen. A case study is able to research a phenomenon in the real-life context [59]. This is especially relevant if the context and the phenomenon are not strictly separated, as is the case of our research. Since this research is aiming to better understand resilience and not measure it, qualitative methods were applied. This includes observations, document analysis and interviews. This triangulation of data facilitates the answering of the research question.

3.1. Methods

This research evolves around two research questions; (1) How are physical, financial and social resilience dimensions (referring to private land) part of the recovery process? (2) How are these resilience dimensions interrelated? In three research steps we aim at answering these questions, while all three methods feed into both research questions. First events discussing the recovery process were observed, gaining an insight into the process and the relevance of resilience. To deepen this first observation, a document analysis was applied. As a last step, expert interviews were conducted in order to go a step further and gain insight knowledge on resilience dimensions and the interrelations.

3.1.1. Observations

In order to get an overview of the situation on site and gain quick but informative knowledge of the recovery process in Rhineland-Palatinate and North Rhine-Westphalia events on the topics of resilience, recovery and flood risk were visited. One public event and one non-public meeting was held by the Flood Competence Centre (HKC) and one other public event was organised by the Association for Urban, Regional and State Planning (SRL). The events included discussions of a broad range of stakeholders on the recovery process. During these sessions, the method of non-participatory observation was applied, and a protocol was composed. The protocol focused on discussions on resilience (social, physical and financial) and on possible interrelations that were mentioned. This step was an exploratory way to gain a first insight into the topic of resilience during the recovery process. It therefore catered to answering both research questions. Stakeholders from different disciplines (e.g. water management, spatial planning, insurance, public sector, etc.) were taking part in the events. This showed that various disciplines are involved in the recovery process, which were then also represented in the discussions.

3.1.2. Document analysis

Starting from the information gained during the events, the next step was a qualitative document analysis. Besides enhancing the overall knowledge on the recovery process, it was used to detect resilience dimensions and possible interrelations within formal documentation. This step therefore builds on the information gained from the observation and further extend it. In total 6 publicly accessible documents about the recovery on a national and county (Länder) level were analysed. This includes the reports and follow-up documents on the recovery process of Rhineland-Palatinate, North Rhein-Westphalia and on a national level. A document analysis has the advantage that it usually requires few resources to get the documents [60]. The non-participatory observations and document analysis served to get an understanding of the recovery process and detect first aspects of multidimensional resilience.

3.1.3. Expert interviews

With the purpose to deepen the understanding of the dimensions and their interrelations and gain perspectives from different disciplines, semi-structured expert interviews were conducted. Qualitative interviews as a research method are broadly used within social sciences [61,62]. An expert interview aims to gain specific knowledge from experts in their field [63]. Because it is a semi-structured interview, a guideline as an outline helps to lead the interview. Depending on the interviewee's response, this leaves

Table 1

a: Analytical Framework - Dimensions.

	Categories	Examples
Dimensions	<p>Physical dimension: Build and natural measures to absorb a shock, and adapt to it.</p> <p>Social dimension: Social networks and individual knowledge that serve to absorb and adapt to a shock.</p> <p>Financial dimension: Financial measures to support the ability to absorb and adapt a shock.</p>	<p>Location of the fuse box, private flood adaptation during the recovery process (for further examples see [32])</p> <p>Existing social networks, raising awareness after a flood event, helping each other out, trust towards governmental organizations.</p> <p>Private or public funding to support the recovery process, incentives for adaptation measures during the recovery process, financial reserves, income.</p>

b: Analytical Framework - Interrelations

	Categories	Exemplary Description
Interrelations	<p>Conflicting Impact</p> <p>Dependency</p> <p>Synergies (Complementary interests)</p>	<p>The increase of the social dimension leads to a decrease of the financial dimension, leading to a trade-off.</p> <p>The social dimension can only increase if the financial dimension increases, which makes one resilience dimension dependent on another.</p> <p>The increase of the social dimension leads to the increase of the financial dimension, which leads to synergies between the dimensions.</p>

room for further in-depth discussion [61]. The interview guideline was based on the literature research and structured as followed: the tasks of the interview partner, measures taken during the recovery process and measures that could be implemented for a resilient development. Further the coordination with other stakeholders and the tasks of other stakeholders were discussed. In addition, the window of opportunity and what chances the recovery process offers was part of the interview guideline. The interviews help to enhance the information on resilient recovery based on real-life situations, processes and projects.

The overview of the relevant stakeholders gained during the events helped to find and get in contact with interview partners. The interview partners inhabit different functions in relation to the recovery process, such as being directly affected by the flooding and therefore directly involved from the start. Others have a more outside-perspective and they are involved and informed due to their expertise. We interviewed politicians on a local and regional level, administrative staff, flood risk managers from water boards, planners, engineers and heads of companies involved in flood risk management topics, civil society, and an expert on insurance. Some interview partners inhabit more than one field of expertise, see Table 2. In total, 12 interviews with 13 experts were conducted. One interview could only be done written via e-mail; the rest was in person (or via videoconference). The interviews were held in German and recorded as well as transcribed. For the results section specific quotes were translated to English.

3.2. Analytical framework

The interviews and documents contain the information to answer the research questions. A systematic analysis is therefore necessary to get the most out of it and not overlook essential information. Hence, this research applies a qualitative content analysis according to Ref. [64]. As the aim is to get a better understanding of multidimensional resilience the three dimensions (Table 1a) and their interrelations (Table 1b) are used as categories. This analytical framework was developed for this research, based on the literature discussed in section 2. Using these categories, the documents and interview transcripts were analysed systematically using MAXQDA.

3.3. Case study area

In July 2021 Germany was affected by extreme pluvial flooding. The storm Bernd mainly hit Rhineland-Palatinate and North Rhine-Westphalia (see Fig. 2), but also Bavaria and Saxony. The recovery process in Rhineland-Palatinate and North Rhine-Westphalia serves as a case study for our research.

The flood event affected many people and was the event with the highest damage since 1962 in Germany [65]. Insurance losses concerning residential buildings, household goods and businesses amount to € 6.500 million, for motor vehicles it was € 450 million

Table 2

Interview partner.

Interview partner	Field of expertise
1, 2, 5, 7, 8, 13	Water and flood risk management (ex.: water board, hydrologists, Private flood risk prevention)
4, 9a, 9 b	Public sector (administration and politics)
10, 11	Planner (ex.: architects, infrastructure planning)
3, 11, 12	Civil society (ex.: civil initiative, affected people)
6	Insurance

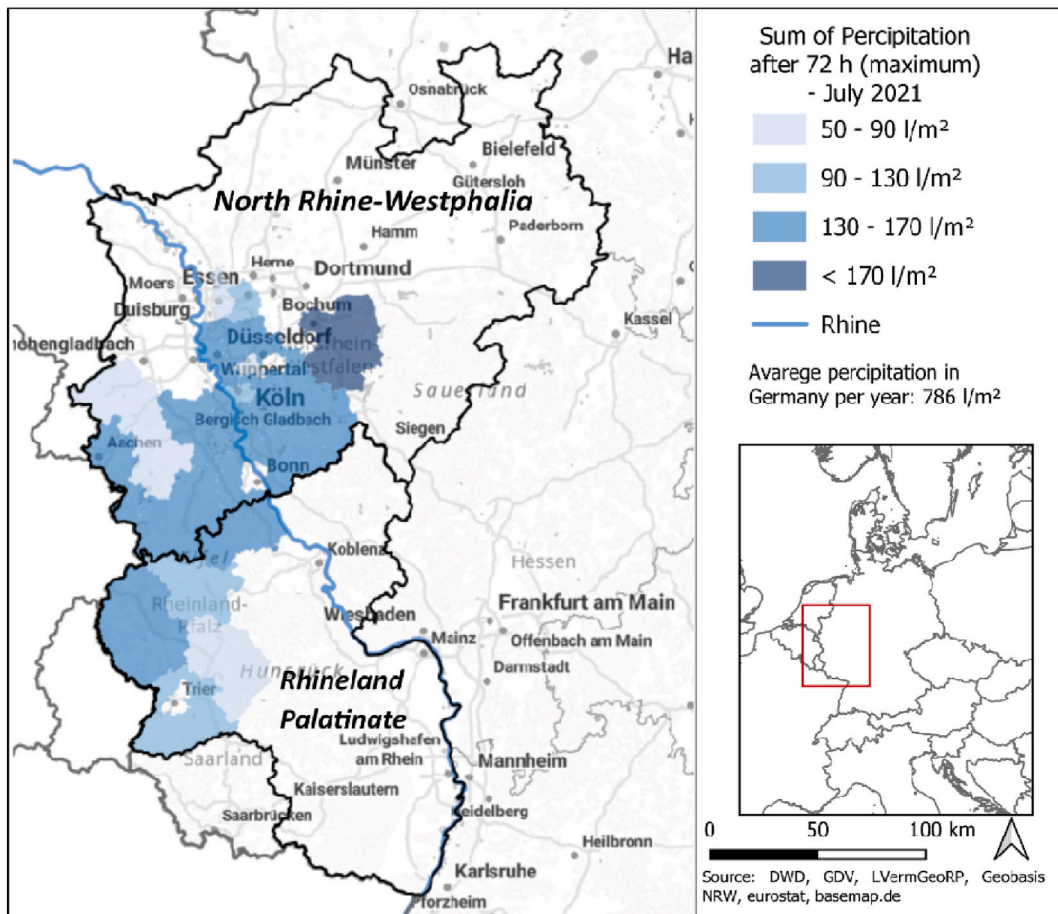


Fig. 2. Affected regions in north rhine-westphalia and rhineland palatinate.

[66]. More than 180 lives were lost, and more than 800 people were hurt. In North Rhine-Westphalia as well as in Rhineland-Palatinate private households were among the most affected areas [65]. The reason for the massive damage was on the one hand the heavy rain. On the other hand, the dense construction, the high proportion of sealed surfaces and limited retention areas also impacted the flood damages [65].

This research was conducted approximately one year after the event in May and June 2022. One year after the event, some people could move back into their houses, while others were still living in temporary accommodations [67]. There were still signs of the damage in the region, but there were also long term visions being discussed [68].

4. Results

The interviews underline the importance of private responsibility for a resilient recovery. A resilient recovery in this context includes a resilient development, meaning adaptation and transformation measures [10] as means to build back better [19]. The distribution of the responsibility between private and public with regard to the recovery process was discussed during the interviews. Often flood risk management is seen as a state responsibility, and measures on private land still need to be improved. “The state and the municipalities will not be able to protect everything; it is also on the citizens to implement prevention measures.” (I9). There is a need for an increased resilience on private land, which includes a variety of measures. This is reflected in the multidimensional resilience approach.

4.1. Resilience dimensions

4.1.1. Social dimension

The Ahr Valley was the area mostly affected by the flooding. During the recovery process, up to 100.000 volunteers showed their support alone in the Ahr Valley [65]. This shows the high degree of willingness to help, that goes beyond the borders of the affected region.

The interviews and documents discuss social networks and their relevance during the recovery process. The interview partners communicated that there was strong cohesion, high solidarity and helpfulness after the event. “[...] you experienced the sense of

community. [...] especially because of the support of private people, it was an incredible thing, that also helped mentally, that was really special, meeting so many strangers." (I11) The support within local communities did decline over the year that passed between the event and the interviews (I4). However, help was still present (I11).

Besides the existing social networks that can help absorb a shock, actions taken during the recovery can also further increase this cohesion. Spaces are created to foster personal exchange. For example, quickly repairing local recreation areas offers people space for interactions (I4). Similarly, the documents describe a Pop-up Mall, which besides shopping serves as a point of exchange for communities. Further, the recovery report in Rhineland-Palatinate describes a round table for the recovery of social infrastructure focusing on its sustainable reconstruction. These are all measures to create spaces that can increase social networks.

Further awareness and knowledge are prominent topics in the material. The flood of 2021 increases awareness, which however decreases again over time, referred to as 'flood dementia' by interviewees. "Resilience also means that the public needs to be sensitised [...]" (I9). It is about knowing what is possible and accepting the existing risk.

4.1.2. Physical dimension

In the aftermath of the flooding, quick solutions were needed to provide shelter for people who lost their homes. A new paragraph was added to the building law, which allowed the construction of certain mobile structures that deviated from the building code. This regulation was, for example, used to install provisional 'tiny houses' in Rhineland-Palatinate for temporary living.

Besides the short-term aim of offering temporary housing, the general question is whether damaged houses should be rebuilt in the same spot. The regional broadcasting station states, that within the Ahr Valley, 34 buildings are not allowed to be rebuilt, due to their location in high risk-areas [69]. Research in the Ahr Valley showed, that one year after the flooding, approximately 14% of survey respondents have moved permanently [70]. Detailed information on relocations in the whole research area is not available. The data still shows that it is a prominent topic in the area.

Some interview partners emphasise the need to push the development away from rivers (I2,3,4). This would require suitable and affordable building plots in areas not at risk of flooding as an attractive alternative for homeowners (I8). In some communities, space is limited, so there is no room for new building land away from the river. Resettling is therefore confronted with various challenges.

Besides resettling, rebuilding flood adapted is a key topic during the recovery process. This includes for example flood proof basement, door guards or walls [32]. However, possible measures are often not implemented and the status quo is being rebuilt. There are consultations on property-level flood risk adaptation, for example the KAHR-Mobil, which was implemented in April 2022. Since then, approximately 1.500 consultations were conducted with homeowners. Still, there is no systematic monitoring of actual implemented measures on private land.

With the flood event in 2021, requests for private property flood adaptation were increasing (I2, I7). Nevertheless, what is missing is a clear regulation on what is understood as flood adapted. "The people rebuilding in the Ahr valley receive a building permit, and the notice says that flood adaptation measures are required. [...] The planner and executing companies can only rely on very limited regulations and norms; there is hardly anything there." (I6) The lack of clear regulations makes proper implementations difficult. Private adaptation measures are often implemented as part of a consultation. Not one system fits all, and it is often helpful to be on-site to see what is possible (I2, I3). Private flood adaptation is not a simple and easy fix, but requires the input of experts.

4.1.3. Financial dimension

In Germany, an average of 52% of buildings are insured against natural hazards, in North Rhine-Westphalia this amounts to 56%, while in Rhineland-Palatinate it is 46%. 124.000 insured damages were reported in North Rhine-Westphalia, which results in € 5.1 billion refunds. In Rhineland-Palatinate 20.000 damages worth €2.7 billion were conducted [66]. The public funding by the state will be up to €30 billion; Rhineland-Palatinate will receive 54,53% of the funding and North Rhine-Westphalia 43,99% (the rest will go to Bavaria and Saxony) [71]. These funds will be separated between private households, businesses, and public facilities.

One of the main financial supports during the recovery process is the disaster relief fund. Public funding is necessary because homeowners' private savings are often not sufficient to cover the damage (I1, I3, I7). Two funds support people affected by flooding. The emergency fund and the recovery funding for medium and long-term support to repair the damage caused directly or indirectly by the flooding [65]. Information centres in affected areas were installed, and a mobile information truck and on-site visits took place to support households in applying for the funds (I9, I10). The funding scheme in Germany offers much needed financial support for homeowners.

Besides public funding, the insurance coverage offers financial support. Households with insurance are not eligible for public funds (with exceptions). There was a critique that households with insurance needed to wait for an expert to evaluate the damage before it could be repaired. This led to a long waiting period in some cases (I13). Flood insurance can help to be financially better prepared for future flooding, but it also comes with difficulties.

4.2. Interrelations of dimensions

4.2.1. Conflicting impacts

A challenge during the recovery process is the conflict between time pressure and long-term adaptation plans. Most interview partners acknowledge the chance the flood offers to rebuild different. However, there is also the expectation of affected communities to rebuild quickly; " [...] there is a mindset to get through it quickly and forget all the bad." (I1). "The discussion if it is even resilient to rebuild at the same place is not been held to that extend." (I3) It is important to 'get back to normal'. If the recovery takes a long time, it can take a strain on social networks, as the willingness to help can decline over time (I4). The wish for a quick recovery can stay in conflict with the implementation of proper flood adaptation, as a means to bounce forward.

A part of bouncing forward could be resettling of damaged houses, which is however a complex topic. Moving houses out of hazard areas would lead to a decrease of damage potential. Hazard maps can offer an objective basis for resettling (I 3, I5, I8). The space is however limited by the spatial situation (topography, limited space) of municipalities in some of the affected regions such as the Ahr valley.

Besides the physical component of resettling, there is also the emotional aspect of the homeowners that need to be acknowledged (I5, I8). There can be an existing social network within a community which is an argument against moving away. "So, they say, we have been living here for years, and the family has been living here for generations, [...] and we want to stay here and rebuild here." (I8). And "The people that come from here, they really want to rebuild here, stay here and start new in their known environment." [72] The existing social networks within a community and the emotional attachment can impact resettling programs and may be conflicting with relocating outside hazard areas.

4.2.2. Dependency

The results show that the successful implementation of certain measures to increase resilience depend on other measures. It has been commented by some interview partners, that either public funding or insurance money would be necessary to increase private adaptation measures during the recovery process (I2, I6, I13, I7). At the moment physical adaptation measures (with some exceptions) have to be paid by the homeowners. Due to a lack of economic resources and knowledge this is however not sufficiently implemented (I2, I13). "[...] maybe they [homeowners] cannot afford it, I don't know. In any case, it's difficult to actually have such a resilience of recovery, the way I'm observing it at the moment, it could go even better. People are still very fixated on the status quo." (I7) The support of insurance companies varies greatly depending on the company. Generally, insurance companies support rebuilding a house of the same type and quality. Insurance companies do not pay for flood adaptation; the households must cover the additional costs themselves (I6, I2). There are limited insurance companies that fund private adaptation measures. "From a prevention point of view, it would be good if [insurance companies] also pay for adaptation, but that would have to be included in the insurance premium." (I6). The reduction of the insurance premium due to flood adaptation does not work as an incentive. Public incentives or funding via the credit institute for private adaptation measures would be helpful (I6).

The financial support via public funding is a challenging process for homeowners. In order to support affected people during the application process, information booths (mobile and fixed) have been organised. "We are still present at multiple locations. At the beginning there were consultations in more or less every municipality. [...] In the best-case scenario, the application will be sent at the end of the consultation." (I9) In many cases, the professional consultation from public authority is necessary to be able to apply for financial support. The need for professional consultation also extends to the implementation of flood adaptation measures during the rebuilding process. "A good recovery should be accompanied [by experts]." (I1).

4.2.3. Synergies

Different stakeholders are involved to develop synergies. An example of involving the public in the recovery process is the so-called 'future-conference' (Zukunftskonferenz). It was a participatory event to discuss the future of the Ahrtal [72]. The idea for the event was to allow all ideas to be discussed without limitations. The 'future-conference' did not extend further at the point of the interviews, but one interview partner suggested different working groups would be helpful (I4). Such an event can help, on the one hand, to further develop the Ahrtal, but it also plays into strengthening social networks.

Having discussions about the recovery and the future of affected areas also includes private adaptation measures. While some rare insurance companies pay for flood adaptation during the process of rebuilding, it generally has to be covered by the homeowner. However, this is often not implemented. In the interviews, the lack of clear regulations was mentioned as a reason for limited private adaptation. This could be addressed via the development of certificates and norms. Norms would also raise awareness and give homeowners (and business owners) the opportunity to make informed decisions (I7, I2, I6). Having such certificates would make it easier for homeowners and insurance companies to invest, as they can inform themselves and compare safety levels and costs for specific measures (I2). Clear regulations and norms could support the process of flood adapted building and could also lead to a synergy with flood insurance.

A possible tool of perusing private flood adaptation, awareness raising, and flood insurance is a floodlabel. Floodlabel is an internationally research tool, that offers a holistic assessment of private property to define the current flood risk and recommend flood adaptation measures [73,74]. The floodlabel (Hochwasserpass) referred to in this research, has been developed by the Flood Competence Centre and it is applied in parts of Germany. There are some occasional examples, when an insurance company refers to the floodlabel and includes it into the insurance modus. In some rare cases a floodlabel is mandatory to even get insurance (I7). This cooperation should be extended further (I1, I13, I8). The floodlabel also serves as a tool for awareness (I2). "[...] it is important that people have heard the risk, know it and can assess it for themselves." (I7), and can, therefore, serve as tool to increase adaptation measures in combination with receiving insurance. This complementary approach however is rare in practice and would need further cooperation of the involved stakeholders.

5. Discussion

This research produces a framework that not only analyses different resilience dimensions, but also includes the interrelations. Using this framework, the results show interrelations that can emerge between different resilience dimensions. Interviews as well as the documents show that all three dimensions are addressed during the recovery process. The dimensions can have conflicting impacts, meaning that increasing one resilience dimension can lead to the decrease of another. The results also show dependencies, i.e. the increase of one dimension depends on another. In addition, the empirical evidence also indicates complementary interest between two

or more resilience dimensions, which represents the interrelations as synergies. However, beside the fact that the interrelations are part of a resilient development, there is not enough attention paid to them in practice and in theory.

Conflicting impacts between different resilience dimensions can mainly be found between physical and social resilience in the case study. Private flood adaptation was a main aspect of physical resilience that was discussed during the interviews. Adaptation measures undertaken by homeowners can vary greatly. This can include mobile flood walls and waterproof windows, but it also entails the location of the electricity box for example. Similar approaches mentioned in the interviews and documents can also be found in the literature on private flood adaptation [32].

In our research flood adaptation was described by the interview partners to be in conflict with a quick recovery and the wish to 'get back to normal'. A quick recovery is important for limiting emotional distress [75]. A house is more than merely the physical structure, during recovery it represents privacy, identity, a room for family life and social stability [76]. Providing housing, also referring to temporary housing, is needed to reach some normalcy and restore the livelihoods of affected communities [77,78]. Slow recovery can, therefore, take a strain on well-being and social stability, which is relevant for social resilience. Temporary housing is mentioned as a solution to have the time to rebuild properly after a disaster [77]. This example shows the conflicting impacts of physical and social resilience dimensions.

Resettling is a way to increase physical resilience by relocating out of hazard areas. Due to a sense of place and a strong social network, relocating might not be considered a viable option by homeowners. Social resilience can be lost due to resettling. Resettling is a rather extreme intervention; involved stakeholders might not see the bigger picture and lack an understanding of the consequences it entails [79]. The conflicting interests of physical and social resilience become very prominent in this example and it represents a communication vessel. If the focus is put on physical resilience and people are resettled out of hazard areas it can decrease social resilience. This therefore describes a trade-off between the physical and social resilience dimension.

Understanding that the dimensions can stay in conflict to each other opens up the question in what way different dimensions can outweigh others. This can therefore lead to the necessity to decide which dimension should be strengthened. Here we connect to the topic of system boundaries and the question of 'whose resilience' [10,46,80]. Due to the fact that it is an engineering concept, which is applied to a social system, the question of power is often overlooked, however some people gain, while others lose [10]. The missing consideration of 'politics and power relations' within the resilience debate has been criticized, which is connected to a normative understanding of resilience, because the desired state is often decided by a small group of individuals, putting further strains on already marginalized groups [48,81].

This becomes evident, when there needs to be a weighing of which resilience dimension to favour in case of conflicting impacts. If, for example the public authority puts the focus on physical resilience in order to address flood risk, groups who rely on social resilience might be overpowered by the pressure for physical resilience. The dynamics between conflicting dimensions depends on the political and social context of a system. Within the case study, it can be observed that a strong social network can push towards social resilience and against resettling. Resilience is therefore a highly political concept [41,46]. If we weigh up one dimension against another the question who loses and who wins becomes prominent. The multidimensional framework can help to better understand the question of power within the resilience debate, as it highlights conflicts, dependencies and synergies.

Dependency of the financial on the social dimension exists within the case study, as well as a dependency of the physical on the financial dimension. Public funding is a core instrument of financial resilience of homeowners. Public disaster funding is dependent on the institutional system in place and can vary in other countries [82]. The access to financial support however, can depend on the social status, networks and the access to information [83]. The social coherence within communities was especially prominent in the immediate aftermath of the event. But social resilience goes beyond social networks, and also refers to the relation with other stakeholders and the trust in governmental institutions [47]. Within the case study it was clear, that the process of applying for public funding is a rather complex one. In order to support affected people, it was necessary to establish information booths. These were places, where affected people could go to get the necessary information and apply for funding with the help of experts. Consultation and information are part of social resilience. Social resilience therefore would be necessary in order for financial resilience to prevail. This is especially relevant for social equity to ensure that the social status does not impact the accessibility to public funding [17,84]. To simply have the public economic capacity is not enough, social coherence beyond the community and broad information are crucial in order to access financial resilience.

In addition to public funding, flood insurance is a main aspect of financial resilience. However only some of the affected homes were insured, because there is no mandatory flood insurance in Germany. Public funding as well as private insurance generally don't pay for adaptation measures during the process of rebuilding. Therefore, the public offers financial means to absorb a shock, but does not help to adapt to future shocks. It was pointed out by some interview partners that financial incentives are necessary for homeowners to implement flood adaptation. This could be for example included in the insurance scheme, or public funding can serve as an incentive. We can therefore see a dependency of the physical resilience (especially the ability to adapt) on the financial resilience. This interrelation is especially relevant during recovery processes, as this is often the time when public financial support is made available more broadly. With the financial resilience being dependent on the social and the physical depending on the financial dimension, the connection between all three dimensions is evident.

Synergies that were discovered in the case study area refer to specific projects. For example, a participatory event on the development of an affected region could serve to increase physical resilience, while the event itself offers space for exchange that can enhance social networks. Participatory events can help to offer opportunities where communities can connect and develop networks; and a shared aim can increase the willingness to take active part in a community [85]. Including participatory events in a recovery process can help to increase physical and social resilience.

Another example discussed in the results was the combination of financial and physical resilience. The introduction of labels,

certificates or norms can help to support this synergy. There are rare examples when insurance companies demand a floodlabel, meaning that a building undergoes an expert assessment to determine the level of risk. With the expert assessment, adaptation measures to increase physical resilience can be better implemented. Combining this with private insurance as part of financial resilience can support the absorption of and adaptation to flooding. It would also further increase awareness of homeowners and includes the knowledge on flood risks and an understanding of the responsibility individual people have.

Synergies can be found within specific projects in the case study. In comparison to the dependent and conflicting interrelations, which can be observed in a more general setting. In the case study synergies evolve around the physical dimension and its complementary interest with other dimensions. However, tools with a focus on all relevant resilience dimensions and their interrelations need to be developed. This can help to overcome problems that arise from conflicting or dependent interrelations.

All three resilience dimensions are represented within the interviews and documents. The acknowledgement of all dimensions within the recovery process in Rhineland-Palatinate and North Rhine-Westphalia has to be highlighted. However, the interrelations only got partial attention, which is connected to limited coordination. Different stakeholders often have a stronger focus on only one of the dimensions, water management mainly takes place within physical resilience, insurance companies are part of financial resilience. If and how the interrelations are addressed, therefore, depends on the different stakeholders and how they work together. In addition, different disciplines view resilience differently [41]. An increased coordination is therefore important. The need for coordination within flood risk management [86] and specifically the recovery process has been discussed in other research as well [87]. The framework of multidimensional resilience can offer a view that overarches different disciplines and strengthens coordination.

While some aspects of the results are more context specific, other parts of the research produce generalizable novelty: First and foremost, the development of a multidimensional resilience framework (see Fig. 3). Including the interrelations in the analysis enhances the understanding of resilience. The research provides empirical evidence for the interrelations, pointing out the importance of including them in the resilience debate. This understanding provides further evidence for resilience as a non-static, dynamic concept [88]. If there are for example conflicting impacts, decisions have to be made which dimension(s) to focus on. Weighing different dimensions against each other and finding a balance is subject to political discussion, depending on the context (e.g.: the institutional context). The framework developed in this paper provides insight into resilience as a political concept.

Besides the conceptual relevance of the research, there are practical aspects, that can be derived from the results. The framework can support the development of a resilient recovery strategy. All three dimensions and the interrelations will be included in the recovery process and a balance can be found between them. The development of a recovery strategy can also be done in advance, rather than during a shock [89]. This can help to take the window of opportunity after a flooding and build back better [19]. Further, acknowledging and knowing how different resilience dimensions relate to one another is relevant for planning decisions due to their long-lasting impacts. It can therefore serve as a planning framework, that can establish a multidimensional understanding, in order to increase resilience within a community or a region. For this to happen the exchange between relevant stakeholders must be improved, which requires specific tools and methods. Some examples have been presented in the synergies chapter already, such as participatory events or norms and labels. These synergies show that coordination can bring together different resilience dimensions in order for them to complement each other. The multidimensional framework is therefore a relevant analytical as well as normative planning framework.

The analytical framework has proven to be useful in order to look beyond the individual dimensions and understand the interrelations and how they can impact a resilient development. It's strength is the possibility to be applied to other case studies, as it is not limited to flood recovery cases. The framework offers the possibility to get an overall understanding of a resilience development in

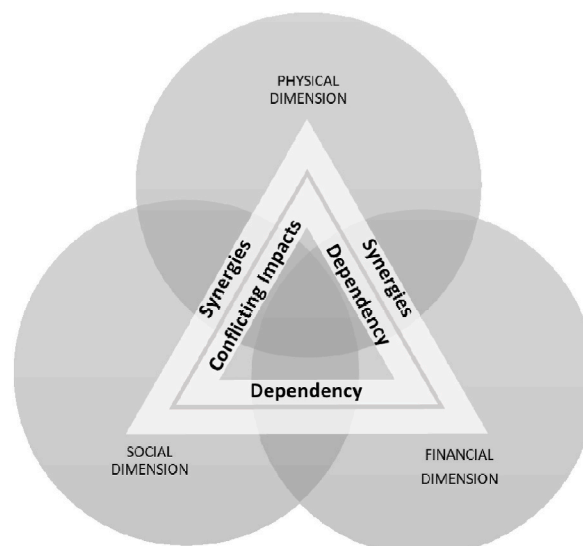


Fig. 3. Framework multidimensional resilience - results.

a study area. If further resilience dimensions are relevant, an extension of the framework is possible. The use of the analytical framework is therefore versatile.

Due to the limited information on interrelations between resilience dimensions an explorative study design was chosen. And while it was the right choice for the research questions, the research design does have limitations.

The chosen methods offer a good option to dive into the topic, especially the expert interviews give insight into the recovery process. However, it has to be acknowledged that the focus was on the perspective of professional experts rather than affected citizen (which are experts in their own rights). The citizen to government relation was therefore only indirectly included through the documents and perspectives of interview partners.

As it is a single case study, certain results are strongly connected to the institutional background it is settled in, for example the disaster funding scheme in Germany. This makes transferability to other continents or even countries difficult. Still, there are more general results, such as the framework that can support the pursuit of a resilient recovery as it can help to develop recovery strategies. It further highlights the different actors that are included in the process and can therefore support the highly necessary coordination.

The focus on one case can also lead to limited results. For example, in literature conflicting impacts can be found between the financial and the physical resilience dimension [41,79]. This did not show up in our empirical data. Additional case studies to research multidimensional resilience and extend the knowledge on interrelations is, therefore, necessary.

Besides extending research using the multidimensional resilience framework, a step further is needed to find tools and methods to apply the framework in practice. Some tools were already mentioned in the synergy section. This however needs to be extended and further investigated. The practical implementation would help to increase flood resilience.

6. Conclusion

Social, physical and financial resilience dimensions are highly relevant during a recovery process in order to absorb a shock and adapt to it. Researching resilience through analysing the three different dimensions presents a way of gaining a broader understanding of resilience that moves beyond discipline boundaries. Because flood risk affects a wide range of stakeholders, bringing together these diverse perspectives can help to increase flood resilience, especially given the uncertainties associated with climate change. Using different resilience dimension to better understand flood resilience is enhanced through analysing the interrelations between the dimensions.

The interrelations show, that the different dimensions are connected and impact each other, which impacts flood resilience. By exploring the interrelations, we could see that there are conflicts, dependencies and synergies between different dimensions. Conflicting impacts can lead to a trade-off between dimensions. This, however, depends on the political context. Being aware of dependencies is especially relevant, as the focus on only one resilience dimension can lead to no increase of resilience at all. Synergies can offer tools as a way to overcome problems that arise through conflicts and dependencies. This requires a focus on more than one dimension and therefore includes different stakeholders and their perspectives. In order to increase flood resilience of the whole system, attention needs to be put on the interrelations. This research therefore developed a multidimensional resilience framework.

Besides a better conceptual understanding of resilience, this framework can also be applied in practice. Using the knowledge on the interrelations for developing a resilient recovery strategy allows an inclusive perspective on resilience. This can also support finding a balance between the different dimensions. Further it addresses the need for coordination. Certain disciplines generally stronger connect to one of the three dimensions. With limited coordination, not much attention has been put on the interrelations. Resources therefore have to be focused on increasing coordination, so that different stakeholders with their diverse resilience perspectives work together. Applying the framework in practice builds on an understanding of resilience as a non-static concept, coordination is therefore required.

While homeowners and affected people are core stakeholders, the multidimensional perspective shows that a variety of disciplines are involved in the recovery process on private land. Private land is a major asset of increasing resilience. It is important to take on this multidimensional resilience perspective, otherwise inequalities can be further enhanced and some might lose while others win. Private land is part of a system such as a city or community and in order to increase resilience multiple stakeholders need to work together.

The research shows the importance of understanding resilience as multidimensional. Using the framework within practice can help to approach flood resilience in an interdisciplinary way that considers the coherent system and not only individual parts of it.

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Data availability

The data that has been used is confidential.

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