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Management of Climate-Related Hazards in Germany through Adaptive Social Protection: The Case of the Ahr Valley Flooding in 2021

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Abstract

In July 2021, unprecedented water levels affected Germany, Belgium, and the Netherlands. From July 12 to 15, 2021, a storm complex stalled over the European region, leading to heavy rain and flooding. In Germany, a month's rainfall fell within 48 hours. Soils were heavily saturated after a wet spring, leading to extraordinary water levels. Due to its surrounding landscape, the Ahr river meanders through the steep rocky vineyards. People settled and built in the areas close to the river, which overflowed its banks. More than 130 died. The floodwaters destroyed critical public infrastructure. Buildings collapsed, roads and railways were destroyed, and thousands lost their homes, causing billions of euros in economic loss. The recovery efforts in Germany continue three years after the disastrous event, despite well-developed response procedures and highly established social protection systems.

Through the literature review using a qualitative case study approach, the article assesses the floods' impact on the Ahr valley and analyzes climate-related flood hazard management processes in Germany. The theoretical framework focuses on policies and programs reducing communities' vulnerability to climate-related hazards while promoting long-term resilience and sustainable development. Transformative change is possible along four building blocks, namely data and information systems, programs, institutional arrangements, and partnerships, as well as finance. Germany can reduce the disaster risk of climate-related flood hazards by strengthening its control and management capacities as well as enhancing readiness and resilience against future climate-related threats.

Keywords: Resilience; Germany; Climate; Floods; Risk

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1. Introduction

Social protection systems ensure prevention, management, and responses to shocks and stressors throughout life, especially for poor and vulnerable people (Davies et al., 2009). Recent developments have increased the need for effective prevention, management, and responses to climate-related hazards. Over the last decades, the human-induced climate has become a significant threat to humans and the planet (Intergovernmental Panel on Climate Change, 2022). As the earth is a complex system where everything is interconnected, even small changes can significantly influence and impact other areas (United Nations, n.d.).

Through social protection policies and programs, countries like Germany contribute to alleviating poverty and creating sustainable and inclusive development worldwide (GIZ, 2023). These measures correspond with achieving the 2030 Agenda for Sustainable Development and its goals to create a peaceful and prosperous world for current and future generations (Press and Information Office of the Federal Government, 2023).

The disastrous flooding in the Ahr valley in 2021 served as an unprecedented stress test for the German social protection system, highlighting the severity of climate-related hazards and their devastating impacts on a regional scale. This event underscored the vulnerability of German regions to extreme weather events. Several critical issues surfaced during the flood, including the effectiveness of early warning systems in ensuring community preparedness, the delivery of adaptive social protection programs during floods, coordination among disaster management actors, and the substantial state expenditures resulting from high damage costs. These challenges emphasize the urgent need for investment in initiatives to manage climate-related flood hazards, adapt to climate change, and enhance resilience to reduce disaster risk in Germany. Furthermore, the flood event revealed structural ineffectiveness concerning the German emergency-type response to manage the disaster in the aftermath (Golnaraghi et al., 2020; Manandhar et al., 2023; Rubinato et al., 2019; Truedinger et al., 2023a).

Instead of using reactive emergency-type measures to address the immediate consequences of the crisis, designing systematic solutions to tackle shocks and climate-related hazards anticipatorily would build on and improve existing social protection systems, saving time and money while proactively reducing the risk of future climate-related disasters. Tanner et al. (2015) call for immediate global anticipatory action on adaptation and mitigation, claiming that, internationally, just 12 percent of disaster management funds are invested in risk reduction and prevention. In comparison, 88 percent go into the response for repair or reconstruction after an event. In sum, Germany has already paid more than 40 billion euros for damage caused by flooding and 25.6 billion euros for forests and agriculture due to climate change (Deutsche Welle, 2022). The significance of preventive systematic solutions becomes more evident when considering that "[…] all flood endangered European landscapes could be equipped with live telemetric seismic stations at a fraction (0.006 percent) of the costs caused by the Ahr flood in July 2021," allowing for rapid response-mode policies and systematic early response mechanisms (Dietze et al., 2022a, p.7).

This article investigates the case of the Ahr valley flood in 2021 from a new angle. The primary research question is: How can the four building blocks of adaptive social protection (data and information systems, programs, institutional arrangements and partnerships, and finance) reduce the disaster risk of climate-related flood hazards in Germany? As the research question indicates, the case study analysis integrates the adaptive social protection (ASP) theory and its concept of the four building blocks. ASP offers a suitable theoretical lens as it strongly focuses on the interrelation of social and environmental factors. The four building blocks offer the most comprehensive framework to structure the research, including the chosen case study of the Ahr valley flood in 2021. Moreover, the building blocks provide a concise framework to inform the design and implementation of ASP interventions and a method to tackle climate-related hazards through appropriate disaster management measures worldwide (Bowen et al., 2020).

Each building block provides insight into interrelated yet distinctively analyzed aspects concerning the flood event. For each building block, there is one concrete hypothesis that is tested throughout the analysis process of this research: (1) Data and information: Despite meteorological risk evidence, the residents of the Ahr valley received insufficient early warning information; (2) Programs: During flooding, the German government faces challenges in managing existing adaptive social protection programs; (3) Institutional arrangements and partnerships: The 2021 Ahr valley flood stressed the importance of cooperation, coordination, and communication among disaster management actors; and (4) Finance: The climate-related flood hazard resulted in significant economic costs. After discussing the case study's findings, the article concludes and provides policy recommendations for managing disaster risks associated with climate-related flood hazards in Germany.

2. Theory

Given the climate-related hazard impacting Germany, there is an intensified need for research on climate change as a crucial policy field within the framework of social protection systems. Therefore, the primary purpose of this article is to present the analysis of the Ahr valley case from the perspective of the ASP approach. Davies et al. (2009) consider social protection systems as part of a broader framework of ASP, which seeks to integrate social protection with climate change adaptation (CCA) and disaster risk reduction (DRR). Moreover, ASP offers an anticipatory approach to prevent climate, pandemic, economic, and political shocks by enhancing the resilience of households and relevant systems (Ziegler, 2016).

The theoretical framework of ASP shows similarities with the management of climate-related hazards. Managing climate-related threats also aims to reduce possible risks through adaptation to create a more resilient future (Global Facility for Disaster Reduction and Recovery, 2016). The international and national agreements in force ensure joint action against climate change for sustainable development worldwide (Intergovernmental Panel on Climate Change, 2014; United Nations, 2020). Although ASP is a relatively new concept, it has evolved significantly over the last decade. At its core is the need to react to the effects of climate change on vulnerable societies, a need that has become more evident in recent discussions. While seminal work on ASP by Davies et al. (2009) focuses on enhancing the resilience of poor rural communities that are dependent on subsistence agriculture, Bowen et al. (2020) expand the focus to include all poor and vulnerable households, protecting them from poverty by investing in their capacity to deal with shocks. These two definitions extensively cover the aspects of social protection and disaster risk reduction. Carter et al. (2019) also highlight the environmental aspect of adapting to climate change by emphasizing preventive and long-term measures. The definition developed for this research is:

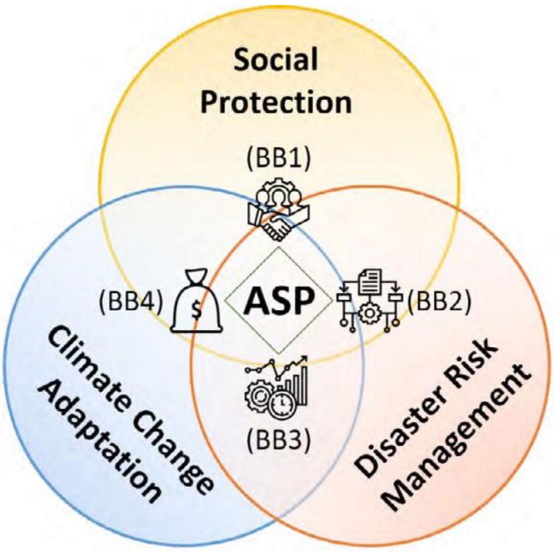
> ASP is a set of policies and programs aiming to reduce communities' vulnerability to climate-related hazards while promoting long-term resilience and sustainable development.

Finally, ASP creates a framework harmonizing social protection, DRR, and CCA to reduce vulnerability and build resilience. Although disaster risk management incorporates CCA and DRR, the focus on disaster risks, social protection, and its systems requires further improvement (Cacciotti et al., 2021).

Within the framework of ASP, Bowen et al. (2020) recently utilized the concept of the four key building blocks. They address several critical issues: community preparedness and early warning systems (data and information systems), the delivery of adaptive social protection programs to manage flooding (programs), cooperation among disaster management actors (institutional arrangements and partnerships), and financial disaster risk approach and expenditures (finance). The analysis considers existing and missing ASP mechanisms in the process of disaster risk and flood management in Germany, examining the effectiveness of these measures in mitigating the effects of risks. Additionally, it evaluates the strategies and policies being implemented to reduce the vulnerability of communities to climate-related hazards.

Figure 1 visualizes implementing the four building blocks into the framework of ASP and its three core sectors. The Ahr valley flood management findings are translated within each building block in this research, considering the German context. This exploration aims to develop a possible theory of social change towards greater structural resilience through ASP.

Figure 1: ASP as an integration of its three core sectors along the four building blocks



Source: Sett et al. (2021)

The Ahr valley flood event in 2021 suggests a potential relationship between the effectiveness of Germany's ASP implementation and the absence of anticipatory mechanisms for flood hazards and related disaster management procedures. Specifically, the impact of the flood on evacuation warnings and response measures suggests improvements to the ASP implementation and disaster management procedures. Further research is required to substantiate this relationship.

This study's central research question is: **How can the four building blocks of adaptive social protection (data and information systems, programs, institutional arrangements and partnerships, and finance) reduce the disaster risk of climate-related flood hazards in Germany?**

Furthermore, the overarching research question encompasses four underlying hypotheses. Neuman (2010) claims that drawing a hypothesis from a broad topic is complicated, while it is simple to extend the research question because "hypotheses are tentative answers to research questions" (p.193). Kumar (2011) considers the term more isolated and toward effective operationalization, stating that "a hypothesis is a speculative statement that is subjected to verification through a research study" (p.89). Halperin and Heath (2020) differentiate between confirmatory and exploratory research, with the latter being relevant to this thesis, progressing from fundamental questions to concrete hypotheses through plausibility testing. For each building block, specific hypotheses will be tested throughout this research analysis:

(1) Data and information: Despite meteorological risk evidence, the residents of the Ahr valley received insufficient early warning information;
(2) Programs: During flooding, the German government faces challenges in managing existing adaptive social protection programs;
(3) Institutional arrangements and partnerships: The 2021 Ahr valley flood stressed the importance of cooperation, coordination, and communication among disaster management actors; and
(4) Finance: The climate-related flood hazard resulted in significant economic costs.

How can a natural hazard negatively impact a region with well-developed and highly established social protection systems? The Ahr valley flooding in 2021 is not an isolated event of its kind, and with climate change, the likelihood of extreme weather events is expected to increase. However, studies on the event take on certain focal aspects without integrating relevant interconnections, especially regarding social protection systems.

3. Methodology

The methodological approach of this study is qualitative. It explores causal relations and examines empirical evidence using textual sources rather than quantitative measurements (Halperin & Heath, 2020). A qualitative study design is "flexible and emergent in nature" and, therefore, beneficial to "understand, explain, explore, discover and clarify situations, feelings, perceptions, attitudes, values, beliefs and experiences of a group of people" (Kumar, 2011, p.99). The qualitative research of the thesis consists of a desk study reviewing and examining existing literature. After introducing the topic, the research question and the hypotheses define the research aim. The desk study then offers further background information, integrating the issue and elaborating on managing climate-related hazards. Here, the focus shifts toward climate exposure, vulnerability, and resilience and introducing existing flood management mechanisms in Europe, focusing on Germany.

Following this, the study analyzes the status quo of the ASP theoretical approach. According to Gilbert (2008), the theory contains the concept, and measuring the concept requires indicators: "An indicator is a method of measurement that aims to measure the concept accurately" (p.17). Gilbert claims and suggests "independent indicators" for each concept that are "valid (accurately measuring the concept) and reliable (consistent from one measurement to the next)." Against this background, the conceptual and theoretical chapter operationalizes the nexus between management, climate-related hazards, and ASP.

The thesis follows a case study design based on data analysis. Walton (1992) describes that the "logic of the case study is to demonstrate a causal argument about how general social forces shape and produce results in particular settings" (p.122). A case study is integral to the qualitative research framework as it ensures a holistic exploration and understanding of the phenomenon within a chosen case (Kumar, 2011). Selecting a case offering comprehensive information from various sources is essential to quickly analyze its idiosyncratic complexity (Gilbert, 2008; Grinell, 1998; Kumar, 2011; Neuman, 2010). While a case study can connect individual circumstances at the micro level to overarching macro-level strategies, its generalisability is limited (Kumar, 2011; Neuman, 2010; Vaughan, 1992). As specified in the theoretical and conceptual framework, the case study of this research focuses on hydrological hazards such as floods. It analyzes explicitly an event-driven climate-related hazard, the surge in the Ahr valley in 2021, and its sudden occurrence. To answer the research question and its underlying hypotheses, the chosen case study examines how Germany managed the climate-related flood hazard through ASP measures.

3.1. Case Study Selection

The case study was selected based on its relevance and recency. The risks for vulnerable people also grow with the increase in global crises. Therefore, it is necessary to adapt social systems. As it is essential to tackle climate change impacts, the research analyses a devastating flood event and its effects on a German region through the lens of ASP, which connects social protection, CCA, and DRR. Climate-related hazards such as heavy precipitation may lead to catastrophic consequences (Netzel et al., 2021; Su et al., 2015). The natural disaster with the most extreme effects is a flood, which requires compelling disaster management and adequate flood warning (Apel et al., 2022). There are five large river basins in Germany, namely the Elbe, upper Danube, Rhine, Weser, and Ems, of which the first three are international rivers (Hattermann et al., 2014). Besides climate change, urbanization is a factor influencing water-related disasters. Therefore, Kron et al. (2022) stress readiness at the local level, support from state and federal governments, and the relevance of sharing disaster lessons.

The flood event in 2021 affected a sizeable region across Europe, concentrating its worst impact on the Ahr river. Heavy precipitation generated severe flooding in rivers and their tributaries in Belgium, Luxembourg, the Netherlands, and the rivers Erft and Ahr in western Germany from July 12 to July 19, 2021 (Apel et al., 2022; Lehmkuhl et al., 2022; Ludwig et al., 2023; Szönyi et al., 2022). Austria, Italy, Switzerland, and the federal states Saxony and Bavaria were less strongly affected, while the catchment along "[…] the entire river basin of the Ahr river starting as far upstream as Ahrdorf, then on to Schuld and Altenahr through Bad Neuenahr-Ahrweiler to Sinzig, where the Ahr empties into the Rhine" were affected most vital (Szönyi et al., 2022, p.108). While "the year 2021 abounded in many severe weather events," the Ahr Valley flood was the "deadliest natural disaster in Germany since 1962" (Wilgan et al., 2023, p.1). Altogether, over 230 people died in the flood event, 186 in Germany, of which 134 lost their lives in the Ahr valley (Szönyi et al., 2022; Wilgan et al., 2023). The numbers of Apel et al. (2022) slightly differ as they allocate 184 fatalities to Germany, of which 133 occurred along the Ahr. The flood caused extensive damage to buildings, bridges, and wineries in the Ahr area, record-breaking peak flows at many gauges, and economic costs of 30 billion euros for Germany (Apel et al., 2022; Dietze et al., 2022a; Korswagen et al., 2022; Lehmkuhl et al., 2022).

3.2. Data Analysis

Since the methodological approach taken in this study is qualitative, the literature represents a sufficient number and variety of reliable secondary sources. Due to time constraints, the choice for secondary data is subject to a conscious decision against gathering primary data through unstructured interviews. The idea for the case study came shortly after the event's occurrence through participation in webinars on the flood event. Initially, the recency of the event posed a limitation due to a lack of academic literature. However, three years later, extensive accessible online literature on flooding is available.

A broad approach was taken during data collection to understand the topics' comprehensiveness, including various diverging interests and research subjects. Generally, the literature was searched for in Google Scholar via a keyword search clustered into three topics: climate-related hazards, ASP, and the Ahr valley flooding in 2021. The data may be fragmentary due to the chosen data collection method and the researchers' bias in selecting and interpreting the data (Gilbert, 2008; Kumar, 2011). The literature is determined in line with the main criteria of availability, accessibility, affordability, topic-relatedness, and relevance. Overall, 395 secondary data sources have been reviewed, of which 290 were actively used within the desk study. The secondary data sources include but are not limited to the following: (1) academic literature, including books and journal articles; (2) policy documents, including strategies and evaluations; (3) legal documents, including laws, regulations, and decrees; (4) grey literature, including reports and papers; and (5) other sources, including internet documents, presentations, and dissertations. Additionally, non-specific thematic sources are collected on demand, for example, for the methodological chapter. As Kumar (2011) summarizes, the data collection method depends on the required information, the availability of resources, the research purpose, the researchers' preference, and the studied population involved.

4. Results

The case study considers many macro-level aspects related to policies and structures on the global or European level that influence the national governance for disaster management in Germany. It assesses existing and missing ASP mechanisms in the process of disaster risk and flood management in Germany, the effectiveness of these measures in mitigating the effects of climate-related hazards on vulnerable populations, as well as strategies and policies that have been implemented to reduce the vulnerability of communities to the impacts of climate-related hazards. The most crucial research results are divided along the most relevant aspects from each building block: early warning, governance response, disaster management actors, and expenditures.

4.1. Early warning

The most critical challenges from analyzing the first building block of data and information systems, which analyzes the performance of the early warning systems to guarantee community preparedness, can be categorized as warning, awareness, and expectations, respectively.

Although there were warning signs, the warning chain, including dissemination, reach, and understanding, failed (Deutsches Komitee Katastrophenvorsorge e. V., 2022; Fekete & Sandholz, 2021; Szönyi et al., 2022; Thieken et al., 2022). Emergency flood management has lacked data and information regarding the extent and impact of the event (Apel et al., 2022; Kron et al., 2022). Prevailing natural disaster risk assessments have not acknowledged the occurrence of multi-hazard disasters (Guo et al., 2021; Pelling, 2004; United Nations Office for Disaster Risk Reduction, 2017, 2020; Ward et al., 2020). Germany's disaster protection system, alarm apparatus, gage, discharge, and the water levels at gauges require repair (Apel et al., 2022; Bundesamt für Bevölkerungsschutz und Katastrophenhilfe, 2023; Deutsche Welle, 2021; Kron et al., 2022).

Many Ahr valley residents were unaware that they live in a flood-prone area and, hence, were unaware of the risks involved (Truedinger et al., 2023b). Despite weather forecasts, the warning system did not adequately inform or motivate people to take action (Kron et al., 2022; Mohr et al., 2023). After the flood, some affected people shifted their attention to international DRR conventions such as the Sendai Framework and its benefits (Klonner et al., 2021; United Nations Office for Disaster Risk Reduction, 2015). During the recovery and reconstruction process, there has been a tendency to ignore future disasters instead of focusing on building back better (Hassel & Werners, 2023; Surminksi et al., 2020).

Flood-affected people received insufficient information too late, and the most affected Ahrweiler district did not receive warning information via any smartphone application (Kron et al., 2022; Mohr et al., 2023; Szönyi et al., 2022). Despite warning signs of a high likelihood of a flood, the information was not precise on the possibly affected locations or concrete consequences. This caused uncertainty, underestimation of the severity, and hesitance in preventive action (Kron et al., 2022; Schmitt & Scheid, 2019;

Szönyi et al., 2022). Another crucial challenge for expectation management and adequate disaster reaction at the administrative level is that districts must cover subsequent costs when declaring a state of emergency, making them think twice before acting (Kron et al., 2022).

4.2. Governance response

The key challenges in the second building block of programs, examining the governance response in delivering ASP programs to manage the flood, can be classified as coping, adaptation, and resilience.

The Ahr flood in 2021 revealed a lack of flood protection, compatible program design, and flood protection concepts (Schmitt & Scheid, 2019). The governance response has been exacerbated by the fact that uniform methods for risk, impact, and vulnerability analyses were missing, and state-run programs did not financially support property-level mitigation (Kron et al., 2022; Maiwald et al., 2022; Schmitt & Scheid, 2019; Surminksi et al., 2020). Coping with climate change requires balancing mitigation and adaptation, necessitating updates on outdated local climate policies (Maiwald et al., 2022; Otto et al., 2021).

Implementing climate protection measures has not been mandatory for municipalities (Abel, 2021; Schaffrin et al., 2014). Transformation would require the integration of related climate change issues into sector policies through the science-policy nexus as well as systematic planning based on learnings from previous historical events (Biesbroek et al., 2010; Garrelts & Lange, 2011; Giddens, 2009; Kron et al., 2022; Mickwitz et al., 2009; Roggenkamp & Herget, 2014; Schanze, 2006; Wisner et al., 2004). Even the German DRR failed to integrate strategies and plans for the CCA (Bubeck & Thieken, 2018).

The evacuation order was inadequate, while flood risk management focused on protection instead of system-wide resilience. Despite a low resilience level, Germany has taken considerable time to recover from the flooding (Manandhar et al., 2023; Surminksi et al., 2020; Szönyi et al., 2022). Private households and individuals especially lacked resilience due to disagreements over responsibility for flood prevention and the absence of targeted recovery aid for long-term mental health (Bubeck, 2013; Kron et al., 2022; Surminksi et al., 2020; Truedinger et al., 2023b).

4.3. Disaster management actors

Preparedness, accountability, and communication are the primary challenges in the third building block of institutional arrangements and partnerships, which investigates suitable responses and collaboration among disaster management stakeholders.

The 2021 Ahr flood revealed the unpreparedness of societies, policymakers, and scientists across many dimensions (Dietze et al., 2022b). The current German flood management system retained traditional structures, lacking anticipatory and coordinated approaches, unbureaucratic and rapid financial aid, and heavy equipment for civilian protection forces (Becker et al., 2015; Juling, 2022; Surminksi et al., 2020).

Due to climate change and recurrent high-impact flooding, the German water management bodies, the public, and industry have experienced uncertainty and concerns about the need for action (Becker et al., 2015; Bubeck, 2013; Kundzewiecz, 2012; Surminksi et al., 2020). This raised questions regarding roles and responsibilities, such as the German military's response to national disasters, given its primary mission to defend the country and its allies (Juling, 2022).

The lack of technical capabilities to deploy and prepare communication among all stakeholders and disaster management actors across hierarchies caused barriers during the crisis (Klonner et al., 2021; Kron et al., 2022; Reichel & Frömming, 2014; Usón et al., 2016). The degree of risk awareness, missing standards for maps and terminology, and the use of risk data in decision-making altered substantially among stakeholders (Kron et al., 2022; Manandhar et al., 2023; Meon, 2006).

4.4. Expenditures

The fourth building block of finances, reviewing the financial disaster risk approach and respective expenditures, faces challenges mainly related to administration, severity, and disbursement.

The disaster was handled as an unpredictable humanitarian crisis. The prevailing model for the disaster risk financing response was not performed on time, and the transformation to enhanced ASP systems will impose further financial burdens on the government (Bowen et al., 2020).

The material consequences resulted from vulnerabilities, values at risk, and the control over flood waters (Kron et al., 2022). The flood caused a billion-euro loss across Germany, Belgium, and the Netherlands. It surpassed previous floods of the Ahr regarding how it affected private households, infrastructure, industry, agriculture, and viticulture (Dietze et al., 2022b; Fekete & Sandholz, 2021; Guo et al., 2021; Kron et al., 2022; Maiwald et al., 2022; Mohr et al., 2023).

In Germany, only around 8.2 billion euros had been insured and reimbursed based on contracts for which t premiums were paid, while the government has compensated losses to uninsured people using taxpayers' money (Kron et al., 2022; Mohr et al., 2023; Munich Re, 2022). Nearly 60 million euros were handed to the Federal Bank for replacement, including 1.5 million wet and soiled euro notes and 1.2 million euro coins (Kron et al., 2022).

5. Discussion

This chapter evaluated the outcomes of the Ahr Valley flood in 2021 within the context of German climate-related management, focusing on the four building blocks of ASP. It provides a clear and logical presentation of the research results while integrating the theory. The discussion identifies what is needed for change and offers solutions and recommendations. It interprets the case study results in a broader and more general context and challenges the limitations of the study at hand. The following paragraphs summarize the most pertinent findings from the literature review of the case study and answer each hypothesis.

H1 Data and information: Despite meteorological risk evidence, the residents of the Ahr valley received insufficient early warning information.

The first building block of data and information systems stressed the importance of the relationship between climate change and disaster risk. The German government must accept that the Ahr valley flood in 2021 was not an uncommon effect of climate-related hazards. Hazards, exposure, and vulnerability are dynamic. Hence, data and information are crucial for managing disasters (Cremen et al., 2022). The Sendai Framework considers forecasting and early warning essential in DRR for addressing the hazards exposure, vulnerability, and capacity (Apel et al., 2022; United Nations Office for Disaster Risk Reduction, 2019). The government must prioritize risk reduction and adaptation against climate-related hazards, considering that densely populated urban areas face higher vulnerability to climate change (Birkmann & Welle, 2015; Eckstein et al., 2021; Hobbie & Grimm, 2020). To apply ASP, Bowen et al. (2020) stress the importance of linking information systems and the social protection sector through effective early warning systems for early action and collecting post-shock data to choose adequate response programs.

The first building block then analyzed the early warning mechanisms and the community preparedness for the Ahr valley flood. Actions on the regional and local levels include, for instance, alarms, smartphone application warnings, flood maps, sirens for civil protection, and cell broadcast services (Apel et al., 2022; Klonner et al., 2021; Schmitt & Scheid, 2019; Szönyi et al., 2022). While it is crucial to prepare and warn the possibly affected community in a participatory procedure, and while there have been warning forecasts and existing mechanisms, the early warning process and evacuation did not work well (Apel et al., 2022; Kron et al., 2022; Mohr et al., 2023; United Nations Office for Disaster Risk Reduction, 2019). However, decision-makers and disaster managers would have needed timely and detailed flood information to operate the warning chain, protect critical infrastructure, evacuate affected residents, and distribute emergency resources (Deutsches Komitee Katastrophenvorsorge e. V., 2022; Fekete & Sandholz, 2021; Mohr et al., 2023; Szönyi et al., 2022; Thieken et al., 2022). Precise data could contribute to warning information. Scientists suggest using the impact-based river flood forecast, which uses hydrodynamic surrogate model results based on machine learning as it evaluates the nexus among the river peak discharges and the expected impacts (Apel et al., 2022; Dale et al., 2014; Hofmann & Schüttrumpf, 2020, 2021; Merz et al., 2020). Germany must constantly prepare communities in flood-prone areas to manage flood risk by raising awareness, facilitating training, and ensuring clear communication. A participatory approach is necessary since only residents integrated into the DRR process can provide valuable, up-to-date local knowledge to complete available data sets (Klonner et al., 2021; Szönyi et al., 2022; Truedinger et al., 2023b). In the aftermath of a flood disaster, the German government must be recovery-oriented on building back better, creating space for remembrance, and reappraising local knowledge to reduce future disaster risk (Hassel & Werners, 2023; Klonner et al., 2021; Surminksi et al., 2020).

Therefore, the analysis of the first building block on data and information systems did not support the hypothesis, which stated that despite meteorological risk evidence, the residents of the Ahr valley received insufficient early warning information. The analysis showed that weather forecasts and warnings were sufficiently available. However, failures in dissemination and reach left flood-affected people without realistic expectations, awareness, and understanding.

H2 Programs: During flooding, the German government faces challenges in managing existing adaptive social protection programs.

The second building block on programs demanded reconsidering existing programs and flood responses. The increase in climate-related flood hazards has required a multilayered adaptation of social protection programs and political framework conditions for more resilience (Abel, 2021; Bouteligier, 2013; Bulkeley, 2010; Bulkeley et al., 2003; Busch & Jörgens, 2012; Gupta, 2007; Kern & Alber, 2008; Ohlhorst et al., 2013). Therefore, Germany must question the effectiveness of existing programs, eliminate the current vulnerability, and design safety net programs supporting the adaptation to shocks (Bankoff et al., 2013; Bowen et al., 2020; K. Dietz, 2006; Garrelts & Lange, 2011; Intergovernmental Panel on Climate Change, 2001, 2007; Manandhar et al., 2023; Wisner et al., 2004). Germany's governance response must target residents of mountainous sub-basins in the western ranges as they are most vulnerable to river discharges (Hattermann et al., 2012, 2014). Moreover, a particular focus must be on historically flood-prone areas like the Ahr valley, which experienced significant flood impacts in 1804 and 1910. Learnings from these previous historical events with 100-year flood levels shall build the foundation for contemporary prevention and protection measures (Kron et al., 2022; Lehmkuhl et al., 2022; Ludwig et al., 2023; Roggenkamp & Herget, 2014; Szönyi et al., 2022; Szymczak et al., 2022).

Besides highlighting that historical events must be considered when transforming the governance response, the second building block provided practical implications for the process. Flood risk management must focus on system-wide resilience to mitigate climate change impacts. Local climate policies from the 1990s require updates, while land management in headwater regions needs regulation (Dietze et al., 2022a; Kron et al., 2022; Maiwald et al., 2022; Otto et al., 2021; Surminksi et al., 2020; Truedinger et al., 2023a). Research, innovation, and the contribution of citizens promote adaptation only when the science-policy nexus functions (Biesbroek et al., 2010; Garrelts & Lange, 2011; Mickwitz et al., 2009). The creation of uniform analysis methods provides cost-benefit considerations and estimations of area-related statistical damage values, while a city-wide flood hazard and risk analysis considering the vulnerability and impact factors may solve the lack of flood protection concepts (Kron et al., 2022; Maiwald et al., 2022; Schmitt & Scheid, 2019). Generally, Germany must ensure that the subsidiarity principle, which makes its 16 federal states responsible for flood protection, does not harm individuals, the alarm, or the response system. Moreover, bureaucratic processes and structures shall not slow down immediate action and adequate governance response (Blank, 2020; Esping-Andersen, 1990; Kaufmann, 2003; Surminksi et al., 2020).

Therefore, the analysis of the second building block on programs did not support the hypothesis that the German government faces challenges in managing existing adaptive social protection programs during flooding. The German government did manage the Ahr flood in 2021. However, the governance response has shown crucial gaps in the ASP capacities for coping, adaptation, and resilience. This building block provides much potential for a positive transformation toward better climate-related flood disaster management in Germany.

H3 Institutional arrangements and partnerships: The 2021 Ahr valley flood stressed the importance of cooperation, coordination, and communication among disaster management actors.

The third building block on institutional arrangements and partnerships stressed the relevance of anticipatory cooperation among disaster management actors and cross-sectoral collaboration. This is the prerequisite for ASP, especially for those actors operationalizing climate change adaptation initiatives and stakeholders in the disaster risk management sector (Bowen et al., 2020; Surminksi et al., 2020). Unfortunately, the July 2021 flood in western Germany revealed the unpreparedness of societies, policymakers, and scientists across many dimensions (Dietze et al., 2022b). Cross-sectoral coordination usually depends on policy coherence, equal commitment, and a common understanding among the actors in different sectors (Bowen et al., 2020; Golnaraghi et al., 2020; Meon, 2006; O'Brien et al., 2018). Therefore, the task of the German government is to assign roles and responsibilities to the disaster management actors, allocate monetary means, build resilience through preparedness, coping, and adaptation, and commit their policies to social protection, CCA, and DRR (Bowen et al., 2020). It is also crucial for the government to involve flood-prone communities and citizens in every process step during the preparation, response, and recovery as this helps citizens prevent, respond, and adapt to environmental changes in their social and cultural context, enhancing their absorptive, adaptive, and transformative capacities (Birkmann & Teichman, 2010; Hadorn et al., 2008; Manandhar et al., 2023; Reichel & Frömming, 2014; World Bank Group, 2020).

Besides stressing the unpreparedness and the role of the German government in successfully managing disaster management actors, the third building block introduced strategies for more anticipatory and coordinated approaches. The relief and reconstruction process became a national task involving professional and well-trained public actors, such as firefighters, the German Federal Agency for Technical Relief, the German Red Cross, the Armed Forces, the police, and organized civilian volunteers (Kron et al., 2022). While these actors were generally satisfied, they criticized the provision of heavy equipment for civilian protection forces, unbureaucratic and rapid financial aid, and the independence to work outside inefficient procedural structures (Juling, 2022; Kron et al., 2022; Szönyi et al., 2022). So far, Germany has not managed a transformation to a more anticipatory and coordinated flood risk management system. Instead, many systems are still very reactive to flooding (Becker et al., 2015; Golnaraghi et al., 2020; Manandhar et al., 2023; Rubinato et al., 2019; Surminksi et al., 2020). Floods and their effects could be managed with an adaptive co-management concept, which integrates unpredictable occurrences within complex systems under changing circumstances such as climate change (Armitage et al., 2008; Becker et al., 2015; Folke et al., 2005; Pahl-Wostl, 2009; Plummer et al., 2013; Scarlett, 2013; Young et al., 2006). For a prospectively comprehensive flood risk management and disaster reduction, Germany may establish a competence center for civil protection to improve coordination between the Federal Office of Civil Protection and Disaster Assistance, the 16 German federal states, relevant relief organizations, and rescue teams (Kron et al., 2022).

Therefore, the third building block analysis on institutional arrangements and partnerships supported the hypothesis that the 2021 Ahr valley flood stressed the importance of cooperation, coordination, and communication among disaster management actors. The main challenges were the unpreparedness of the current German flood management system, the accountability of the German water management bodies, and the communication among all stakeholders and disaster management actors. Besides the cooperation of the government, disaster management actors, and volunteers, cross-sectoral coordination of actors by the German government is required. Effective communication is defined by a common understanding among actors and standards for maps and used terminology.

H4 Finance: The climate-related flood hazard resulted in significant economic costs.

The fourth building block of finances concluded that a disaster risk financing approach to ASP is necessary for resilience-building interventions. Therefore, Germany must improve the prevailing model for financing disaster response to predict climate-related flood hazards and provide financial aid promptly (Bowen et al., 2020; Maher et al., 2018). The flood affected Germany, Belgium, and the Netherlands across borders in July 2021. With an estimated total damage of 33 billion euros, it was one of the five costliest disasters in Europe in the last half-century, surpassing previous events, namely in 2002, 2010, 2013, and 2016, causing billion euro loss in the 21st century (Bundesministerium des Innern und für Heimat, 2022; Fekete & Sandholz, 2021; Mohr et al., 2023; Munich Re, 2022; Szönyi et al., 2022). From the total damage cost, 75 percent were uninsured, and around 20 billion euros were accounted to Rhineland Palatinate, with the Ahr valley region as the worst flood-affected area (Deutsches Komitee Katastrophenvorsorge e. V., 2022; Kron et al., 2022). In Germany, only 37 to 47 percent of residential buildings were insured, making this event the most extensive industry loss for 2021 and the highest insured loss ever from a single event in Germany (Gesamtverband der Versicherer, 2022; Kron et al., 2022; Mohr et al., 2023; Munich Re, 2022; Szönyi et al., 2022). The financial consequences depend on vulnerabilities, values at risk, and control over flood waters. The expected total damage is distinguished into direct and indirect monetary damage costs and possible social consequences (Kron et al., 2022; Schmitt & Scheid, 2019).

The fourth building block also elaborated on the governmental financial aid to cover the high costs of the disaster while considering further challenges. Beyond the economic loss, the tragedy was also the deadliest because it killed more than 240 people (Guo et al., 2021; Kron et al., 2022). The flood affected 17,000 of 42,000 people in the Ahr valley, private households, public infrastructure, industry, agriculture, and viticulture (Deutsches Komitee Katastrophenvorsorge e. V., 2022; Dietze et al., 2022b; Fekete & Sandholz, 2021; Kron et al., 2022; Mohr et al., 2023). As Germany suffered the worst damage, the German federal and state government released emergency and recovery funds to support those most in need, containing 30 billion euros for reparations and reconstructions, of which 25 million euros were for the Ahrweiler district, with an average direct aid of 2,000 euros per affected household (Kron et al., 2022; Szönyi et al., 2022). However, a fair solution is needed for differentiating between insured people receiving reimbursement based on contracts for which they paid premiums and, on the other hand, uninsured people receiving loss compensation using the taxpayer’s money (Kron et al., 2022). As incentives to invest in reducing flood risks are low, the German government should provide payouts only for those who preventively obtained insurance coverage (Surminksi et al., 2020; Zurich Insurance Group Ltd, 2016). Moreover, Germany may reconsider the requirements for receiving emergency relief funds, as private households or companies must amount to at least 3,000 euros in damage costs (Szönyi et al., 2022). Due to the flood's magnitude, additional public funding and grants from the European Union aided the reconstruction processes (Kron et al., 2022; Mohr et al., 2023; Truedinger et al., 2023b). Lastly, the Federal Bank was required to replace large sums of flood-affected cash (Kron et al., 2022).

Therefore, analyzing the fourth building block on finances supported the hypothesis that the climate-related flood hazard resulted in significant economic costs. The increased economic costs were caused by failures in governmental administration and the severity of the flood in the Ahr valley and beyond. Additionally, general challenges with disaster risk financing response, insurance, and disbursements negatively affected the people needing support.

Research Question: How can the four building blocks of adaptive social protection reduce the disaster risk of climate-related flood hazards in Germany?

The rejection of the hypotheses on the first two building blocks and the confirmation of the last two hypotheses contribute to answering the research question.

1. In opposition to H1, residents did receive informative weather forecasts and warnings. The first building block of data and information systems proposes to enhance the dissemination and reach of early warning information to give flood-affected people the necessary awareness and understanding to manage their expectations successfully, hence reducing the disaster risk of climate-related flood hazards in Germany.
2. Contrary to H2, the German government managed existing adaptive social protection programs during the Ahr flood in 2021. However, the disaster risk can be reduced by closing crucial gaps in the ASP capacities for coping, adaptation, and resilience. The second building block of programs suggests that the subject provides substantial potential for a positive transformation toward better climate-related flood disaster management in Germany.
3. The third building block of institutional arrangements and partnerships stresses the importance of cooperation, coordination, and communication, according to H3. These aspects reduce the disaster risk of climate-related flood hazards in Germany

when the three following prerequisites are met: anticipatory cooperation between the government, disaster management actors, and volunteers; cross-sectoral coordination of actors led by the German government; and effective communication defined by a common understanding among actors thanks to standards for flood hazard and risk maps and the terminology used.

4. The analysis of the fourth building block of finances aligns with H4 as the climate-related flood hazard resulted in significant economic costs. There is a demand for a more shock-responsive financial disaster risk approach to reduce the disaster risk of climate-related flood hazards in Germany and respective expenditures. The disaster risk financing response requires a functioning administration across sectors to handle the severity of flooding and offer immediate financial aid through insurance pay-outs and disbursements to the people in need of support.

In summary, the four building blocks of ASP can reduce the disaster risk of climate-related flood hazards in Germany by strengthening the German control and management capacities as well as by enhancing the readiness and resilience of the country and its citizens against climate-related hazards.

To critically reflect on the research carried out, the most crucial constraints of this thesis incorporate practical limitations, researcher bias, ethical concerns, the choice of the case, literature, and methodology. According to Neuman (2010, p.139), methodological limitations include "[…] how the specific measures, sampling, cases, location, or other factors restrict the generalizability of findings or are open to alternative explanations." Due to the qualitative case study approach, the findings at the micro level can be related to strategies on the macro level, whereas the results may only be comparable to other similar cases (Kumar, 2011; Neuman, 2010; Vaughan, 1992). One of the study's weaknesses is that there has been no clear distinction between the Ahr valley case and the management of climate-related hazards in Germany, as they are closely interrelated. Ultimately, the regional actions taken during the emergency response to the disaster are regulated by administrative framework conditions, including the subsidiarity principle and bureaucratic processes, which depend on national and international agreements and conventions.

Another limitation related to the chosen theory is that within the framework of this research, there has yet to be a concrete reference to the adaptability of the German disaster response or its systems in general. Examples of ASP implementation are from outside of Germany, and even when considering the improvement of systems and processes, there is little evidence of the implementation within Germany. The literature indicates Germany’s support in the framework of international development cooperation, for instance, through the Global Shield against climate risks. While partnership ensures the achievement of the Sustainable Development Goals and the Agenda 2030, Germany must ensure the successful execution of national adaptation plans and strategies to improve its resilience against climate change-related hazards. That argument also links to the initial problem statement, which questioned the possibility of a natural hazard negatively impacting a region that is not only well-developed but also contains highly established social protection systems.

Moreover, the financial aspect within the four building blocks of ASP is a limitation. Even though cash flows and insurance are crucial elements within social protection policies and programs, the selected secondary literature on the Ahr valley flood in 2021 barely covers these topics. The analysis of the financial disaster risk approach and respective expenditures shows that the numbers provided were only partially consistent. One reason may be the source’s publishing time. While insurance companies offer comprehensive data sets and qualitative findings on the year 2021 and partly about the specific case of the flood event, there has been little evidence of a German disaster risk financing approach to ASP, which is required for effective resilience-building interventions.

6. Conclusion

The research accomplished to analyze the European-wide cross-border July 2021 flood from a social policy and social protection perspective by investigating the four building blocks of ASP (data and information systems, programs, institutional arrangements and partnerships, and finance) concerning the disastrous impacts on the Ahr valley in Germany. According to the ASP definition developed for this thesis, the theoretical approach provides a study framework focusing on policies and programs to reduce communities' vulnerability to climate-related hazards while promoting long-term resilience and sustainable development. Therefore, the significance of the findings for research has been the distinct study of each building block and the specification of challenges within the sections. These challenges and the limitations introduced in the Discussion Chapter build the foundation for a positive transformation in managing climate-related hazards in Germany.

The implications for policy and practice require the German government and the federal states to revise existent social protection programs, disaster management frameworks, and current CCA and DRR strategies. The research recommends the following changes for the future development of disaster risk management in Germany:

- Ensure functioning information dissemination to set expectations, awareness, and understanding for community preparedness;
- Close governance response gaps in the ASP capacities for coping, adaptation, and resilience;
- Enhance anticipatory cooperation, cross-sectoral coordination, and effective communication; and
- Improve the administrative disaster risk financing response procedures, insurance, and disbursements.

The next step for policy-making is to raise awareness about climate and hazard risks to implement the recommendations for more social protection across the four ASP building blocks. That requires expert revision concerning the applicability and practicability of the findings and recommendations of this research.

Based on the outlined findings of the research, this chapter also identifies the following areas for future research to enhance the German social protection system's resilience and readiness for future climate-related events. For instance, the consistent application of ASP in Germany needs to be investigated, including the individual communities of practice: social protection, CCA, and DRR. Due to time and secondary source constraints, the research does not assess a thorough investigation of the fourth building block of finances. As it solely focuses on expenditures and general financial aspects, the subject holds the potential to investigate the German financial disaster risk approach and mechanisms for prompt aid payouts. Lastly, climate insurance in Germany is another research area relevant to the social protection sector beyond the fourth building block.

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