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Understanding and Tackling Climate Change Adaptation Locally: Place-Based Perspectives on Capacities, Perceptions, and Challenges

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1. Introduction

Climate change adaptation has increasingly become a focus of human geographical research (Görg, 2011; Fünfgeld, 2015; Schäfer, 2017; Wannewitz & Garschagen, 2023). While human geographical research on climate change mitigation encompasses all levels—local, regional, and national—(Becker et al., 2016; Calvert, 2016; Naumann & Rudolph, 2020) studies on adaptation focus far more on the local level (Fila et al., 2023; Riach et al., 2023). This might be because vulnerabilities towards climate impacts, such as heatwaves, droughts, heavy rainfall, or sea level rise, require concrete action on the ground. At the same time, solutions to tackle climate adaptation locally are often very context-specific and thus need to be developed and tested on the ground to account for specific local conditions (Klenk et al., 2017; van den Berg & Coenen, 2011).

It is also crucial to highlight that climate adaptation policies strategies extend far beyond technical measures, such as the construction of dikes, greening or de-sealing projects, and water retention strategies. Equally important are local approaches that focus on the institutional integration of climate adaptation

into municipal governance processes (Göpfert et al., 2019a; Kern, Grönholm et al., 2023), the consideration of vulnerable groups—such as people with physical disabilities, older adults, very young individuals, and people experiencing homelessness (Carter et al., 2016; Teebken, 2024b)—as well as the mobilization of local knowledge, for example through the active involvement of residents and the local civil society (Eckersley, Haupt et al., 2023; Haupt et al., 2025).

Previous studies have shown that local climate adaptation action includes a large variety of different state- and non-state actors as well as actor coalitions (Eckersley, Haupt et al., 2023; Zorn et al., 2023; Haupt et al., 2025). In this context, municipal governments and administrations are often seen as key actors and considered as particularly influential (Dodmann et al., 2022; Kern, Eckersley et al., 2023). At the same time, the ability to mobilize adequate resources and expertise remains a significant challenge for municipalities of all sizes. However, this challenge is particularly acute for smaller or resource-constrained municipalities, where limited capacities hinder their ability to meet the complex, cross-sectoral demands of climate adaptation (Fila et al., 2023; Mitchell et al., 2022; Mitchell et al., 2024; Haupt et al., 2025).

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Keeping the importance of local administrations in mind, a focus on their coordinating role should by no means lead to a neglect of adaptation activities and processes that take place beyond administrative structures. Indeed, as many of the contributions in this special issue highlight, multi-stakeholder approaches to local climate adaptation are urgently needed. Furthermore, local adaptation constitutes a highly dynamic and continually evolving field of practice. This implies that local administrations must repeatedly revisit questions of (environmental and climate) justice and human–environment relations (Tebken, 2024a), as new practices and technologies continually reshape the conditions under which adaptation unfolds (Balogun et al., 2020).

Against this backdrop, this special issue focuses particularly on local actors in the context of climate adaptation in Germany and sheds light on different perspectives. Particular attention is devoted to municipal administrations and politicians and their roles as developers, implementers, and coordinators of climate adaptation solutions at the local level, as well as their perceptions of climate adaptation, including problem awareness, priorities, and obstacles. The contributions in this special issue provide insights into negotiation processes within and between municipal administrations and other actors. They identify key challenges for implementing adaptation measures, outline strategies used to mobilize actors, explore pathways for making relevant knowledge accessible to municipal employees, and discuss the technologization of urban nature. Moreover, the contributions reflect on the broader trend towards geographic climate adaptation research that increasingly goes beyond the study of large, active, and (supposedly) progressive cities. Instead, different types of municipalities, also smaller and less visible and active ones, receive more attention (Bausch & Koziol, 2020; Fila et al., 2023; Haupt et al., 2022; Fünfgeld et al., 2023; Reifentahl et al., 2025).

2. Municipal Climate Change Adaptation in the German Context

In Germany, adaptation to climate change developed into an independent municipal policy field in some pioneering cities during the 2000s and subsequently spread slowly but steadily across other municipalities. Municipalities in Germany¹ have significant autonomy (*kommunale Selbstverwaltung*) in both general

self-governance and climate adaptation (Lorenz et al., 2017). Representative data from 1,062 German cities, towns, and counties show that 12% had developed a climate adaptation plan by 2023, while another 23% stated they were currently preparing one. Regarding the implementation of adaptation measures, 41% reported that they are already taking action, and an additional 39% intended to do so (Friedrich et al., 2024). Overall, this indicates that the municipal policy field of climate adaptation is undergoing dynamic development (see also Otto, Haupt et al., 2025). However, there are various enabling and limiting factors and structures for municipal climate adaptation (Lehmann et al., 2015; Otto, Miechielsen et al., 2025; Schoenefeld et al., 2023). To date, smaller municipalities, for example, have been significantly less active in climate adaptation than larger cities (Friedrich et al., 2024).

2.1 Governance and Legislation

Climate adaptation at the municipal level represents a complex governance endeavor. This includes the internal organization of local authorities, such as institutional integration and the incorporation of adaptation measures into routine administrative procedures (Göpfert et al., 2019a; Kern, Grönholm et al., 2023; Lebrun et al., 2025). Equally important is the inclusion of local populations and civil societies (Göpfert et al., 2019b; Eckersley, Haupt et al., 2023; Mitchell et al., 2024; Haupt et al., 2025). In this context, previous research suggests that the activities of local administrations are often poorly perceived—or even entirely unknown—both among the local population and within local political arenas (Lenzholzer et al., 2020; Purwins & Keck, 2025).

The few studies that have examined municipal climate adaptation in smaller municipalities in Germany suggest that responsibilities may, perhaps out of necessity, shift to a certain degree towards local actors and civil societies (Eckersley, Haupt et al., 2023; Mitchell et al., 2024; Haupt et al., 2025). However, these studies also show that smaller municipalities, unlike larger cities, often lack formalized adaptation policies and long-term planning perspectives. As a result, they tend to be more co-creative and are often more closely aligned with the everyday lives and lived experiences of their residents. Even in these society-led adaptation practices (Eckersley, Haupt et al., 2023) actors from local government, such as (often temporarily

employed) climate managers, still play an important coordinating role (Mitchell et al., 2024; Haupt et al., 2025). In this context, studies highlight the advantages of mixed adaptation approaches that combine institutional and participatory strategies. These approaches are shown to complement each other and enhance overall adaptation outcomes (Maskell et al., 2025). Indeed, local climate actions frequently take the form of negotiation processes involving multiple actors, including local administrations as well as diverse stakeholders from civil society and the private sector (Eckersley, Haupt et al., 2023; Reifensahl et al., 2025). In smaller municipalities with less formalized adaptation policies, this dynamic often becomes even more pronounced (Mitchell et al., 2024; Haupt et al., 2025).

Furthermore, climate adaptation governance encompasses horizontal collaboration between different municipalities, for instance within a region that shares similar climate vulnerabilities (Häußler & Haupt, 2021; Schmidt et al., 2023). In federal systems, numerous additional actors at other governance levels complement the diverse actors at the local level and may set the key framework conditions for local climate adaptation, for instance by establishing legal frameworks, providing financial resources, and offering knowledge and practical support. This holds especially true in Germany, where multiple political and administrative levels significantly affect municipal work (King, 2022; Eckersley, Kern, Eckersley et al., 2023). At the federal level, for example, the first German Strategy for the Adaptation to Climate Change (*Deutsche Anpassungsstrategie*) was published in 2008, which has since been revised several times. This process is accompanied by the creation of action plans and reports on monitoring, evaluation, and climate impact and risk analysis at the federal level (Häußler et al., 2020).

Currently, climate adaptation in Germany is addressed in few sector-specific laws, such as the German Federal Building Code (BauGB; Bubeck et al., 2016) and some states have developed their own adaptation laws (King 2022). A larger step toward strengthening municipal climate adaptation at the federal level was made with the passing of the Climate Adaptation Act (*Klimaanpassungsgesetz*) by the federal government in 2023 and its entry into force in 2024. This law mandates, among other things, the development of municipal climate adaptation plans, though it allows states to exempt municipalities below a certain size

from this obligation if a plan already exists or is being developed at the county level. Furthermore, the law obliges municipalities to systematically consider climate adaptation in planning and decision-making processes without, however, providing specific information on how this should be done. Yet, the Climate Adaptation Act does not include the provision of climate adaptation as a mandatory municipal task or the allocation of financial resources for its implementation. As such, the prevailing resource bottlenecks—especially in smaller municipalities—are likely to persist.

2.2 Resources and Capacities

Many small municipalities, as well as larger, yet financially weak or highly indebted cities, lack the financial and human resources needed for the establishment of climate adaptation plans and the implementation of measures (Fila et al., 2023; Mitchell et al., 2024; Friedrich et al., 2024). In this context, the support for municipal climate adaptation from the federal (*Bund*) and state (*Länder*) governments has always played a central role (King, 2022; Kern, Eckersley et al., 2023; Kammerer & Zeigermann, 2025). Between 2011 and 2019 a uniform national funding landscape at the federal level has thus far ensured that municipalities throughout Germany have had formally equal access to funding for climate adaptation, even in cases where state-level support was insufficient or non-existent (Kern, Eckersley et al., 2023). Federal funding under the German Strategy for the Adaptation to Climate Change has enabled numerous municipalities and counties (*Landkreise*) since 2011, and more extensively since 2021, to develop climate adaptation plans, temporarily hire climate managers, and implement smaller investment projects (Eckersley et al., 2025). The application process is non-competitive, meaning that the majority of applications are approved (Kern, Eckersley et al., 2023). In addition to these federal funding schemes, some of the 16 states also offer funding for climate adaptation measures or plan development that municipalities can apply for.

However, it must be noted that preparing funding applications (often with tight deadlines) and meeting the subsequent documentation and reporting requirements consume significant time and human resources. These resources are then unavailable for other climate-related activities, if such activities are even planned (Eckersley et al., 2025). Moreover,

the preparation, application, and implementation of third-party funded projects require trained and experienced staff, and there is a smaller financial share that the municipalities need to cover themselves (Haupt & Kern, 2022; Kammerer & Zeigermann, 2025). In smaller municipalities with limited administrative capacity, the necessary financial and personnel resources for project acquisition and documentation are often simply unavailable, which leads many municipalities to refrain from applying for funding altogether (Eckersley et al., 2025). Moreover, securing third-party funding, for example, for the creation of climate adaptation plans or the hiring of climate managers, does not solve the issue of inconsistent funding. There is a risk that positions and related work may not continue, or will only be insufficiently continued, due to the project-based and time-limited nature of the funding. In smaller municipalities, this tends to be the rule rather than the exception (Eckersley et al., 2025; Haupt et al., 2025). Such incremental work often negatively impacts planning security and, ultimately, the development and implementation of ambitious and far-reaching measures (Haupt & Kern, 2022). These challenges raise the issue of how municipalities are navigating this situation, and whether responsibilities may, perhaps out of necessity, shift towards local actors and civil societies.

Next to financial resources and available time of personnel, the municipal capacities are influenced by the available knowledge on climate change and adaptation. Extensive knowledge on the state and the development of regional and local climate change, its impacts, and possible adaptation policies—including best practices and guidelines—has been generated, for example, through federally funded research projects². In parallel, exchange, training, and support formats for municipal staff have become increasingly institutionalized, such as through the project-based Centre for Climate Adaptation (*Zentrum KlimaAnpassung*), established in 2021, or through initiatives at the state level, for example, the Hessian Climate Municipalities (*Hessische Klima-Kommunen*). However, the provision of knowledge remains fragmented and therefore time-consuming for municipal staff to navigate (Friedrich et al., 2026), and is insufficiently tailored to the practical needs of municipalities at different stages of climate adaptation. The potential of available knowledge is further limited by challenges within municipal administrations, including limited expertise in using information and data, as well as constrained human and financial resources (Riach & Gla-

ser, 2024; Harrs et al., 2024). Consequently, existing knowledge resources remain relatively little known and underutilized, particularly in smaller municipalities (Friedrich et al., 2024).

Beyond knowledge provided at the state or federal level, municipalities also exchange experiences and lessons learned through inter-municipal networks (Häußler & Haupt, 2021). At the same time, some municipalities with sufficient capacities actively produce their own data and knowledge, partly through technological means framed as “smart” approaches (see Purwins et al., in this issue for a discussion of “smart trees”; Thaler et al., 2021), alongside participatory forms of knowledge production such as collaboration with civil society actors and the integration of citizen science (Haustein & Lorson, 2021; Klement et al., 2025).

3. Contributions to the Special Issue

This special issue comprises a total of five contributions, including three research articles and two short communications. All contributions address climate adaptation at the local level, albeit within highly diverse spatial contexts. The articles focus on an individual city (Purwins et al. on Augsburg), a city and its surrounding county (Neuner et al. on Bamberg city and county), municipalities across a single federal state (Rossow & Friedrich on Hesse), larger regions encompassing multiple federal states (Zorn et al. on Central Germany/*Mitteldeutschland*), and the national level, with Otto, Friedrich et al. synthesizing studies that range from single federal states to the entire country. The key foci of the individual contributions are briefly summarized below.

Purwins et al. (short communication) critically examine the integration of sensor-based technologies into urban green infrastructures, focusing on the case of smart trees in Augsburg to assess their political and ecological implications. Their analysis shows that, although datafication and technologization of urban nature are often portrayed as neutral or apolitical, these interventions tend to benefit a privileged minority and exacerbate broader social and ecological inequalities. Drawing on political ecology, science and technology studies, and Luhmann’s concept of functional simplification, the authors demonstrate that smart technologies isolate and optimize specific ecological functions—such as tree water uptake—while masking complex socio-ecolog-

ical processes and embedding global inequalities. The study further argues that although such technologies can enhance local resilience, they do so in socially and politically uneven ways, naturalizing interventions and obscuring their connections to global political and economic structures.

Rossow and Friedrich (short communication) highlight the central role of knowledge in advancing municipal climate adaptation and examine how knowledge-transfer practices can be improved. Drawing on survey data from the federal state of Hesse, they show that most municipal employees involved in climate adaptation often have limited experience and that responsibilities are dispersed across multiple departments. Survey respondents reveal substantial knowledge gaps related to identifying, prioritizing, and implementing adaptation measures. These gaps are most pronounced in smaller municipalities, whereas preferences for knowledge-transfer formats vary depending on municipality size. Based on these findings, the authors argue that effective knowledge transfer must be tailored to the administrative context, professional background, organizational capacity, and needs of local authorities.

Neuner et al. explore residents' well-being needs under climate change in the Bamberg region, encompassing the city and surrounding county. In this context, they also assess the potential of co-designed interventions to strengthen local climate resilience. Using qualitative interviews and participatory observation, their study underscores the importance of context-sensitive participatory approaches for locally anchored transformation pathways, emphasizing support for vulnerable groups and the cultivation of local change agents. Findings reveal that well-being is closely linked to social gathering spaces, physical activity, and relaxation, while residents express diverse concerns ranging from water scarcity and vegetation stress to perceived limitations on personal impact. The study further highlights that local sustainability networks, while fragmented, are heterogeneous, facilitating engagement with marginalized groups. Moreover, co-designed interventions—such as multi-stakeholder coordination platforms, community sustainability festivals, and children's workshops—enhance participation, self-determination, and social cohesion.

Zorn et al. investigate how municipal decision-makers in small and medium-sized municipalities in Central Germany (*Mitteldeutschland*) perceive climate change,

employing an actor-centered approach based on survey data. Their findings indicate that representatives across municipalities of all sizes report observed climatic changes. However, climate-related issues generally receive low priority compared to other policy areas, reflecting limited engagement in adaptation. The study further identifies significant differences in perceptions between municipalities of different sizes. When combined with structural and resource constraints, these differences create particularly unfavorable conditions for municipalities with fewer than 25,000 inhabitants. The authors place these results in the regional context, which is characterized by economic change, structural weaknesses, and high support for right-wing parties, and recommend comparative studies in other regions to improve the understanding of local adaptation dynamics.

Otto, Friedrich et al. examine the potential and methodological challenges of using surveys to study municipal climate adaptation. This research is set against the backdrop of the growing importance of local authorities and the need to understand the extent and nature of their engagement under specific framework conditions. Drawing on eight recent survey projects across Germany, their research article demonstrates that surveys—particularly those conducted in smaller municipalities where archival data is often limited—can provide valuable insights while also presenting methodological challenges throughout the research process. Challenges arise from the novelty and cross-cutting nature of climate adaptation, as well as from diverse administrative structures and unclear responsibilities within local authorities. The article concludes with recommendations for conducting surveys on climate adaptation and calls for closer collaboration among researchers and greater involvement of local authorities in designing future studies.

While differing in scope, theories, and methods, the articles in this special issue collectively point to key practical implications and future research needs for local climate adaptation in Germany and beyond. Several contributions underline the importance of further institutionalizing and politically anchoring climate adaptation at the municipal level, particularly in municipalities with limited capacities. In this context, building local networks and making climate adaptation a mandatory municipal task could be decisive steps. Beyond funding programs, such a mandate—called for in various policy papers (Albrecht et al., 2022; Riechel et al., 2022) and by local government

representatives (Climate Alliance, 2022; Peters & Balbo, 2024)—would require legislative action by the federal and state governments and a clear allocation of financial resources, potentially strengthening the long-term implementation of local adaptation.

With regard to future research, some of the contributions emphasize the need to evaluate the effects of the Federal Climate Adaptation Act on municipal responsibilities, resources, and the balance between voluntary and mandatory adaptation, once sufficient time has passed. Further research is also needed on the fragmentation, use, and effectiveness of knowledge and transfer offers, the comparability and harmonization of surveys on municipal climate adaptation, and regional and international comparative studies. Additional promising avenues include the analysis of place-specific transformation pathways and the role of change agents, as well as the social differentiation of adaptation needs and everyday practices. Moreover, critical perspectives on digitalization, data, and power relations in climate adaptation constitute an emerging field, with municipal actors likely playing a key role in these dynamics. Finally, the contributions point to the need for new research approaches, particularly the co-production of knowledge and stronger involvement of municipal actors in research and project design. They also highlight the value of closer engagement with insights from other disciplines, suggesting that geographic research on municipal climate adaptation can benefit from more systematic dialogue with political science and public policy studies.

Notes

¹ Germany has more than 10,000 municipalities, most of which are small towns (*Kleinstädte*) with a population between 5,000 and 20,000 inhabitants (Porsche et al., 2021) and belong to a county (*Landkreis*). In contrast, there are 106 independent cities (*kreisfreie Städte*) belonging not to a county with the majority of them having more than 100,000 inhabitants.

² See for example www.klivportal.de.

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The richness and energy of these discussions were a major source of inspiration for this Special Issue, and we are delighted that some of the original contributions are now included here as Short Communications and Research Articles.

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