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ARTICLE

Just Systems or Justice in Systems? Exploring the Ethical Implications of Systemic Resilience in Local Climate Adaptation

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Abstract
The concept of systemic resilience, as it is understood in the context of climate change adaptation addressing systemic risks and polycrisis, is an inherently normative notion that carries ethical weight. To account for these implications, systemic resilience needs to be supplemented with ethical reflections on a system's function, why it should be made resilient, and who the resilience serves. Crucially, considerations surrounding various forms of justice, such as participatory, procedural, distributive, and historical, need to be accounted for when making decisions about a community's resilience in the face of increasing climate hazards. Resilience in the context of systemic risks and climate adaptation currently does not account for its ethical implications. This investigation builds on complexity science research and specifically the expanded concept of systemic resilience. In this article, the concept of systemic resilience is applied to the local level, highlighting its ethical underpinnings in the process. Specifically, a case-study explores the application of the ethically informed version of systemic climate resilience, exploring how the Rhine-Erft catchment in Germany could be assessed on this basis.

Keywords Climate adaptation · Ethics · Resilience · Risk governance · Systems thinking · Theories of justice

1 Introduction

Climate change affects risks and uncertainties across diverse systems, including natural, ecological, or socioeconomic domains (IPCC 2014). Given the projected increases in climate change-related pressures and hazards (IPCC 2023), humanity needs to adapt to an increasingly uncertain environment. The sentiment of needing to learn how to adapt to a dynamic and changing climate less conducive to forms of societal existence under a stable, Holocene climate, is shared among the environmental, climate, and social science nexus. Reports such as "Welcome to the Great Unraveling" (Heinberg 2023), "Governance in Complexity" (EEA 2023), and others highlight a shift from traditional, solutionist thinking in socio-environmental scholarship towards a systemic vision of managing in an uncertain world, rather than seeking to control narrow parts of it. From earth system sciences to the development of complex risks, systemic risks, and polycrisis, one can detect a move towards the acceptance of a dynamic and complex environment, which both consists of and is shaped by innumerous societal structures, relationships, and systems. The acknowledgement of increasing hazards and risks, fused with deep uncertainty, that is, unknowable future circumstances and events (Kwakkel and Haasnoot 2019) manifests itself in calls for a societal transition towards adaptation and resilience, as the action-guiding principles of sustainable policy making (ISC 2022).

How such a transition can reach the rural and small-scale communities deserves particular policy consideration and attention in research, given the challenges climate change and adaptation entail for this space. In particular, how large-scale sustainability agendas can be translated into localized climate adaptation, resilience, and environmental policy is in need of investigation. Accordingly, this article focuses on specific, small-scale areas for analysis that serve as insightful heuristic to better implement, and where necessary, adapt sustainable development policy agendas on a local level.

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Emphasis is put on the systemic and value-laden nature of a sustainable transition, laying the groundwork to explore the ethical implications that come with implementing climate resilience on the regional scale in the face of systemic risks. At the same time, the article actively seeks to avoid solutionist thinking with regards to the complex socio-technical and environmental relationships, conceived here as systems, it addresses. Systems thinking is not assumed to represent a holistic solutions framework. Rather, the systems approach serves as a lens through which climate adaptation and sustainable transitions can be viewed.

The article suggests analyzing "Real World Labs" (RWL), that is, local communities that represent testbeds for adaptation policies (Schäpke et al. 2018), through the lens of an ethically informed concept of systemic resilience. Such a concept of resilience builds on systems thinking, while also reflecting on certain, non-exhaustive ethical implications of resilience. For this purpose, resilience is understood as an umbrella term for a system's ability to resist, recover, adapt, or transform in response to adversity (Ungar 2018). In this context, systems thinking is defined as an approach that analyzes complex systems by recognizing interconnections, feedback loops, and dynamic interdependencies that shape the systems' behavior over time. Through system dynamics modeling, such an approach enables decision makers to anticipate long-term effects, test interventions, and identify leverage points (Forrester 1997; Sterman 2000). To improve legibility and clarification, Table 1 defines some of the key concepts and terms used throughout the article.

Section 2 connects the concept of resilience and its use in climate change adaptation to the systems thinking scholarship, situating this discussion within complexity sciences and the historical context of the term. Moving beyond complex systems, Sect. 3 explores how the concept of systemic resilience in climate adaptation and disaster risk management necessarily entails ethical components in the context of political decision making. Section 3 situates the article's conceptual premises within a basic ideal justice theory framework, and then applies ethical considerations to a case study. The case study serves as a proof of concept, in which the ethically reflected concept of systemic resilience is applied to a real-world example, namely the Rhine-Erft catchment in the west of Germany. The Rhine-Erft catchment was chosen since it is currently an active partner in a European research project to improve local disaster resilience and climate adaptation (DIRECTED – see Sect. 3). For this case study, the catchment is framed as a RWL, wherein local practitioners and experts, stakeholders, public participants, as well as external scientists create a shared research project and agenda. The concluding remarks point towards the need for more ethical reflection in the future of the analysis of complex systems and systemic risk research, while also mentioning some limitations regarding scalability and applicability.

Table 1 Basic concepts

Resilience	The classic understanding of resilience relates to a system's ability to resist, adapt to, or recover from a given hazard (Ungar 2018; Gill et al. 2022). Resilience has also evolved into a more dynamic concept, entailing the resilient transformation towards a specific outcome, specifically in the context of climate change adaptation and sustainable transformations (Renn 2023).[a]
System	A set of interconnected and interdependent elements
Justice	An ethical value with various dimensions. Here, one can distinguish between:[b] - Distributional justice, referring to the fairness in distribution of a given decision; - Procedural justice, referring to the fairness of the decision-making procedure; - Recognitional justice, referring to the equal and historically sensitive recognition of the actors involved; and - Ontological justice, referring to the cultural situatedness of how justice is conceptualized throughout different communities.
Adaptation (Climate Change)	In human systems, the process of adjustment to actual or expected climate effects, in order to moderate harm or exploit beneficial opportunities (IPCC 2014)
Real World Lab (RWL)	A RWL is an experimental and transdisciplinary research group, located at the science-society interface (Schäpke et al. 2018).
Risk	Uncertainty about and severity of the consequences of an activity with respect to something that humans value (Aven et al. 2018)
Hazard	A risk source where the potential consequences relate to harm (Aven et al. 2018)
Risk Governance	Applying governance principles to the identification, assessment, management, and communication of risk (Aven et al. 2018; Gill et al. 2022)

[a]We would like to thank an anonymous reviewer for pointing us towards this dynamic conception of resilience.

[b]Note that this conceptualization of justice is neither exclusive nor exhaustive, but merely serves as a baseline definition for how the concept is used throughout this article.

2 Climate Adaptation, Resilience, and Systems

Holling (1973) introduced the concept of ecological resilience, defining it as the system's capacity to absorb disturbances while maintaining its core functions, structure, and identity. Over time, the concept has expanded across multiple disciplines, particularly towards social-ecological resilience and systems, integrating human and natural systems (Walker et al. 2008; Fraccascia et al. 2018; Hochrainer-Stigler et al. 2020; Li et al. 2020). Fraccascia et al. (2018) built on the work of Holling (1973), Folke et al. (2010), and Gunderson (2012) in framing resilience as a dynamic process that extends beyond maintaining system stability. By distinguishing "resistance," which refers to the system's ability to withstand disturbances without changing, "recovery," which denotes returning to the pre-disturbance condition, and "adaptive capacity," which enables systems to transition into new states, the authors identified system change to range from small adjustments to large, transformational adaptations. This distinction is critical in governance, where adaptation strategies must balance immediate flexibility with long-term systemic change (Schweizer and Juhola 2024).

While becoming increasingly popular in recent decades, the concept of resilience is not new to governance and policy, and at times can represent an unrealistic form of technocratic solutionism, that is, overreliance on technical fixes for complex social-ecological problems (Holmes 2020). Collier and Lakoff (2021), for example, showed how in the context of the United States, closely related concepts such as "vital systems" or "infrastructure" can be traced back to the analysis of a nation's vulnerability towards total war efforts in general, and the threat of thermo-nuclear annihilation in particular. In so doing, they highlighted the fact that "[...] it is only recently that preparedness for events that might disrupt [vital] systems has become a basic obligation for government" (Collier and Lakoff 2021, p. 5). The assumption that a government has the responsibility to increase societal resilience in the face of climate harms, therefore requires one to ask what kind of systems we delineate as being vital, for whom they are considered vital, and why. This historical situatedness is crucial to keep in mind, since the formal concept of resilience assumes that a given system's function ought to be maintained (Doorn et al. 2019). Such a conception is insufficient when it comes to the implementation of climate change adaptation measures, which necessarily imply ethically laden choices about how and why certain systems should be maintained by making them resilient. For example, deciding to build a dam may protect downstream settlement, while potentially causing disruption for the local river ecosystem, which is a trade-off based on the assumption that the settlement's safety is more important than the local flora and fauna.

2.1 Challenges in Operationalizing Resilience and Adaptation

While resilience remains a key concept in complex systems, its broad application across various disciplines has led to conceptual ambiguity (for example, robustness and resistance). Various scholars have observed that research on resilience is distributed across multiple disciplines, with limited cross-disciplinary interaction outside environmental science and ecology (Fraccascia et al. 2018; Schweizer 2021; ISC 2022; Schweizer and Juhola 2024). In addition to fragmentation and ambiguity challenges, the study of resilience, in many social and policy contexts, is to result in actionable knowledge to guide a system towards resilience through adaptivity, and therefore it may be useful to develop the concept towards practical applicability as well. Without practical methods, governance structures may struggle to effectively translate resilience theory into actionable adaptation measures[1]. As a recent study by the German Environmental Ministry highlights, the lack of adaptation and resilience expertise is a central challenge for improving local climate change adaptation (Friedrich et al. 2024). Understanding how adaptation and resilience measures can be effectively implemented may therefore prove particularly beneficial for municipalities.

For example, Fekete and Sandholz (2021) analyzed how the 2021 Ahr Valley flood response exposed governance weaknesses and reinforced patterns of policy inertia at multiple levels. They observed that flood response efforts primarily prioritized immediate recovery—restoring infrastructure and essential services—rather than embedding long-term resilience measures into reconstruction efforts. Despite early warnings, ineffective communication, slow emergency responses, and fragmented governance structures contributed to the disaster's severity. Municipal governments faced significant structural barriers to implementing adaptive measures. Governance fragmentation, financial constraints, and unclear responsibilities between federal, state, and local entities obstructed efforts to integrate systemic resilience (Fekete and Sandholz 2021). A systems dynamics approach may gear governance frameworks toward dynamic, iterative adaptation strategies that continuously integrate adaptive learning and increase resilience.

[1] Importantly, policymakers and the stakeholders and people affected by decisions surrounding resilience may also take other concerns beyond immediate climate change adaptation and disaster risk reduction into account. Resilience might just be one issue among others.

2.2 Connecting Systems and Climate Adaptation

The growing frequency of disasters driven by global and climate change could eventually lead to tipping points and the breakdown of whole systems (Juhola et al. 2022; IPCC 2023). While ecological systems are not able to foresee such disturbances (Gunderson 2010), humans can conceptualize such events and potentially try to manage them, in part by focusing on the concept of adaptation and resilience (Keating et al. 2017). The recent IPCC report (IPCC 2023) further relied on these concepts alongside the general terminology of systems to refer to different dimensions (for example, physical, biological, social, or ecological), as well as scales (for example, from the very local up to the global level).

Defining systems and setting system boundaries has normative implications as well, since what the system in question is, what elements belong to it (or not), and how it should adapt to an uncertain future, may vary across stakeholders and affected people (Churchman 1971). In other words, which components will be prioritized and seen as most important for the risk evaluation also depends on diverse perspectives, values, and worldviews of those thinking about and designing possible short- and long-term interventions (Scolobig et al. 2015). From an expert-driven, top-down perspective, desired system states (for example, in the form of future goals) are formulated on the global as well as regional and national levels. This includes the Sendai Framework for Disaster Risk Reduction 2015–2030 in regard to natural hazard-related disasters, the Paris Agreement in regard to climate change, as well as the Sustainable Development Goals, along with national climate adaptation and risk reduction plans.

Advanced quantitative modeling approaches (for example, IPCC 2022) have been developed to study such desired system states. For example, climate-economic models usually have at least four different modules that can be distinguished: The climate module (for example, describing the link between greenhouse gas emissions and the resulting variation in temperature), the impact module (for example, describing the physical and environmental outcomes as a function of climate change), the economy module (for example, describing the cost of emission reduction and adaptation), and the energy module (for example, describing the different sources of energy used in the future) (Nikas et al. 2019). Depending, in part, on the underlying scientific discipline for each of these modules, a great variety of different approaches for modeling respective dynamics can be found, such as optimal growth models, general equilibrium models, or macro-econometric models (Gambhir et al. 2019; Markandya et al. 2019; Nikas et al. 2019). Irrespective of the modeling challenges, however, the link to the local level is difficult, resulting in many hurdles—such as how to integrate bottom-up perspectives in which climate change is just one risk among many others, or accounting for the complexity of local systems (Rodrigues and Shepherd 2022)—that cannot solely be tackled from top-down approach.

Community-driven, grassroots approaches that take local knowledge and specifications explicitly into account can help bridge the gap between top-down climate information and bottom-up local contextualization needs. Building on the "small is beautiful" concept described first by Schumacher (1973), and adapted for climate change science and policy by Rodrigues and Shepherd (2022), this article focuses on resilience building in climate adaptation policies based on localized, contextual knowledge (that is, communally relevant knowledge). This also has implications on how resilience is defined, as the challenges of local communities are the starting point for such considerations. Consequently, systems thinking to inform resilience is adapted to be able to identify and develop resilience for local communities.

3 Justice and Resilience: Theoretical Context

The relationship between justice and resilience has been explored in a variety of contexts (for an outline and a pragmatist approach, see O'Grady 2025). Given the historical situatedness of resilience in Western governance approaches[2] (Collier and Lakoff 2021), it is important to give a clear account of justice and resilience to openly communicate, rather than hide, the ontological, epistemological, and subsequently ethical premises the present analysis builds on. In particular, the admittedly neoliberal undertones of science as a process of technocratic solutionism and marketable innovation (Grove and Rickards 2022) that may accompany systems approaches and transdisciplinarity—understood as the collaboration with stakeholders across disciplines—can require some theoretical contextualization. Importantly, this clarification should give an understanding of how resilience and justice could be conceptualized, and does not seek to preclude or overrule non-conforming definitions and applications (Grove et al. 2024).

The philosophical basis upon which the following discussion is grounded, is situated within the context of ideal theory of justice thinking, which entails the assumption that while potentially not realizable in the real world, there is an ideal concept of justice that is worthy striving towards. Merging ideal theorizing (for example, Rawls 1999) with a more pragmatic take on transitional theory (Valentini 2012),[3] this approach takes certain assumptions about the

[2] Please note that the analysis may also apply to an array of other sociocultural contexts, which the authors refrain from commenting here due to a lack of experience.

[3] For an application of justice theory to climate policy, see also Zimm et al. (2024).

"rightness" of specific instances of justice for granted, such as the necessity for historically sensitive modes of recognition, participation, and structure in justice (Fraser and Honneth 2003; Young 2011; Butt 2012) and distribution. In short, certain principles of justice are taken for granted and applied to non-ideal circumstances, namely in the context of systems thinking and resilience. Importantly, the approach does not assert that these principles are sufficient or exhaustive in terms of achieving social and environmental justice in a broader sense, nor does their application assume that these justice principles represent objective values or any superior mode of rationality. Instead, these justice assumptions build on the systemic risk governance literature's focus on participation and institutional structures (Schweizer and Renn 2019), and are accordingly vulnerable to meta-ethical and critical assessments surrounding alternative theories of justice and ontological frameworks.

Situated in the systems thinking scholarship, resilience is conceived here as a formal concept that describes the capacity of a given system, structure—or indeed, human-nature-technology network—to withstand external stressors and retain functional continuity. Conceiving societal relationships as such systems comes with inevitable buy-in regarding the ontology of whatever object one seeks to understand. It necessarily places certain kinds of ethical and epistemological frames above others, by virtue of the concepts relied on for this assessment in order to explore justice and resilience in the context of systems thinking.

With this conceptual outline as a basis, the starting point for the exploration between resilience and justice is based on the systemic resilience concept presented in Ungar (2018). The original article is thorough in its scholarship, and the principles laid out can be readily formed for application to the local climate adaptation context. According to Ungar, resilient systems operate on seven central principles. Namely, systems exhibit resilience in the context of *adversity*; resilience itself is a *process* rather than a pre-emptive state; *trade-offs* between systems occur when a system experiences resilience; resilience requires *openness*, *dynamism*, and *complexity*; resilience promotes *connectivity*; resilient systems demonstrate *experimentation* and *learning*; and resilient systems include *diversity*, *redundancy*, and *participation* (Ungar 2018).

Understanding the local climate change adaptation context is a thoroughly ethical enterprise as well. Building on scholarship from the climate adaptation ethics—a subfield of climate ethics (Hourdequin 2024)—one can highlight the moral and sociopolitical issues arising with regards to building resilience for climate change. Ethical considerations relevant to climate adaptation in particular can be formulated via a variety of justice considerations that intersect with aspects of well-being, individual and communal liberty, and other morally salient concepts (Heyward 2017; Byskov et al. 2021). As they stand, both the systemic resilience principles as well as the ethical considerations surrounding climate adaptation are arguably abstract. Contextualizing these principles and bringing them to the local level can help make them more applicable. To test the applicability of an ethically reflected form of resilience, this section draws on a real world example.

3.1 Case Study: The Rhine-Erft Catchment

The Erft catchment in the federal state of North-Rhine Westphalia serves as a testbed for the exploration of systemic resilience and justice.[4] The region's need to build resilience for disaster risk management and climate change adaptation makes the case study particularly relevant for this exploration. For this case study, the catchment is framed as a Real World Lab (RWL), wherein local practitioners and experts, stakeholders, public participants, and external scientists create a shared research project and agenda. This framing follows the developments within disaster risk and adaptation scholarship to move towards working with regional partners in order to ensure a co-creative approach guided by external experts as well as local stakeholders and practitioners (Renn 2018; Bergmann et al. 2021).

The Erft catchment consists of various local municipalities and stakeholders, as well as regional and federal actors, which makes the region an interesting case study for how different levels of governance systems (municipal, regional, federal) interact. Managing disaster risks and climate change adaptation are highly pertinent challenges in terms of hydrological extremes for the catchment, ranging from combined pluvial and fluvial flooding compounded by the local Erft River, to droughts. The flood of 2021 wreaked havoc in the region and beyond, leading to a death toll of over 100 people and enormous economic losses[5] (Fekete and Sandholz 2021). The regional waterboard, the *Erftverband*, is deeply involved in decision making with respect to extreme weather events and climate adaptation in the region, and is one of the key local stakeholders for the RWL. It is on the basis of the *Erftverband's* expertise that the systemic resilience concept and its justice implications are applied. Importantly, the issues explored here are not exhaustive but should serve as a proof of concept and point towards potential future research endeavors.

[4] This information is based on the DIRECTED Project, a Horizon Europe project focusing on improving disaster risk management and climate change adaptation throughout various regions in the European Union. For more information, see https://directedproject.eu/.

[5] https://www.theguardian.com/world/2021/jul/16/all-wrecked-german-town-stunned-flood-damage

3.2 Experimentation and Participation

In the Rhine-Erft RWL, climate change information is taken into account during the prevention and mitigation phase before an event, to the extent that extreme events are expected. Accordingly, the 2021 event is considered with regards to the current flood statistics, which is a clear reflection of the learning and experimentation capacity that formally resilient systems exhibit (Ungar 2018). In the context of the Erft catchment, learning can be understood as the municipality's ability to work through and reflect on the possible implementation of a given sustainability policy on the local level, as well as learn from past disruptions. In particular the implementation of a regional inter-municipal flood protection (the *hwsErft*[6]) cooperation shows a capacity to experiment with novel governance structures to account for the administrative and physical uncertainties arising after a disaster, and in anticipation of more climate change driven challenges.

Developing a shared flood protection cooperation such as the *hwsErft,* can be interpreted as an instance of adaptive governance, a form of governance more apt at addressing cases of deep uncertainty (Haasnoot et al. 2013; Kwakkel and Haasnoot 2019; Marchau et al. 2019). Since adaptive governance processes assume uncertain futures by design, they presuppose that policy agendas are set iteratively and can be molded and reshaped continuously. It is important to note that adaptivity might always be partially restrained by the reality of polycentric governance structures and established legal and political responsibilities. The Erft catchment is part of the federal state of North-Rhine Westphalia, and further needs to comply with federal climate policies (Schink 2024), which is in turn also tied to the policy agenda of the European Green Deal.[7] Understanding and accounting for these limitations is also important for the planning and potential implementation of climate resilience interventions, clarifying the decision-making space(s) of policymakers, stakeholders, and local communities.

From an ethical viewpoint, experimentation and learning also highlight the need to cope with normative uncertainty. Normative uncertainty is a phenomenon that describes the way in which societal values may change over time for various reasons, subsequently leading to changing socio-political evaluations of a given intervention or policy (Taebi et al. 2020; Hofbauer 2023). Since it is difficult to anticipate how values will change, it is recommendable to keep policy goals malleable, within certain boundary conditions. Grey flood protection infrastructure, such as dams and dikes, might have been supported at a given time due to perceived gains in safety and limited concern for its impacts on the local ecosystem. However, a community's perspectives on the value of the local ecosystem may change, and such infrastructure may no longer be ethically acceptable for a majority of the community members after some time and generational shifts[8]. Avoiding policies that create path dependencies and irreversible, technological buy-in can help to preserve a community's capacity to experiment and learn, and subsequently increase its resilient capabilities. Such considerations could bolster the Erft catchment's capacity to also build novel visions of how the future could look like through the building of scenarios and participatory workshops and engagement opportunities (Cumiskey et al. 2025).

While formally resilient, learning and experimentation are not reflective of any ethical considerations concerning the moral justification to ensure broad and meaningful participation. In order to account for recognitional (that is, accounting for the historical and structural injustices a community might have faced) and participatory justice concerns (Fraser and Honneth 2003; Whyte 2011), it is necessary to ensure the participation of a socioeconomically, ethnically, gender, and age diverse group of people. This entails that historically marginalized groups who experience structural injustices are explicitly recognized in the decision-making process and that their voices are amplified within this process. Such considerations are beyond the scope of the Flood Protection Committee. Rather, the decision and the implementation of the Flood Protection Committee could be rationalized as a purely epistemic means to an end, since a system that builds on diversity and participation is more likely to identify all relevant stressors to its community, and increase political legitimacy and acceptability.

3.3 Connectivity and Sociocultural Context

When it comes to resource allocation and funding frameworks to increase the catchment's resilience, there is potential for improvement of connectivity. Connectivity describes the community's capacity to interact with other systems well throughout a disruption (Ungar 2018). In the context of the Erft catchment, it is at times unclear, for example, whether funding only applies to flood protection or also to measures to protect against heavy rainfall. While the government currently provides funding for the creation of concepts and heavy rain hazard maps, there is no targeted funding for

[6] https://hws-kooperation.erftverband.de/

[7] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[8] It is an open question, whether or not majority rule is a sufficient basis for ethical deliberation. However, in the participatory ideal of climate adaptation and disaster risk management, it may be argued without much controversy that decisions supported by the majority of a given community should at least bear some ethical weight. For a discussion on this, see for example Taebi (2017).

the implementation of heavy rain measures. Given the various governance levels at play in the Erft catchment case, reaching from local, regional, national, all the way to European funding measures, the exact allocation of funds and their respective responsibilities thus is at times diffuse. This affects the potential for targeted and efficient information sharing, and may lead to the exclusion of relevant stakeholders in the decision-making process, making it harder to realize a more just procedure.

As work on institutional analysis has shown (Ostrom 2011; Valdivieso and Anderson 2017), enabling communication and information sharing between stakeholders and affected people increases the system's capacity to respond to external stressors. From an ethical perspective, such a connection also requires procedural justice considerations to be part of the communication and knowledge sharing process. Procedural justice (Rawls 1951; Nozick 1974; Habermas 2004) entails that the decision-making process itself is fair and equitable, which necessitates an equal playing-field in terms of the initial communication setting. No party should be at a disadvantage through the negotiation. While accounting for all these justice requirements may be difficult to achieve in the Erft catchment, ensuring open communication channels and clarifying responsibilities could be a first step towards a more effective, and in turn potentially more just, implementation of resilience measures.

The region's main focus on extreme weather events that seem particularly serious and relevant at a given time further highlights the historical situatedness and value-laden function of climate resilience measures and the systems that implement them. While there was a clear focus on floods and droughts until 2021, now there has been a marked shift towards floods. Dealing with climate change is also always a political issue and its capacities to be resilient are highly dependent on the way in which the system's functions are framed. Here, short-term governance structures (for example, election cycles) and neoliberal frames of reference might lead to establishing the continuation of unsustainable business-as-usual processes and the fulfillment of immediate, minimal policy measures. Many citizens see technical flood protection as the only solution, because other measures would interfere greatly with their own lives (resettlement as a serious example) or entail personal initiative (private provision is obligatory, but is often put off). Since drastic measures are very unpopular, they are also often not pursued politically and do not become part of the decision-making process.

An important note here is that for smaller or medium floods, that is, events that occur more frequently, an improvement can be brought about by spreading the water over the surface and generally lengthening the flow paths. Both of these measures "slow down" the flood wave. Yet since the watercourse areas are intensively used in the region, flood protection solely through green flood protection measures, such as renaturation, would not be feasible, especially in high intensity events. Any incisions in the landscape further come with the potential for immediate societal pushback, especially from local farmers. Accordingly, there are limitations to the system's capacity to react dynamically, and the trade-offs between the systems (business-as-usual livelihoods versus radical adaptation measures through resettlement, for example), are importantly limited.

3.4 Openness, Dynamism, and Adversity

The governance mechanisms of the Erft catchment are characterized by static policy and authority structures, which at times may hinder meaningful participation and decrease connectivity. For example, there are legal obstacles due to disparate competences among the relevant institutions when it comes to warning or informing the public about a developing event. However, the legally sanctioned authorities do not always have the information necessary, while institutions that do have access can only share their information via informal settings, such as ad hoc online meetings. The regional water board is not part of the official warning and response chain, barring it from any formal decision-making procedure. Yet decision makers have found a compromise by sharing information on the situation assessment with relevant stakeholders in the catchment area and contributing the water board's expertise at a local level.

This is an interesting case of how various levels of governance systems create barriers for connectivity and participation, which leads to the unintentional creation of new connections and parallel forms of information sharing, highlighting a case of external adversity (Ungar 2018), and openness and dynamism (Ungar 2018). Adversity can be detected in the shared but differentiated struggle against a changing climate, and concomitant disaster relief efforts between the Erft catchment and the German federal government. While the local community is part of the national and international governance agenda, and the goal of building resilience is shared, local communities may not share the same priorities as national agendas. The water board's initiative to hold ad hoc meetings in order to share information crucial to the handling of a potential extreme weather event shows that it has a clear understanding of its own function as a knowledgeable and responsible information producing system, despite the structural governance barriers. This self-understanding gives reason to establish informal modes of connection in order to fulfil its function despite the hurdles that come with nested responsibilities of multi-level governance structures.

These hurdles have important ethical implications. How smaller communities can respond to pressure from hierarchically higher-tiered administrators raises questions about the

communities' respective justice, freedom, and well-being claims that come with the potential rejection of adaptation and disaster interventions. Some claims may be legitimate from a perspective of distributive, historical, or participatory justice. Importantly, the reason for diverging opinions on what is and is not an acceptable option cannot merely be determined by the acceptance of the system's populace alone. As Taebi (2017) pointed out, there is a difference between what he called social acceptance and ethical acceptability. The fact that a community agrees to a given intervention (that is, social acceptance) does not yet entail that this intervention is ethically justifiable. Coercion, misinformation, structural and historical inequities, ignorance, and other factors that may impact the decision-making process affect the ethical acceptability of that decision's outcome.

This distinction does not entail that there is a singular, "correct" way to achieve ethical acceptability. Rather, the distinction between societal acceptance and ethical acceptability in the context of climate resilience calls attention to the fact that communities might end up agreeing to certain interventions regardless or in spite of justice considerations. Accordingly, reflecting on the ethical relevance of how larger systems (for example, the regional government) relate to the relevant subsystems (a small-scale community within that region) can help align the decision process with basic justice principles.

4 Discussion

The case study of the Erft catchment demonstrated that there are numerous mechanisms that enable a formal type of resilience, that is, resilience that only ensures functional continuity. Learning, experimentation, the handling of adversity, connectivity, and dynamism were all to some degree present and partially accounted for in its governance structures. At the same time, how complexity and uncertainty are addressed, and the potentially undermining effect of policy rigidity on the system's connectivity may decrease its resilient capacities. Specifically, there is little acknowledgment of the ethical issues underpinning many of these resilience aspects, which is both an issue for the ethical acceptability as well as practical feasibility of potential policy interventions. This could be improved by designing decision-making processes and climate adaptation policies intended to increase a given community's resilience in a way that includes reflecting on issues of justice, for example, through workshops and co-creative practices with the locally affected communities.[9]

Including systemic resilience and justice considerations into the decision-making process surrounding climate adaptation and resilience policies may be a fruitful way to improve the implementation of new policies with regards to their ethical justifiability as well as their feasibility and acceptability. Systemic resilience and justice can further bolster existing studies and frameworks, such as the various approaches assessing urban climate adaptation and resilience, for example (Brown et al. 2018; Chelleri and Baravikova 2021). Especially quantitative approaches for measuring resilience may benefit from the qualitative and ethical considerations presented throughout this article (Feldmeyer et al. 2020). Regarding the scalability of the approach, the justice and systemic considerations are first and foremost geared towards regional applicability. While justice issues arise at every governance level, the requirements of meaningful participation and the recognition that resilience issues need to account for highly specific, localized contexts may prove practically difficult and theoretically unsuited for larger-scale governance questions and may need to be adjusted accordingly.

5 Conclusion

The approach towards systemic climate resilience has shown that any decision surrounding resilience and climate adaptation always comes with important ethical implications. Accounting for these ethical implications is crucial for both the moral justification and the applicability of increasing resilience towards systemic climate risks. This exploration does not offer a clear-cut way to increase, for example, distributional justice when it comes to necessary intra-system trade-offs. Yet it may serve as an important first step towards actively acknowledging the ethical weight that otherwise remains unduly implied and hidden in actions seeking to increase resilience. Future research efforts should accordingly be put into systematic ways to account for the ethical underpinnings of systemic risks and resilience.

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[9] For an example of how such a process could be set up in the Erft catchment and other Real World Labs around Europe, see Parviainen et al. (2025)

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