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Climate Adaptation through Urban Planning: Entry Points and Barriers in Three German Cities

Abstract

Cities must adapt to increasing impacts of climate change, necessitating comprehensive and effective planning processes and instruments. This study investigates the integration of climate adaptation into urban planning, focusing on the experiences and perspectives of planners from three distinct German cities: Remscheid, Potsdam, and Würzburg. The findings reveal that despite a general awareness of adaptation measures, such as greening and open space preservation, substantial challenges remain, particularly in incorporating these measures into existing urban frameworks. Key barriers include financial constraints, regulatory obstacles, and competing land-use priorities. Differences also arise among professional perspectives; landscape planners highlight the potential of formal instruments like binding land-use plans, while land-use planners tend to express skepticism about their effectiveness. In contrast, informal instruments are predominantly viewed positively due to their flexibility and participatory nature. Stakeholder dynamics are crucial in shaping climate adaptation outcomes. Public pressure emerges as a significant driver for action, while administrative bodies often face conflicting interests that can hinder coordinated efforts. The study concludes with recommendations for better alignment of formal and informal planning instruments, increased political and administrative support, and more strategic integration of adaptation measures in the early planning stages to ensure successful implementation and enhance urban climate resilience.

Philipp Lebrun[1]*, Ariane Walz[1], Christian Albert[2]

1) University of Potsdam, Institute of Environmental Science and Geography, Potsdam, Germany

2) Leibniz University Hannover, Institute of Environmental Planning, Hannover, Germany

*Corresponding author email: phschneider@uni-potsdam.de

Philipp Lebrun
https://orcid.org/0000-0001-5447-0671

Ariane Walz
https://orcid.org/0000-0001-5616-4424

Christian Albert
https://orcid.org/0000-0002-2591-4779

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1 Introduction

The past summers illustrated which extensive challenges urban communities will most likely face globally in the course of climate change, as extreme heat affected western North America, the broader Mediterranean region and central Europe and led to widespread wildfires (Lhotka & Kyselý, 2022; World Meteorological Organization, 2021). Urban areas are facing a severe intensification of the urban heat island effect (UHI) with increased mortality and morbidity, especially among the vulnerable parts of society (Muthers et al., 2017). In 2021, heavy precipitation led to extreme flood events claiming 183 human lives and over 800 injured people in Germany alone. In addition, enormous damage was made to private households, companies and community infrastructure (BMI & BMF, 2022). Floods caused by heavy rain occurred throughout central Europe in the past years and are not necessarily tied to specific geographic conditions (Kaiser et al., 2021). Thus, cities need to adapt physically to mitigate negative effects of increasing meteorological extremes (Watts et al., 2019), which in turn requires adequate planning processes.

Ambitious policies, plans and strategies have been put forward to facilitate climate adaptation in Europe and its member states. On February 24, 2021, the European Commission published the "EU's Climate Adaptation Strategy" (European Comission, 2021) following its announcement as part of the European Green Deal in December 2019 (European Commission, 2019). Reckien et al. (2018) were able to show that numerous cities across Europe already published adaptation concepts within the first two decades of the century. Especially larger cities tend to take on the topic of climate adaptation, with smaller ones falling behind mainly due to limited resources, as shown for Germany (Otto et al., 2021).

One catalyst for adaptation planning is the presence of national regulations, which significantly influence local climate planning (Reckien et al., 2015). In Germany, the Federal Building Code was amended in 2011 to explicitly include climate mitigation and adaptation as municipal development objectives. Since then, formal land-use planning has been required to consider and promote climate adaptation. Owing to their mandatory and legally enforceable nature, combined with structured procedural requirements, formal planning instruments are intended to enable systematic and transparent urban development (Briassoulis, 1997). As highlighted by Bausch and Koziol (2020) and Fila et al. (2023), formal planning instruments therefore play a central role in shaping adaptation efforts.

In the German planning system, three planning domains are particularly relevant for integrating climate adaptation into urban development: informal planning, landscape planning and land-use planning. Each of these domains works with specific planning instruments that guide municipal decision-making. Informal planning instruments typically focus on a specific issue or sector. They can comprise climate adaptation concepts, urban development concepts or climatic maps that go beyond descriptive analysis by providing planning guidance relevant for municipal decision-making. Landscape planning, as a legally defined planning domain under nature conservation law, produces instruments such as the landscape plan, which sets environmental objectives and provides ecological assessments that must be taken into account in subsequent urban development. Land-use planning (Bauleitplanung) comprises two planning instruments: the preparatory land-use plan (Flächennutzungsplan), which outlines intended land uses for the entire municipal territory, and the binding land-use plan (Bebauungsplan), which establishes legally enforceable land-use and building regulations for specific areas. Environmental assessments (Strategic Environmental Assessment for plans and programmes, and Environmental Impact Assessment for individual projects) are integrated into the application of these formal planning instruments and require that environmental effects of planning decisions (including, among others, climate effects, biodiversity, soil, water, air, and human health) are systematically evaluated. Together, these instruments form the central regulatory and procedural framework through which German municipalities can address climate adaptation in planning practice.

Despite of several advances in policy making, shortcomings and knowledge gaps persist on how-to best

plan climate adaptation, especially at the city scale, and how to implement such strategies in different urban contexts. The literature points to a deficiency of actual implementation of measures in land-use planning (BBSR, 2016; Birchall & Bonnett, 2021; Diepes & Müller, 2018). In the past, municipal efforts have been characterized as rather reactive responses to experienced extreme events and not proactive adaptation processes (Amundsen et al., 2010). A survey conducted as part of the assessment of the German adaptation strategy revealed that many municipalities in Germany voiced concerns about inadequate human resources for addressing climate change effectively (Hasse & Willen, 2019). Barriers origin from organizational, procedural, and legal settings (Boehnke et al., 2023; Braunschweiger & Pütz, 2021; Shi, 2019). Similarly, Fila et al. (2023) noted that limited financial and personnel resources represent the most significant barriers to climate adaptation in small and medium-sized cities. They also highlighted a lack of empirical studies and the resulting knowledge gap regarding approaches to overcome these barriers, prompting them to advocate for a more focused examination of the specific responsibilities and roles of key stakeholders in urban planning, as well as in-depth case study research to gain insights into how institutions with limited resources have successfully addressed barriers in adaptation planning.

This paper addresses the notable gap in the current literature by examining planners' perspectives on the performance of specific urban planning instruments in the context of climate adaptation. The novelty of this research lies in its focused analysis of planners' assessments of three key urban planning instruments: informal planning, landscape planning, and land-use planning. Since planning instruments constitute the core of urban planning practice, and because their use is closely intertwined with the interactions and responsibilities of local stakeholders, examining how planners perceive their strengths, limitations and practical applicability offers important insights into the dynamics that shape local climate adaptation. The study not only explores the planners' views on these instruments but also investigates the practical hurdles and synergies they encounter during the implementation of adaptation measures. Additionally, it examines the roles and interactions of key actors, networks, and institutions, and how these influence both the use of planning instruments and the successful implementation of adaptation measures.

Furthermore, the paper analyses whether there were differences in the responses between cities and the professions of the interviewees.

Germany serves as a useful case study due to its one and a half decades of experience with climate adaptation planning, its federal governance structure and the resulting diversity of approaches across federal states. The strong role of formal planning instruments, combined with a well-established system of informal instruments, provides a particularly insightful setting for analysing institutional and procedural challenges in local adaptation. At the same time, insights derived from the German context may inform planners and policymakers in other countries by illustrating how adaptation can be integrated into multilayered planning systems and how local administrations navigate political, legal and organisational constraints.

The study focuses primarily on municipal land-use planning in three medium-sized cities in Germany. Further instruments with more specific urban development goals have not been explicitly considered as they are often tied to specific national legislative frameworks.

2 Research methodology

2.1 Research design

The interviews were conducted in the cities of Remscheid, Potsdam and Würzburg in Germany. The three cities were purposively chosen to represent different geographical contexts within the shared location in the moderate climate zone. Remscheid is located in North Rhine-Westphalia (51°11'N 7°12'E) with a population of 111.516 inhabitants (as of 2020) living in an area of 74.6 km^2. Potsdam is the capital and largest city of the state of Brandenburg (52°24'N 13°4'E) with a population of 182.112 inhabitants (as of 2020) living in an area of 187.28 km^2. Würzburg is situated in the south of Germany, in the Free State of Bavaria (49°47'N 9°56'E). It has a population of

126.954 inhabitants (as of 2020) and covers around 87.63 km^2. Würzburg is situated in a basin at the banks of the river Main, whereas the topography of Potsdam is dominated by a series of large moraines left after the last glacial period. Remscheid is located in the low mountain range region "Bergisches Land" with most of the settlement areas concentrated on the plateaus. Thus, all three cities differ noticeably with regards to their geographic starting point.

This analysis is of qualitative nature. Data was collected using nine semi-structured expert interviews, three conducted in each city. A key advantage of using semi-structured interviews is that beside being able to follow and cover all aspects identified prior through literature, potential unknown aspects can be recognized too. Although the use of a limited sample of respondents should always be viewed critically, even a limited number of perspectives can help to provide context-specific insights that are relevant to the aim of the research (Brower et al., 2000; Crouch & McKenzie, 2006).

2.2 Recruitment of the interviewees

The participants were chosen based on their profession and position within the municipal administration. In each city, three interviewees were selected: two from the field of urban land-use planning, one of whom represented binding land-use planning, and a third from landscape planning (or nature conservation in the case of Remscheid). Furthermore, one participant in Remscheid was the department head of land-use planning and thus expert for both domains of land-use planning. All participants had several years of professional experience in their respective areas of expertise, along with extensive administrative experience.

We informed all participants prior to their interview about the goal and use of the interview and received their written consent to participate in the research. All interviews were conducted between February and June 2020 and held in German. All but one was recorded using voice recorders. Later, interviews were fully transcribed. The average interview length was 1 hour, ranging between 45 minutes and 1.5 hours. With three participants, a face-to-face interview was conducted. However, due to the COVID-19 pandemic's traveling and contact restrictions, the remaining 6 interviews were done via videoconferencing.

2.3 Design of the questionnaire

To address our main research aim, we developed a structured interview guide based on an analysis of relevant scientific and grey literature, as well as planning and legislative documents. The basic structure of the questionnaire is provided in Appendix 1 and follows the lines of the research questions by addressing four themes around climate adaptation in urban planning.

Firstly, the extent of climate change impact in their respective cities was assessed, along with the background and reasons behind introducing climate adaptation measures in urban planning. As Kox and Thieken (2017) were able to show, people's decision-making thresholds on climate change related issues are inversely related to the severity of anticipated weather events, this initial segment therefore aimed to understand the urgency and context of climate adaptation in each city. Participants were questioned about the frequency and severity of extreme weather events experienced in their cities and the resulting impacts on infrastructure, public health and the environment.

Secondly, the study also delved into the range of climate adaptation measures implemented within the city. Participants were asked about the effectiveness and challenges associated with the execution of these measures, to identify successful practices and potential areas of improvement. To understand the preferences for specific adaptation measures, the interview guide explored the participants' perspectives on prioritizing certain measures over others. Factors influencing these preferences were also investigated to gain a nuanced understanding.

Thirdly, we inquired about the use of urban planning instruments, including formal, informal, regulatory and financial tools, and the participants' experiences with their implementation in the context of climate adaptation. One goal was to detect potential synergies between climate adaptation measures or strategies and other urban objectives, along with conflicts arising from competing priorities in the planning process.

Fourthly, the involvement of different stakeholders in climate adaptation planning was a crucial aspect of the study. The roles of proactive, hesitant, resistant, and insufficiently engaged stakeholders were explored to understand their impact on the planning process. Moreover, the study investigated collaboration between the participants and municipal climate coordinators, as well as interactions with major property owners regarding climate adaptation initiatives.

2.4 Analysis of the interview data

The transcribed interviews were coded with the software MaxQDA (Version 2020). To identify supportive and constraining factors for climate adaptation we assessed each answer in terms of supportive (driver) or constraining (barrier) character and coded it correspondingly. When answers were not assignable, since they did not contain any evaluation, they were not coded. The data was then analysed using deductive content analysis and focused on identifying supportive and constraining factors for climate change adaptation within the urban planning process. Additionally, we analysed whether there were differences in the responses between the cities and the professions of the interviewees. To identify these differences, the responses of the interviewees regarding local climate change impacts, climate adaptation measures, urban planning instruments, and various stakeholders were classified, evaluating their effectiveness and, in the case of measures, their feasibility. The results are presented in Figure 1. This allowed us to identify specific patterns and tendencies in the interviewees' statements and assess whether certain supportive or constraining factors for climate adaptation were more or less prominent depending on the city or the professional background of the respondents.

3 Results

3.1 Perceived local-scale effects of climate change

The effects of climate change are evident in all three municipalities. All respondents confirmed that they are facing some kind of challenges linked with climate change. However, the respondents emphasized that topography plays a crucial role in determining the vulnerability to the effects of climate change in all cities (s. Figure 1-I).

In Würzburg, the prominent urban heat island effect, caused by the city's location in a valley, has been a central issue for a long time (I8). In Potsdam, a city with a flat terrain, respondents stated that heavy rain events in the past have demonstrated to have significant impacts on infrastructure and public health even though one respondent considers vulnerability to extreme weather events generally as not extreme and rather limited to certain local areas (I5). In Remscheid, densely built settlement areas with a high proportion of impervious surfaces are located on the plateaus. During heavy rainfall, runoff from these elevated areas is channelled into the lower-lying valleys, where flooding tends to occur (I3).

3.2 Perceived opportunities and challenges regarding the implementation of climate adaptation measures

The knowledge about implementing adaptation measures is generally available in all cities. However, according to our interview partners, implementation still poses significant challenges (s. Figure 1-II). For instance, facade and roof greening face obstacles such as fire protection, structural concerns, and costs (I5; I7; I9). Lack of integration of urban greenery in parking areas and heritage protection hinder greening efforts (I8). Existing infrastructure (I8) and high maintenance costs further impede progress, especially in heavily indebted municipalities (I2). Convincing property owners to actively green undersupplied areas is challenging and may necessitate city regulations (I1). Water management receives limited attention due to past practices (I5) or limiting constraints, e. g. implementing rainwater infiltration measures is challenging if space is limited (I5; I7).

Despite the challenges posed by technical solutions and high costs, there is still untapped potential for roof and facade greening, particularly in infill and renovation projects (I8). The benefits of greening, such as evaporation and shading effects, effectively promote their implementation as they enhance the living and residential environment, one goal of urban development (I8; I9). Additionally, the integration of

multifunctional approaches in land use, such as combining sports fields with infiltration basins or using orchards for infiltration purposes, is an increasingly important solution (I5). These measures are relatively easy to implement when the respective areas are in municipal ownership (I6). One interviewee noted that implementing certain nature conservation measures on private land can sometimes be more feasible than imposing climate adaptation measures, as the latter often lack a comparable legal foundation (I6). Nature conservation measures are understood to refer to actions that are primarily justified based on ecological protection or enhancement as mandated under nature conservation law, even though many of them also generate co-benefits for climate adaptation. Climate change adaptation measures, in contrast, denote actions whose primary justification is the reduction of climate-related risks such as heat, or flooding. Creating synergies between nature conservation and climate adaptation may therefore offer additional opportunities in specific cases (I5; I6). Remscheid is considering natural vegetation succession/afforestation as a climate adaptation strategy, moving beyond a sole focus on preserving open land (I1). Nature conservation measures were only mentioned in response to the question about which measures were perceived as easier to implement (see Figure 1, Section II, Question B). In the previous question, where interviewees were asked to report on measures that had already been implemented, nature conservation or related measures were not mentioned. Therefore, their mention in Section II B indicates that these measures were specifically discussed in terms of implementation feasibility, rather than as measures that have already been adopted by the municipalities.In the case of water management, linking economic savings opportunities with local rainwater management offers potential and incentives for implementation (I4; I5).

In light of potential differences between the cities or professions, a consistent picture emerges among the interviewees regarding the integration and implementation of climate adaptation measures. In all cities, measures for greening and open space preservation are primarily implemented. These, alongside construction measures, are also regarded as the most contentious. In contrast, potential in water management is recognized solely by landscape planners. Despite various opportunities, incorporating measures often requires strategic consideration in initial planning, such as building orientation, to avoid irreversible consequences at a later stage (I7).

3.3 Perceived strength and deficits of urban planning instruments regarding climate adaptation

Informal instruments: Informal planning instruments such as climatic maps or urban development concepts are present in all cities, valued for their ability to convey topics and raise awareness about issues such as heavy rain and heat stress among the public and administration (I2; I3; s. Figure 1-III). They offer greater flexibility in involving the public and addressing multiple topics simultaneously and in greater depth compared to formal instruments (I5; I8). As a result, informal planning can directly influence the subsequent formal urban development process (I5). In Potsdam, the climate analysis map is considered a scientific basis for implementing future green spaces. It was emphasized that urban climate can only receive appropriate consideration in planning if addressed prior to the land-use planning process. However, realizing the full potential of informal instruments requires a genuine commitment within the municipality to respect their outcomes (I8).

While informal planning instruments have supportive elements, respondents identified barriers that can hinder their effectiveness. In Würzburg, one interviewee noted that certain sections of the climate analysis report seemed contradictory, which made it challenging to draw clear planning implications. For instance, the report emphasizes that trees can be an effective measure for mitigating heat through shading and evapotranspiration. However, it also mentions that tree stands may obstruct nocturnal ventilation, thereby reducing nighttime cooling (I7). The relevance of informal instruments is strongly tied to their topicality, with older concepts being less likely recognized (I8). Furthermore, the development of informal instruments and the implementation of accompanying measures often necessitate additional financial funding, requiring appropriate funding opportunities to be available (I2).

Landscape planning: Landscape planning is considered a relevant tool for climate adaptation as it can effectively convey and illustrate various environmental topics and their interdependencies, similar to informal instruments (I7; s. Figure 1-III). For example, landscape plans are legally mandated to address the urban microclimate and focus on protecting and expanding local cold air production or green spaces within a city (I9). Furthermore, the ability to integrate climate change and biodiversity goals provides an additional strength, according to the respondents. It serves as a database for assessing the environmental state and establishes development goals for both the environment and human well-being (I4). Therefore, it forms an essential basis for environmental assessments such as the Environmental Impact Assessment (EIA) (I4). An updated landscape plan that incorporates climate change considerations can provide valuable guidance for projects, as it can establish limits for urban development, particularly in peri-urban areas and in conjunction with the EIA (I2).

Land-use planning: All interview partners agreed climate adaptation has not been addressed in preparatory land-use plans so far, apart from concerns regarding nature and landscape conservation (I6). Topics such as blue infrastructure or public health have not been given due consideration as integral parts of land-use plans (I5). Preparatory land-use planning focuses on citywide land use and has no legally binding external effect. As a result, it cannot mandate the implementation of small-scale climate adaptation measures, especially on private property (I2; I4). Nevertheless, respondents added that the preparatory land-use plans can conceptually integrate climate adaptation by considering the provision of appropriate open spaces (I2; I5). Revisions of a land-use plan can therefore serve as an "opportunity window" to promote green infrastructure and additional adaptation measures (I8). It was mentioned that information about local cold air production and circulation can be relevant for land-use plans, as they can influence the selection of new development areas and prevent existing buildings from being completely detached from wind circulation access (I5). Overall, respondents from all cities indicated that the goals and content outlined in city-wide land-use plans cascade down to subordinate binding land-use plans, with minor or noncritical differences (I2; I5; I8). However, a land-use plan can become irrelevant as it ages, leading to a reversal of the planning process where new binding land-use plans necessitate adjustments in superior land-use plans (I7).

With regards to binding land-use plans, the respondents stated unanimously that they are important for climate adaptation since in those plans, the implementation of adaption measures can be imposed and regulated or be agreed upon through urban development contracts (I2; I5; I9). There is a high potential to address climate threats and adaptation, especially when new projects are planned (I4; I6; I8). To implement measures successfully, planners need to balance competing interests and overcome barriers during the planning process to guarantee the legitimacy of imposed requirements (I5; I6). In general, the less competing interests and conflicts exist, the more measures for climate change adaptation can be implemented in binding land-use plans (I6; I8). Beside the potential for climate adaptation through binding land-use plans, their spatial impact remains rather low as just a small proportion of the urban area is addressed with new binding land-use plans each year (I7).

3.4 Perceived impacts of actors, networks and institutions on implementation

In Remscheid the importance of federal policy was repeatedly emphasized regarding new regulations and frameworks (I1; I2; I3). Strict standards and requirements at the federal and state level were seen as helpful in overcoming barriers caused by competing interests during the planning process (I3).

Across the interviews, political bodies such as city councils were frequently described as actors whose decisions can slow down the implementation of adaptation measures. While political representatives may publicly advocate for climate mitigation and adaptation, they often take a more critical stance when discussing the integration of adaptation requirements into binding land-use plans, frequently referring to additional costs for landowners (I1; I2). At the same time, interviewees emphasized that political positions are not static and may shift after elections, as observed in Würzburg and Potsdam (I1; I4; I7).

The environmental department was highlighted as the leading and driving force for climate adaptation in all cities. In Potsdam and Würzburg, interviewees emphasized the role of newly established coordinating offices, which serve as internal administrative units facilitating communication and cooperation between different departments on climate-related issues. According to the respondents, these offices help to improve cross-departmental linkages and support the integration of climate adaptation into administrative routines. Despite these supportive actors, one respondent noted that individual-level barriers can arise when certain persons show limited interest or prioritisation of climate adaptation issues (I1). Departments for heritage preservation or building construction were found to offer little support or willingness to implement certain measures, partly due to their own legal guidelines or competing objectives (I4; I6; I8; I9).

Housing associations, like municipal subsidiaries, are drivers for climate adaptation as they are generally open to implementing measures (I1; I3; I4; I9). However, conflicts can arise when there is a high demand for social housing and limited budgets for construction, making more cost-intensive adaptation measures economically unfeasible (I3; I6).

The public, like municipal alliances, networks, and citizens' initiatives, has consistently pushed the issue of climate change forward (I2; I5; I8). Movements like Fridays for Future are seen by some as important drivers of political pressure, bringing climate change to the forefront of local politics (I2; I4). NGOs such as the "Nature and Biodiversity Conservation Union (NABU)" and the "German Federation for the Environment and Nature Conservation (BUND)" provide important impulses too (I1; I7). Local citizens' initiatives often emerge as a countermovement against large construction projects, constraining their realization and therefore directly and indirectly supporting the consideration of climate adaptation issues (I7).

Investors and large companies are also considered key actors for implementing climate adaptation measures due to their financial capabilities and involvement in large construction projects. Individual entrepreneurs with strong networks and personal commitment can advocate for climate adaptation (I2). However, according to the respondents, investors generally show reluctance in addressing climate adaptation (I1; I6; I7). Additionally, actors such as the Chamber of Industry and Commerce, business development agencies, and project developers were criticized by respondents in two of the cities for collaborating with investors to evade the implementation of adaptation measures (I1; I6).

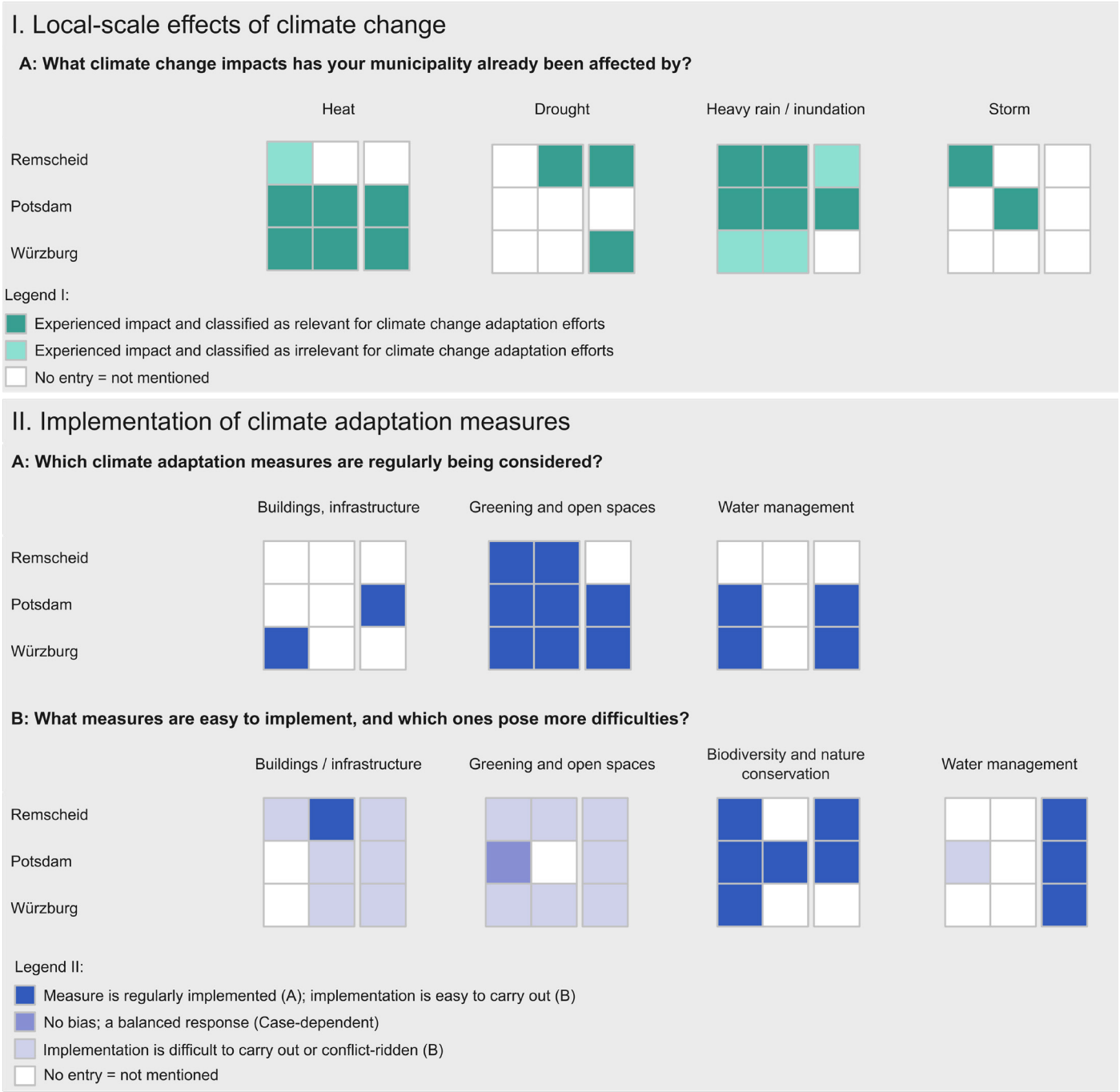
3.5 Agreement and differences between the cities and professions

Regarding the experienced climate change impacts, differences are observed between the city of Remscheid and the cities of Potsdam and Würzburg. In the latter two, heat is a relevant issue (6 out of 6 interviewees), whereas in Remscheid, heavy rainfall is particularly highlighted as significant (2 out of 3). In contrast to Würzburg, heavy rainfall is also of central importance in Potsdam (3 out of 3). Across all cities, greening and open space preservation were consistently regarded as standard adaptation measures (8 out of 9), though also as the most challenging to implement (7 out of 9). Differences between professions emerged mainly with respect to water management: all landscape planners (3 out of 3) described measures like infiltration areas, swales or retention within green spaces as comparatively feasible, whereas most land-use planners (5 out of 6) did not mention water management at all, and the one who considered such measures difficult to implement. Measures related to buildings or infrastructure were regarded as difficult to implement by landscape planners (3 out of 3) and, to some extent, by land use planners (3 out of 6), with one exception noted in Remscheid.

Regarding instruments, no significant differences in the evaluation of planning tools were found between the cities. While the assessment among landscape planners is largely consistent, except for the question of the usefulness of informal instruments, land use planners showed a more differentiated view across all instruments. However, with one exception (Remscheid), no instrument was deemed entirely unsuitable.

A more nuanced picture emerges in the evaluation of stakeholders. The driving role of the public is almost unanimously emphasized (8 out of 9). In con-

trast, interviewees' perceptions of the role of local politics and administration vary: Landscape planners particularly highlight environmental departments as key drivers, whereas land-use planners hold more mixed views regarding the role of politics and administration, with no consistent pattern emerging. Investors are perceived as more of a hindrance, especially among landscape planners (2 out of 3) and in the city of Potsdam (2 out of 3). Housing associations, when mentioned, where seen differentiated as well. Science and experts were only cited as positive drivers by 3 interviewees (2 in Remscheid and 1 in Würzburg).



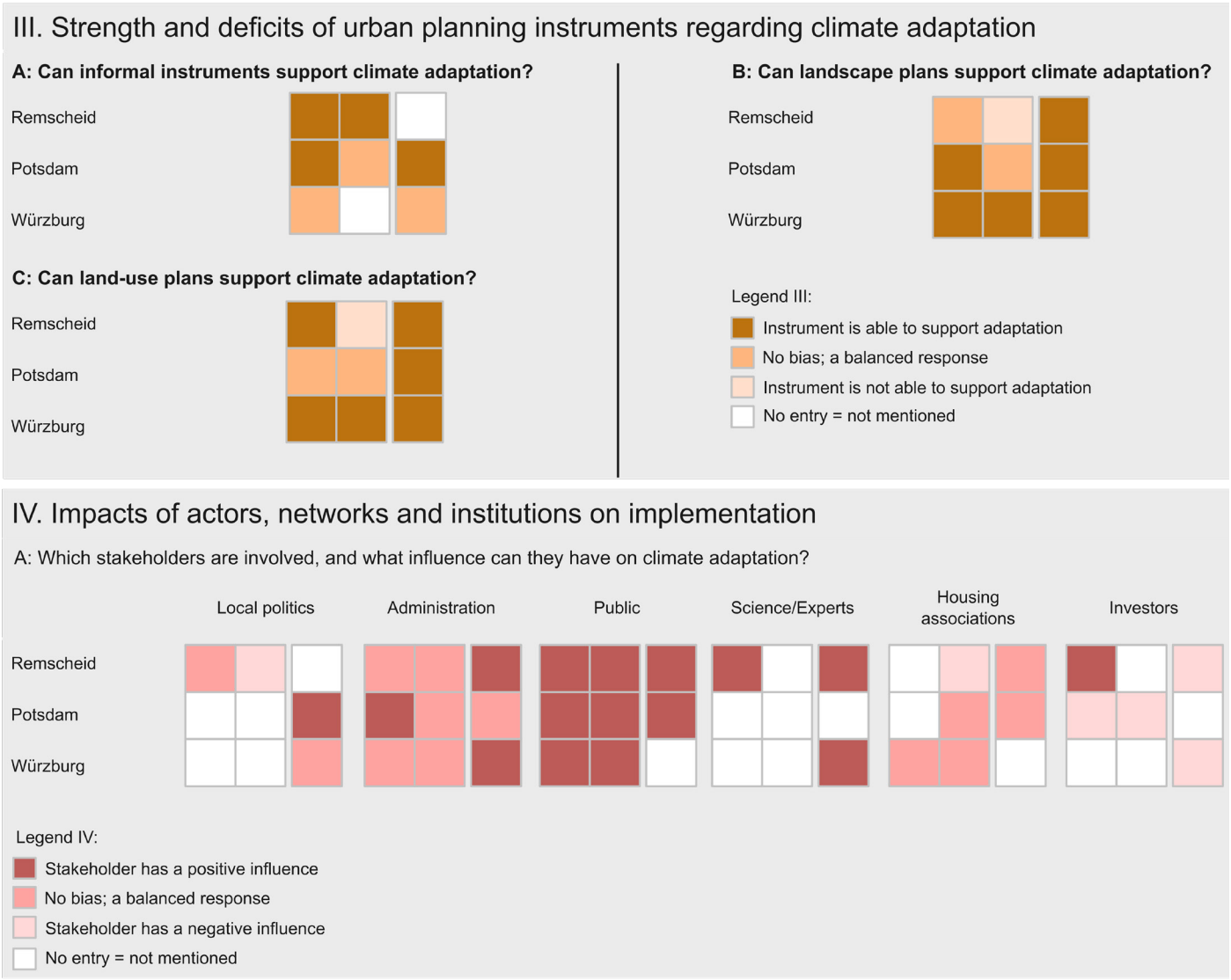


Figure 1. Interview responses from the municipalities of Remscheid, Potsdam, and Würzburg regarding local climate change impacts (I), climate adaptation measures (II), urban planning instruments (III), different stakeholders (IV). The responses to the question were clustered into main themes/heads. Each box represents the respective response to the question and the perspective of an interviewee. The tendency of the response is color-coded. The rows represent the respective cities, while the columns represent the professions: Column 1 = land-use planning, Column 2 = binding land-use planning, Column 3 = landscape planning.

4 Discussion

4.1 Supportive and constraining factors for climate adaptation in urban planning

The study presented here aimed to identify the supportive and constraining factors for climate adaptation in urban planning. Similarly to Lehmann et al. (2015) the findings reveal a critical understanding among respondents regarding the localized impacts of climate change, emphasizing the role of environmental conditions in shaping their vulnerabilities.

Despite general awareness across municipalities, significant barriers persist, including regulatory, structural, and financial challenges. For instance, issues related to facade and roof greening underscore the complexity of integrating such measures into existing urban frameworks. Structural concerns highlight the need for a coordinated approach that balances safety regulations with adaptation goals. Additionally, the high costs associated with greening efforts can deter property owners, suggesting financial incentives or city regulations may be necessary to motivate action. In the German context, nature conservation measures may offer a feasible entry point for

broader adaptation efforts, as they are supported by established legal frameworks and well-developed administrative practice.

Informal planning instruments have proven to be valuable in conveying topics, raising awareness, and involving both the public and administration in addressing climate-related issues such as heavy rain or heat stress. This is especially important in the field of climate adaptation (Burns et al., 2022), particularly considering that smaller municipalities often exhibit more substantial knowledge gaps concerning the probable local consequences of climate change and the potential of adaptation measures and strategies (Clissold et al., 2020). Their flexibility allows for a more in-depth and multi-faceted approach compared to formal instruments, which, in turn, directly influences the subsequent formal urban development process. The case of Potsdam exemplifies how the climate analysis map serves as a scientific basis for implementing future green spaces and emphasizes the importance of proactively addressing the urban climate right from the outset in the urban planning process.

However, the effectiveness of informal planning instruments is subject to certain limitations. Issues such as contradictory and imprecise statements in climate analysis reports (as observed in Würzburg) can impede the successful implementation of measures. Moreover, the relevance of these instruments is closely tied to their topicality, with older concepts being less likely recognized, especially in the context of uncertainty related to future climatic data. This might hamper the development of complex adaptation strategies (Mauree et al., 2019), necessitating continuous updates and monitoring.

The findings also emphasize the value of landscape planning as a relevant tool for climate adaptation. Landscape plans not only serve as essential databases for assessing environmental conditions but also establish development goals that align with climate change and biodiversity objectives. This dual focus enhances their efficacy in addressing urban microclimates and promoting local cold air production and green spaces. By integrating climate change considerations into landscape planning, municipalities can provide vital guidance for future projects. However, the binding effect of landscape plans varies between federal states; in many cases, they become legally effective only when integrated into land-use plans, which influences their practical impact.

In contrast, preparatory land-use planning appears to have been less effective in addressing climate adaptation concerns. Respondents noted that while nature and landscape conservation are acknowledged, other critical elements, such as blue or green infrastructure, have not been integrated into land-use plans. Although land-use plans primarily focus on current and future land-use, they can still promote conceptual goals for developing open spaces. Revising city-wide land-use plans can serve as an "opportunity window" to push for green infrastructure and adaptation measures, which suggests that planners should be proactive in identifying and leveraging these moments for enhancing climate resilience.

Regarding binding land-use plans, respondents recognized their importance in climate adaptation, noting that they can impose and regulate necessary measures. The potential to address climate threats is especially pronounced in new projects, which can integrate adaptation strategies from the outset. However, the effectiveness of these plans in addressing climate adaptation is contingent upon the planners' ability to balance competing interests and navigate conflicts during the planning process. The findings suggest that fewer competing interests typically correlate with more successful implementation of climate adaptation measures, emphasizing the need for collaboration and consensus-building among stakeholders. In light of the need for comprehensive adaptation across the entire city, however, binding land-use planning may not be a suitable instrument for effectively addressing these challenges, as only a relatively small area is typically planned and developed at any given time.

Our research emphasizes the significant role diverse actors play in shaping climate adaptation outcomes through stakeholder dynamics. These results are consistent with the research conducted by Hoppe et al. (2016), which highlighted the active involvement of citizens' initiatives, business firms, and housing associations in climate action. Similarly to Bausch and Koziol (2020) and Desthieux and Joerin (2022), our findings highlight the need for dedicated personalities to drive climate adaptation efforts and sup-

port the aspect of constant communication among various urban government levels and sectors as a requirement for the integration of climate adaptation into daily planning practice (Mahlkow & Donner, 2017). Private actors and investors can act as facilitators. However, convincing investors and private owners to implement adaptation measures is challenging, as they often prioritize immediate costs over future benefits. This reluctance can hinder implementation, especially in financially weak municipalities, where going against investors' interests is difficult for planners and decision-makers. Conversely, public pressure from citizens' initiatives, particularly after extreme weather events, can further drive action and results in tightened rules and requirements. Politics play a crucial role as they represent the ultimate authority in decision-making and legislation, both at the local and national levels. Their resolve and the corresponding political and policy structures frequently influence the ultimate results in climate adaptation and urban planning, as illustrated by McClure and Baker (2018) as well as by our results.

Regarding the differences between cities and professions, the study highlights that the impacts of climate change are recognized in all three municipalities, with local physical and climatic conditions shaping the specific vulnerabilities of each municipality. In terms of adaptation measures, traditional greening and open space preservation are commonly recognized as standard climate adaptation measures in all cities (8 out of 9), though they are considered difficult to implement (7 out of 9). Landscape planners are more optimistic about implementing water management measures, likely due to their experience in integrating such measures.

When it comes to planning instruments, the study found no significant differences in the evaluation of planning tools between the cities. However, there were notable differences in how landscape planners and land use planners viewed certain tools. Landscape planners generally displayed a more consistent view on the usefulness of planning instruments, except for informal instruments. On the other hand, land use planners exhibited a more nuanced approach. The scepticism among land use planners, particularly in Remscheid and Potsdam, may reflect concerns about the formal nature of land-use plans and their perceived ineffectiveness in driving rapid adaptation to climate change.

Interestingly, landscape planners particularly emphasize the importance of preparatory land-use and binding land-use plans, whereas interviewees from land-use planning show less confidence in their effectiveness for climate adaptation. This suggests that landscape planners perceive a need for a more restrictive instrument of their own, which is currently being sought within the realm of land-use planning but is not yet fully addressed.

Overall, the results indicate that the nearly uniform planning schemes and processes in Germany result in relatively small differences between cities. The differences between professions, on the other hand, reflect the varying objectives and priorities. This highlights the need for an improved planning process that integrates diverse perspectives, as this would likely benefit all cities, regardless of their specific vulnerabilities or characteristics.

4.2 Opportunities for enhanced implementation of climate adaptation

Based on the interview results, two sequential and interdependent prerequisites shape the municipal pathway to climate adaptation, as shown in Figure 2. First, it is essential to establish political and organizational conditions. This includes securing political support and commitment, as well as fostering cross-departmental cooperation. This cooperation can be facilitated through coordinating offices, for example. Secondly, it is essential to implement current and well-aligned planning instruments across departments to establish a practical framework for decision-making. This alignment serves as the foundation for making climate-adaptation-oriented decisions and allows for the execution of specific adaptation measures, even in the face of financial and structural limitations. The interviews suggest that these prerequisites are interconnected; deficiencies in earlier steps can hinder the effectiveness of later ones, especially in small and medium-sized cities.

Various ideas can be discussed to further enhance climate adaptation within urban planning. The long time periods needed to update or draft land-use and landscape plans (Bubeck et al., 2016), often ex-

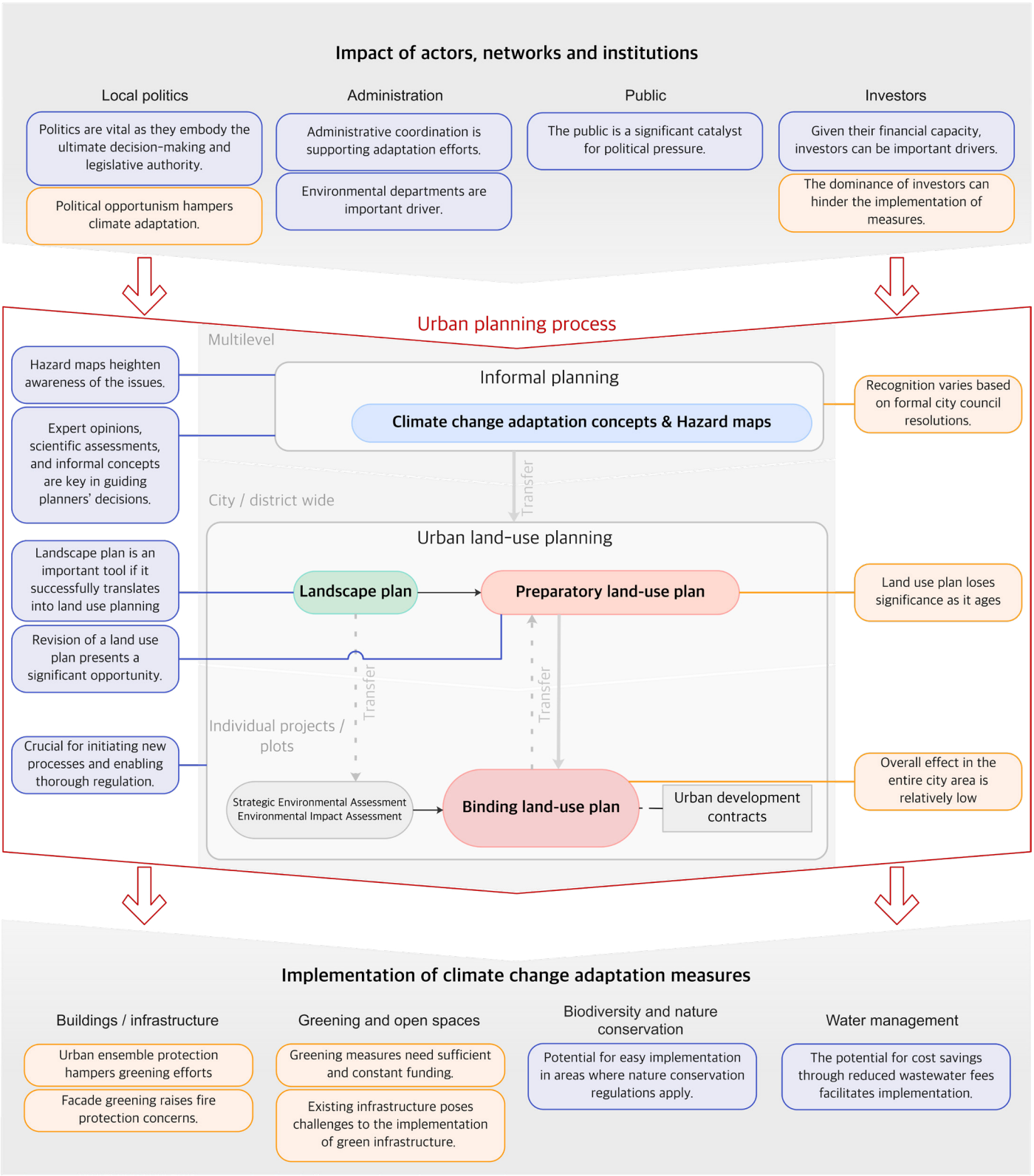


Figure 2. Pathway to climate adaptation through urban planning with an overview of supportive (blue boxes) and constraining (orange boxes) factors. The figure highlights the roles of key actors, their potential influence on the urban planning process, and the subsequent implementation of climate change adaptation measures.

ceeding 15 years (Lebrun et al., 2021), may not adequately reflect the ever-faster climatic change. As mentioned by Bubeck et al. (2016), climate adaptation is much more context and location dependent than, for example, climate mitigation. Hence, adjustments to land-use and landscape plans might need to follow an incremental or spatially limited approach utilizing informal instruments. This would preserve their relevance over time, reduces the resources needed, especially beneficial for financially constrained municipalities and further address the problem that long-term planning of measures, such as open space conservation, is often constrained by political election cycles and the prevailing short-term focus among political decision-makers (Campos et al., 2017).

The consistent use and integration of informal planning instruments might as well serve for long-term urban planning under climate uncertainty as the latter often requires a balance between robustness and flexibility of possible adaptation strategies (Krishnan et al., 2022). Furthermore, leveraging vulnerability information from informal instruments, including socio-demographic and spatially disaggregated data on populations at risk, can guide decision-making regarding future land-use within municipalities. Birkmann et al. (2021) provide an illustrative example of how vulnerability information can inform decisions on future land-use within a municipality. These informal approaches can help to overcome limitations in resources and mitigate a lack of understanding or uncertainty about the benefits of adaptation in smaller municipalities, which pose significant barriers (BBSR, 2016).

Transferring knowledge from informal participation processes into formal planning should be explored further to leverage the strengths of formal instruments. Ideas like citizen monitoring, as suggested by Adelekan et al. (2015), could complement official data and offers additional space for civic engagement. Embracing new systematic and deliberate forms of participation in planning can involve different and previously overlooked groups of actors, breaking down barriers faced by citizens' initiatives and fostering effective goal setting for climate adaptation (Cloutier et al., 2015; Göpfert et al., 2020; Uittenbroek et al., 2019).

Despite the available opportunities, long-term climate adaptation can be accomplished solely through the provision of sufficient resources (Wamsler et al., 2020). Without adequate support, particularly in financially challenged municipalities, climate adaptation will remain an additional task, consequently diminishing the ability for research, coordination, and engagement (Burns et al., 2022). Recognising climate adaptation as a joint federal task could create stable and long-term funding structures, similar to existing arrangements in regional economic development or agricultural policy. Such a status could enable more predictable financial support across federal, state, and municipal levels, reduce competition for short-term project funding, and strengthen the capacity of smaller municipalities to plan and implement adaptation measures in a sustained manner. Overall, political determination remains essential, as political actors hold the authority to establish these long-term frameworks and embed climate adaptation sustainably within administrative actions.

These findings align with international research that highlights administrative capacity, political commitment and coordination across departments as key determinants of local adaptation (e.g. Braunschweiger and Pütz (2021); Amundsen et al. (2010); Boehnke et al. (2023); Uittenbroek et al. (2019)). At the same time, the strong reliance on formal instruments and the particular role of landscape planning reflect distinctive features of the German planning system. These characteristics offer insights that may not be visible in planning systems with weaker formal frameworks.

4.3 Methodological limitations

The research design chosen, entailing semi-structured expert interviews with deductive content analysis, may have influenced the study's outcomes. The structured nature of the interviews, utilizing predetermined questions to steer discussions, could have restricted the depth and scope of the acquired information. This structured approach may have limited participants from offering supplementary insights or alternative perspectives that could have emerged in a more open-ended interview format but holds the advantage of better comparability.

Furthermore, the application of deductive content analysis might have introduced bias into the data analysis process. Employing pre-established categories or themes for analysing interview responses could unintentionally overlook novel or unexpected patterns that a more inductive approach might have unveiled.

In urban planning, additional instruments exist to pursue individual paths towards climate adaptation. These additional pathways are facilitated by instruments related to nature conservation or municipal statutes. Both possess the capacity to ensure and endorse specific climate adaptation measures while being interconnected with the planning instruments at focus. These interconnections were not explored in this study and could offer additional opportunities for climate adaptation.

As the study is based on nine expert interviews, the findings are not statistically representative and reflect the subjective perceptions of the interviewees. Since the interviews were conducted in 2020, these perceptions may have evolved over time in response to political, societal or administrative developments.

5 Conclusions

This study highlights both supportive and constraining factors for climate adaptation within urban planning, revealing a gap between awareness and implementation. Regulatory, structural, and financial barriers, often impede progress despite widespread recognition of climate risks.

Urban planning instruments, both formal and informal, play a crucial role in facilitating climate adaptation, though they exhibit limitations. Informal instruments offer flexibility and are valuable for raising awareness and engaging stakeholders, while formal instruments such as land-use and landscape planning provide structured guidance. However, slow update cycles and competing interests can hinder their responsiveness. Notably, binding land-use plans offer opportunities for integrating adaptation in new projects but may struggle to address citywide challenges due to their localized scope.

Taken together, two key recommendations for practice emerge from this study. First, it reconfirms the complementary roles of formal and informal planning instruments, emphasizing the need for better alignment and combined use to support climate adaptation (Albert et al., 2020). Second, overcoming barriers to successful implementation requires strong political and administrative support, as political determination and proactive commitment are essential to embedding climate adaptation into administrative actions.

Opportunities for future research include examining the findings from this study in additional German cities and other governance contexts, to identify commonalities and differences in climate adaptation strategies. Additionally, investigating the synergies between nature conservation legislation and climate adaptation planning presents a promising avenue for maximizing the effectiveness of planning instruments in urban climate adaptation. Ultimately, research on the recent adoption of the Federal Climate Adaptation Act, which mandates the development of informal climate adaptation concepts, will present a valuable opportunity in the field.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix I: The basic structure of the questionnaire

1 Nature and Extent of the Impact

- Reasons for the introduction of "Climate Adaptation" at the respective planning level
- Frequency of extreme weather events (as well as possible further noticeable consequences of climate change) and resulting subsequent effects

2 Adaptation Measure

- Range of adaptation measures considered at the respective planning level
- Definition of the more preferred and less preferred measures
- Synergy and conflict potentials between climate adaptation and other urban measures
- Specific to urban binding land-use planning: Climate adaptation in new development areas as opposed to existing areas

3 Use of Available planning instruments

- Planning instruments (including the interactions between different planning levels, such as binding landuse plans, preparatory land-use plans)
- Regulatory instruments (e.g., the Building Code [BauGB] and its amendments)
- Informative instruments (e.g., climatic maps, environmental reports)
- Financial instruments (e.g., funding programs)

4 Involved Actors & stakeholders

- Driving, hesitant, braking, and (so far) insufficiently involved actors
- Collaboration with municipal climate coordination offices/climate managers
- Collaboration with large real estate/property owners

5 Outlook

- Assessment of the relevance of climate adaptation in the future decision-making process in general
- (Further) Future challenges at the respective planning level
- Assessment of whether the urban planning level can/should be seen as a key element for climate adaptation.