Regional Environmental Change (2022) 22: 40
https://doi.org/10.1007/s10113-021-01870-3

ORIGINAL ARTICLE

Sixteen ways to adapt: a comparison of state-level climate change adaptation strategies in the federal states of Germany

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Received: 18 March 2021 / Accepted: 18 December 2021 / Published online: 9 March 2022

Abstract

Climate change adaptation (CCA) to reduce or prevent negative climate change impacts and, in some cases, maximize potential benefits is a complex challenge demanding multi-level policy action. In federalist systems, sub-national governments are among key actors for enabling adaptation and their clear commitments can increase collaboration and innovation at the local level. Germany serves as a particularly insightful case for observing the variance among sub-national approaches due to its role as a "leader" in CCA at the national level. This paper provides the first systematic assessment of all sixteen state adaptation strategies in Germany and examines how German states are fostering adaptation, the extent to which their approaches vary, and which patterns have emerged. Based on a qualitative document analysis of over 30 documents, this assessment focuses on five indicators synthesized from literature climate policy analyses and on barriers and facilitating factors of adaptation. Results find that German state strategies are often non-committal sets of recommendations and identify three clusters displaying different degrees of institutionalization and guidance. While federalism allows for flexibility among state responses, the absence of federal mandates and policy standards allows some states to fall behind while others continue to develop their strategies to foster adaptation. These sixteen diverse approaches each have implications for adaptation governance at other levels.

Keywords Climate change adaptation · Germany · Policy analysis · State-level · Climate governance · Cluster analysis

Introduction

Climate mitigation and adaptation to climate change impacts are more urgently needed than ever, with extreme weather events becoming "the new normal" (Msuya, 2021). While many impacts manifest at the local scale, e.g., flash flooding, several impacts cross administrative boundaries, e.g., sinking groundwater tables, have cascading consequences for other administrative units, e.g., forest dieback exacerbating flood risks. Though there cannot be total protection from the impacts of climate change, which include extreme temperatures, torrential rains, and damaging storms, widespread and effective adaptation policies can help societies reduce their vulnerability to the impacts of climate change (Adger et al. 2005). Governments can be both initiators of policy innovations and enablers of broader society-driven measures, which gives them an "unparalleled capacity" to steer public governance and adaptation action (Biesbroek et al. 2018a, p. 778).

In the large and growing field of climate policy research, scholars have studied the emergence of climate change adaptation (CCA) policies and strategies. Previous assessments range in focus from international to municipal levels of governance. Numerous studies compare and assess national-level approaches and strategies (Biesbroek et al. 2010; Termeer et al. 2012; Heidrich et al. 2016; England et al. 2018; Jurgilevich et al. 2019) or the municipal level (De Gregorio Hurtado et al. 2015; Aguiar et al. 2018; Lesnikowski et al. 2019; Olazabal et al. 2019; Reckien et al. 2019). Yet, the sub-national level of governance remains underrepresented in climate adaptation policy research (Vogel et al. 2020; Biesbroek and Delaney 2020), especially considering the multi-level nature of the issue.

Climate change is a complex challenge with wide-reaching and diverse impacts across sectors, landscapes, and

Communicated by Chandni Singh.

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administrative borders (IPCC 2014). National government policy efforts, for example, play a crucial role in initiating adaptation at lower levels, particularly in unitary states (e.g., UK, Sweden, Finland) (Amundsen et al. 2010). However, the adoption of a national adaptation strategy does not guarantee the implementation of adaptive measures nor is it a prerequisite (Jurgilevich et al. 2019). National mandates for policies at the local level are shown to have a significant impact on the development of city climate policies, but compliance is not guaranteed (Reckien et al. 2018). In the absence of strong national or regional policies, cities with sufficient resources are more likely to initiate their own climate policies, but smaller municipalities often lack the capacity without support from higher levels (De Gregorio Hurtado et al. 2014, 2015). No single level of governance has been found at which climate change policy is most effective for substantial action (Jurgilevich et al. 2019). Like many complex environmental challenges, adaptation to climate change is intrinsically a multi-level matter that requires policy action at various levels of governance (Adger et al. 2005; Urwin and Jordan 2008; Bauer et al. 2012; Clar and Steurer 2019). Interactions across levels are inevitable but not yet well understood (Clar and Steurer 2019).

In federated states, such as Germany, Australia, Mexico, India, Nigeria, and the USA, sub-national governments often wield the authority of certain policy sectors. Within the climate change mitigation discussion, sub-national governments are recognized for their pivotal role (Hsu et al. 2020). In several policy areas, which affect mitigation *and* adaptation, states have the power to instigate action through their jurisdiction over the municipalities (Vogel et al. 2020). In contrast to most local governments, state governments are equipped with larger administrations, more financial resources, and a broader scope than single municipalities. Thus, research to date suggests that this authority combined with more resources makes state governments, as one of several levels, key actors for fostering adaptation action particularly in small- and medium-sized municipalities. Their clear commitments to adaptation can increase collaboration and innovations in local adaptation efforts (Mimura et al. 2014; Jurgilevich et al. 2019; Vogel et al. 2020). Analyses by De Gregorio Hurtado et al. (2015), Heidrich et al. (2016), and Reckien et al. (2018) provide evidence that policies at higher levels of government can positively influence the actions of lower level governments. These findings and consensus among scholar highlighting the importance of action at *all* levels of government in tackling the climate crisis indicate the need for a better understanding of adaptation policy action at the sub-national level.

Roughly 40% of the global population lives in federal countries, which together constitute almost 50% of global landmass (Forum Fed 2021). A greater understanding of the role of state governments in this multi-level challenge may offer lessons how other federal states, especially those in which adaptation is a newer issue, may (better) guide both national and sub-national CCA policy. Examining sub-national[1] CCA policies could offer new insights on adaptation deficits commonly observed by adaptation researchers (Ford and Berrang-Ford 2016; Runhaar et al. 2018). This particular analysis lays the foundation for further investigations of causal relationships and interactions with contextual conditions and other levels of policy and their impact on adaptation action.

Germany provides a fruitful example for analyzing sub-national adaptation policy with more than a decade of evidence and stable support for adaptation at the national level of government (Otto et al. 2021). Germany is considered an "early adopter" and "leader" on adaptation planning at the national level (Massey et al. 2014; Lesnikowski et al. 2020). Due to this reputation, its ample resources, and a policy approach relying on strategies as a dominant policy instrument, Germany poses a rich, multi-level case for analyzing the role of states' strategies in stimulating adaptation. Furthermore, existing research on climate policy at other levels in Germany provides additional context to enrich the discussion in this paper on multi-level governance and adaptation policy (Heidrich et al. 2016; Reckien et al. 2018; Otto et al. 2021).

The following research questions are central to this analysis: how are German state CCA strategies fostering adaptation, to what extent do policy approaches and commitments vary within the federal context, and what patterns have emerged? The research therefore responds to the call for comparative adaptation research, in this case within a single country, that analyzes adaptation policies more comprehensively than insights on the specific types of policy mixes (Lesnikowski et al. 2019) and examines the heterogeneity possible in the federalist system.

From literature on evaluating and designing climate policies and research on facilitators of and barriers to adaptation, the research establishes a framework for assessing and comparing state CCA strategies based on five core indicators: (i) *climate impacts and vulnerability assessments*, (ii) *sectors addressed*, (iii) *policy goals and commitments*, (iv) *institutional organization and coordination*, and (v) *plans for policy adjustments.* These indicators aim to capture factors for fostering adaptation throughout policymaking cycle: from agenda setting to evaluation and policy adjustments. The selection of these indicators is explained in more detail in "Analytical framework."

Adaptation is institutionalized in diverse ways from mainstreaming to stand-alone policies, and diverse approaches

[1] Hereafter referred to as the "state level," which describes the German *Bundesländer*.

help fit individual contexts (e.g., cultural setting, administrative traditions, policy styles) (Heidrich et al. 2016; Biesbroek et al. 2018b). Concepts of effectiveness and success are normative and contingent on goals, which themselves are subjective or in some cases absent (Adger et al. 2005; Dilling et al. 2019). Rather than rank the sixteen states according to their strategies which would suggest a superior approach to adaptation policy, the comparison seeks to map diversity within a single country and identifies similar approaches using a cluster analysis. Drawing on results from research on national- and local-level adaptation policies, the discussion reflects on the role of state-level strategies and their impact on adaptation at other levels of government.

Analytical framework

The analytical framework applied in this paper is a synthesis of indicators drawn from literature on the emergence of climate adaptation policies and their evaluation (De Gregorio Hurtado et al. 2014; De Gregorio Hurtado et al. 2015; Heidrich et al. 2016; Aguiar et al. 2018; Reckien et al. 2018; Jurgilevich et al. 2019; Olazabal et al. 2019; Otto et al. 2021), literature on common barriers to and facilitators of climate adaptation (Smit and Wandel 2006; Moser and Ekstrom 2010; Measham et al. 2011; Eisenack et al. 2014; Uittenbroek 2016; Runhaar et al. 2018; Howlett et al. 2019; Russel 2019; Young and Essex 2019; Vogel et al. 2020), and adaptation progress and effectiveness tracking (Ford and King 2015; Berrang-Ford et al. 2019; Owen 2020). These streams of adaptation literature overlap and often complement each other. The chosen indicators were selected because they are proliferous in these literatures and have been proven useful for characterizing and mapping CCA strategies. These five indicators are certainly not exhaustive of all of the factors determining whether adaptation takes place but provide a comprehensive basis to assess and capture the nature of adaptation strategies, which serve as cornerstones and manifestations of states' policy approach to CCA.

Adaptation strategies serve as strategic policy instruments for continuous commitment to prepare for and cope with changing conditions and coordinate CCA in various sectors. Serving as potential initiators for long-term policy changes within multiple sectors (Clar and Steurer 2019), this analysis examines strategies' diverse approaches to adaptation policy based on five indicators for analysis: (i) *the use of climate change data and vulnerability assessments*, (ii) *sectors and areas of action addressed*, (iii) *policy goals and commitments*, (iv) *institutional organization and coordination*, and (v) *plans for policy adjustments and continuous action*. Drawn from the aforementioned convergent literatures on emerging CCA policies, facilitators and barriers to adaptation, and adaptation tracking, these indicators were chosen with the aim of capturing the extent to which they are suited to fostering adaptation in the respective states. Within the literature on facilitators and barriers to CCA and discussions surrounding the emergence of CCA policies, it became evident that common barriers emerge in different phases of the policy cycle. Similar to Biesbroek et al. (2010) and their analysis of European national adaptation strategies, these five indicators holistically include the different phases of policymaking: from scientific data as the basis for informed policymaking to the depth of policy goals and their institutionalization to monitoring and reevaluation as an opportunity for policy adjustments and tools for iterative planning. Indicators along these policy phases help indicate trends among state CCA strategies.

The first indicator identified is the *use of regional climate change data and vulnerability assessments.* Several studies have shown that scientific data on regional climate impacts and the assessment of regional vulnerability provide an important starting point for effective adaptation policies and act as a driver for CCA (Smit and Wandel 2006; Dupuis and Knoepfel 2013; Massey et al. 2014). Conversely, the lack of knowledge on potential impacts of climate change has been identified as a barrier (Aguiar et al. 2018; Young and Essex 2019). Not only do knowledge and awareness of vulnerabilities allow for the development and planning of adequate measures (Olazabal et al. 2019), but they also provide the framing for action. Understanding of the costs of inaction, not just economically, helps prioritize needs and build acceptance for action (Ford and King 2015). In a systematic review of CCA case studies, Owen (2020) found awareness for and solutions to issues of social justice and equity were often missing in adaptation initiatives and research analyses. Therefore, this indicator explores the use of analyses and concepts that capture the differentiated aspects of vulnerability (ecological, economic, and social aspects) within the broader IPCC definition as the composite of exposure, sensitivity, and adaptive capacity (Adger 2006; Smit and Wandel 2006).

The second indicator for comparison is the breadth of the *sectors or areas of action addressed*. Assessments of national and city adaptation policies have documented the range of sectors and, in some cases, considered the diversity of measures as positive indicators (Biesbroek et al. 2010; De Gregorio Hurtado et al. 2015; Aguiar et al. 2018; Otto et al. 2021) Huitema et al. (2016) explain how trade-offs are tied to the breadth of climate adaptation policies: problem or sector-specific policies may miss conflicts with other policy areas, while broader policies may not result in immediate outputs. Though the necessity for adaptation within a sector or problem domain depends largely on its vulnerability, the omission of certain sectors in comprehensive strategies may be indicative of intentional choices or priorities. For the cluster analysis, this indicator is represented by the variable

"stand-alone strategy" which refers to a multi-sectoral policy focused on adaptation.

The third indicator for fostering adaptation consists of *policy goals and commitments.* This includes the formulation of high-level policy goals, the identification of measures, and the extent of commitment to stated goals. Binding commitments to adaptation can foster policies at lower levels, though compliance cannot be guaranteed (Reckien et al. 2018; Wenta and McDonald 2019). Vogel et al. (2020) argue, "Regional governments making clear and firm commitments to adaptation as an important and ongoing policy priority creates the governance conditions for interjurisdictional collaboration and local innovations in adaptation efforts" (p. 1636). Alternatively, unclear and vague goals and the lack of political commitment have been identified common barriers to adaptation implementation (Aguiar et al. 2018; Runhaar et al. 2018; Howlett et al. 2019). Policy goals do not alone lead to adaptation implementation, but the formulation and explicitness of goals provide a basis for action. Rather than a simple box-checking procedure, this indicator examines the specificity of goals and if measures for their achievement are suggested. Both the identification and prioritization of measures and timeframes for their implementation are taken as variables for the specificity of goals (similar to Olazabal et al. 2019 and Otto et al. 2021), which fosters adaptation action (Owen 2020). Finally, this important indicator helps illustrate the nature of states' approaches to adaptation from state mandates with binding goals to recommendations for voluntary action to the informative strategies without policy goals.

The fourth indicator examines the *institutional organization and coordination* of state CCA, which serves to capture both who is responsible and who is involved in CCA policies. Clear authorities, institutionalization, and coordination are key for fostering adaptation (Biesbroek et al. 2010; De Gregorio Hurtado et al. 2014; Ford and King 2015; Aguiar et al. 2018; Runhaar et al. 2018; Berrang-Ford et al. 2019; Howlett et al. 2019; Olazabal et al. 2019; Young and Essex 2019; Owen 2020). Here, institutional organization refers to the working groups, committees, or departments formed or assigned to coordinate or focus on CCA. Empirical evidence suggests that adaptation efforts are more effective when an interagency group oversees adaptation activities or when one agency coordinates intra-organizational efforts (Biesbroek et al. 2010; Ford and King 2015). Coordination, as part of this indicator, may range from the cooperation, e.g., the exchange information, to collaboration, e.g., coproduction of a common governance strategy (McNamara 2012). Particularly in the mainstreaming approach, cooperation and coordination are found to help achieve policy goals (Huitema et al. 2016) and their absence found to be a barrier (Runhaar et al. 2018; Jurgilevich et al. 2019; Russel 2019). Because Germany's national strategy and many other federal initiatives emphasize the cross-cutting nature of adaptation and call for an integrated approach (Stecker et al. 2012), part of this indicator is whether the strategies' development and implementation extend outside of the leading state environmental ministries, either horizontally, with other state-level actors, or vertically, with national or local actors and actors.

The fifth and final indicator evaluates *plans for policy adjustments* in the form of strategies' inclusion of plans for monitoring, reassessment, and continued action. Adaptation is an ongoing process that itself must adapt to new scientific data and contextual changes (Ford and King 2015; Owen 2020). It is not linear with an endpoint but rather a continuous and cyclical process (Smit et al. 2001; Owen 2020). This indicator reviews the inclusion of plans, learning mechanisms, and processes in the adaptation strategies to reassess goals and measures, evaluate implemented interventions, and, if neccessary, readjust them. Olazabal et al. (2019) include this indicator as "learning mechanisms," within "scientific and technical credibility" and Otto et al. (2021) consider these aspects in their indicator on "plans." Progress assessment is key to the reduction of vulnerability and thus a central element of adaptation (Termeer et al. 2012; Berrang-Ford et al. 2019; Jurgilevich et al. 2019).

For a comprehensive list of variables within each of the indicators, a table of codes and sub-codes is included in the electronic supplemental material (Online Resource 2).

Methods

Case study focus on Germany

In accordance with the subsidiarity principle in Germany and considering the regional nature of climate change impacts, the authority and responsibility for adaptation are situated at the state and local levels (Bundesregierung 2008). In samples by Reckien et al. (2018) and Otto et al. (2021), between roughly one-quarter and one-third (respectively) of German cities were found to have CCA policies, with medium and smaller cities less likely to have adaptation strategies. To date, no research has examined the emergence of state CCA policies. Germany's National Adaptation Strategy (DAS) does not mandate but rather requests the states develop adaptation strategies and calls for the integration of climate change in all policy areas. A report from the Conference of the State Environmental Ministers (2008) emphasizes the role of state governments and explicitly calls for the development and implementation of regionally specific strategies to adapt (Bundesregierung 2008). As a key actor in climate change policymaking and agenda setting, state-level strategies for CCA provide an important foundation for assessing adaptation progress across Germany.

The German Environment Agency provides overviews of state documents, projects, and activities on their website, but does not evaluate their progress based on selected criteria or benchmarks in any publicly available reports. The first Federal Progress Report on climate adaptation summarized state activities in succinct, single paragraphs that described rather than assessed the selected examples (Bundesregierung 2015). In peer-reviewed literature, some papers analyze adaptation efforts in single-problem domains (e.g., Blättner et al. 2020; Grecksch 2013) or focus on individual states or regions (e.g., Ebermann 2020; Häußler et al. 2020). Therefore, this paper presents the first country-wide assessment of German state-level adaptation strategies. Because adaptation strategies are often considered the key hub of adaptation policymaking and interact with other levels (Clar and Steurer 2019), this analysis examines state-level CCA strategies based on the analytical framework presented in the last section and their implications for fostering adaptation state-wide and at lower levels of government. Thus, the analysis offers transferable insights on outcomes of a non-binding national policy recommendation in the context of a federal democracy, in which ample resources and political will for CCA are present at the national level; sets the groundwork for further analyses; and may offer lessons for other federated states that have yet to develop adaptation strategies.

Data collection and analysis

The research is based on a qualitative document analysis (as described by Bowen 2009) of German state adaptation strategies. Adaptation strategies refer to written plans of action for multiple sectors that establish a vision for adaptation and either recommend, promote, or mandate specific actions to be undertaken by the state and other governance actors within the state. In some cases, strategies for adaptation were embedded within climate mitigation strategies or sustainable development plans.

Documents were selected based upon the following criteria: a focus on climate adaptation or combined climate mitigation and adaptation strategy, coverage of more than one sector, and published by a state government or ministry. Multiple documents were selected for states that have updated their strategies or released separate documents as part of the same strategy. State laws with a focus on climate policy and paragraphs on climate adaptation were also included. These strategic documents serve as cornerstones and manifestations of states' policy approach to CCA. Project reports, single-sector strategies, or sub-state-level regional strategies were excluded from the analysis. In total, 34 government documents were analyzed. The documents were primarily downloaded from the German Environment Agency's website and state websites but partially acquired by email from state ministries in cases of broken links or for older versions of updated strategies. An overview of the primary sources is included in the electronic supplemental material (Online Resource 1).

The second step of analysis was an iterative assessment process, in which I subjected the data to a thematic analysis and coded according to the five criteria, with sub-codes developed therein to reflect nuances in the data and provide structure for their analysis. This process was supported by keyword search, which served to ensure that no data was missed in the coding of the documents. Coded data were then transferred to spreadsheets for sorting and analysis.

In order to identify patterns among state adaptation strategies, in the final step of analysis, I performed a cluster analysis (similar to those of De Gregorio Hurtado et al. 2015 and Otto et al. 2021). For this, I translated qualitative data into binary quantitative data, where 0 stood for the absence of the variable and 1 for its presence. This was done for 8 variables: use of climate change impact data; performance of a vulnerability assessment; stand-alone CCA strategy; formulation of binding goal(s); set timeframe for implementation; legal commitment to CCA; designation of leading authority for CCA; and plans for continuous action. These variables represent all five indicator areas with an emphasis on policy goals and commitments (as the focus of one research question) and the addition of the presence of a stand-alone strategy. Using this data set (see Table 1), I conducted a hierarchical cluster analysis for the 16 states using the Gower's general dissimilarity coefficient and Ward's method of agglomeration. These were applied to minimize within-group variance while maximizing between-group dissimilarity, and by graphical inspection, it was decided to cut three clusters (Figs. 1 and 2).

Findings: German state adaptation strategies

As of 2021, all sixteen federal states of Germany have strategies or recommendations for adapting to climate change. Strategies *either* are solely focused on adaption to climate change for multiple sectors (56% of the states) *or* have integrated adaptation within climate mitigation or sustainable development plans. The approaches vary in detail from extensive strategies, including climate change projections, risks, impacts, potential measures, and evaluation procedures, to short paragraphs in strategies not solely related to CCA. Based upon the chosen indicators, the majority of states solidly base their strategies on scientific data and vulnerability assessments, have designated authorities for coordinating adaptation and plans for continuing efforts in place, but often lack explicit and binding goals and commitments (see Table 1). In this section, subsections are not structured

Table 1 Summary of the presence (1) or absence (0) of variables in state adaptation strategies with arranged by clusters

Indicator	Variables	Schleswig–Holstein	Saarland	Brandenburg	Mecklenburg-West Pomerania	Saxony	Hesse	Saxony-Anhalt	Bavaria	Lower Saxony	Baden-Württemberg	Bremen	Rhineland-Palatinate	Hamburg	North Rhine-Westphalia	Thuringia	Berlin	%
i	Regional data on CC impacts	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	100%
	Vulnerability assessment	0	0	0	0	0	1	1	1	0	1	1	1	0	1	1	1	56%
ii	Stand-alone CCA strategy	0	0	0	0	0	0	1	1	1	1	1	1	1	0	1	1	56%
iii	Formulation of binding goal(s)	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	25%
	Implementation timeframe	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	1	38%
	Legal commitment to CCA	1	0	0	0	0	0	0	1	0	1	0	0	1	1	1	1	44%
iv	Designated authority for CCA	0	0	0	0	0	1	1	0	1	1	1	1	1	1	1	1	63%
v	Continuous action plan	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	75%

strictly by the five indicators but by relevance and the results of the cluster analysis.

Policy goals and commitments

Overall, state strategies tend to be informative, loosely coordinating, and non-committal. Seven states (44%) have solidified commitments to adaptation through legislation (see Table 1). Of these, three (19%) have binding goals. Berlin, for example, made its "Energy and Climate Protection Program" binding with the 2017 amendment to the *Berlin Energy Transition Act* (2016) and selected 20 measures to be completed or in progress by 2021. North Rhine-Westphalia passed the *Climate Adaptation Act* in 2021 (Landtag Nordrhein-Westfalen 2021), which commits to implementing adaptation measures and legally anchors other existing institutional commitments. Executive decisions in four states call for CCA action through the creation of a CCA strategy, but these decisions are less binding than legislative decisions, i.e., laws. All other state strategies are either explicitly non-binding recommendations or ambiguous in the level of commitment with no evidence of executive or legislative action.

All strategies include at least one or more overarching goals to adapt to the impacts of climate change. These range from data collection and vulnerability analyses, such as "providing the executive and legislative branches of government with information and advice on the need to act and potential adaptation measures" (own translation, Mecklenburg-Vorpommern 2010, p. 3), to high-level agenda setting, e.g., "integrate climate change adaptation into the general performance of state duties" (own translation, Nds. MU 2012) to more specific formulation of policy goals, e.g., "decrease vulnerability and increase robustness, protect the residents […] and to avoid the costs of damage from climate change impacts" (own translation, Bremen 2018). Stated policy goals display a diversity of detail, scale, and scope, yet the majority of aims are formulated in a manner that their progress would be difficult to measure. A quarter of strategies contain any kind of binding goals, half of which are city-states.

All strategies describe adaptation measures at varying lengths of detail. Data for this indicator signifies diverse approaches among states, in that some identify and prioritize specific measures and their implementation, while others present potential measures that state and other actors could consider. Lower Saxony's recommendations include roughly 590 highly detailed measures, of which 380 could be carried out by state-level authorities. However, the implementation strategy states that the prioritization of measures and descriptions of the conditions necessary for their implementation were intentionally excluded from the process (Nds. MU 2013, p. 6). Similar to the goals, state documents display a heterogenous mix of measures ranging from data collection to highly specific tasks such as "liming forest soils," for example.

Fig. 1 States colored by cluster, with green states as the highest levels of institutionalization of CCA and yellow states with the lowest degrees of institutionalization

Institutional organization and coordination

The majority (63%) clearly state which institutions or newly established committees coordinate state CCA actions and initiatives. Several states have multiple working groups and committees focusing on CCA policy and sectors. In contrast, Brandenburg and Saarland have no institutions or working groups mentioned in their strategic documents that explicitly focus on adaptation.

As for vertical coordination, the documents provide scattered evidence referring to the local, county, regional, national, and European levels. The city-state strategies (Berlin, Bremen, and Hamburg) inherently include the local level in the nature of their administrative structures. A quarter of states report the inclusion of representatives from cities and municipalities in the participatory process of strategy development (e.g., North Rhine-Westphalia) or in established working committees (e.g., Saxony-Anhalt). Almost all state documents refer to federal strategies and efforts or funding, embedding their strategies in the national context, and 19% mention participation in national working groups and forums. Horizontal coordination, such as exchanges with other states or participation in national networks, is mentioned in less than 35% of strategies, and roughly 45% of state strategies document coordination between state-level actors within their states.

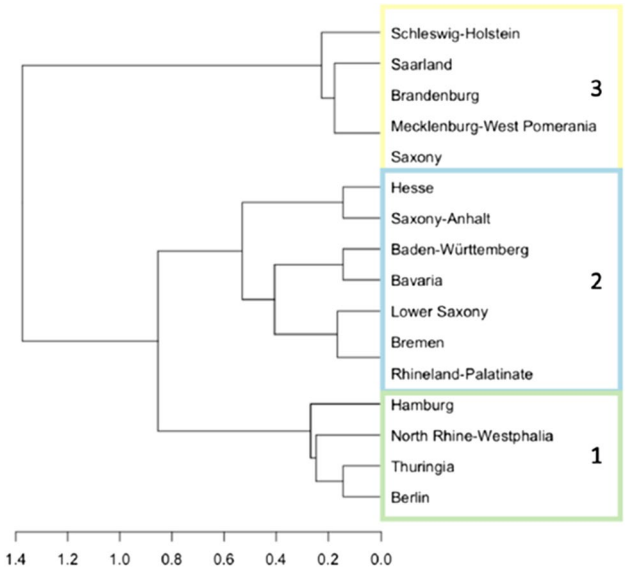

Fig. 2 Dendrogram of clusters with the numerical scale measuring dissimilarity

Impacts, vulnerability, and sectors addressed

All state strategies draw on climate change data and 81% include regionally specific data and/or projections. Though the majority use the concept of vulnerability and 56% reference vulnerability assessments, fewer states (44%) evaluate the vulnerability of individual sectors. Berlin's strategy contains the most in-depth analyses of vulnerability (Reusswig et al. 2016). It includes the ecological, economic, and social aspects of vulnerability and also considers indirect impacts (e.g., climate refugees, negative effects on international trade and tourism, and damage to European energy grids). At the other end of the spectrum, Brandenburg does not explicitly reference vulnerability in any form. The remaining state strategies display varying degrees of risk and vulnerability awareness and refer often more implicitly ecological, social, and economic aspects of vulnerability. Social aspects of vulnerability are rarely considered, and the economic and ecological costs of inaction are often only implicit.

The DAS identifies fifteen areas of action for adaptation, but the sixteen federal states display a wider range of sectors, subsectors, and action areas. Table 2 displays the breadth of areas of sectors in state CCA strategies. These relate to their exposure to climate change impacts but also their geographic characteristics (city-states, e.g., Berlin, do not have large agricultural areas). Water management is the only area of action included in all state CCA strategies and often includes multiple subsectors, e.g., flood protection, surface water, groundwater, and/or water quality. With the exception of Bremen, which structures the strategy by humans, natural environment, and built environment, all other state strategies are structured by sectors and subsectors.

Continuous action

Twelve states (75%) include plans for continuing CCA strategies. Among these states, 44% aim to reassess their plans in the light of new scientific data or other types of knowledge. Calls for new reports and strategies range in timeframes between 2 and 5 years. Thuringia solidified its commitments to adaptation by including requirements of monitoring and adaptation planning reassessments at least every 5 years in its *Climate Mitigation and Adaptation Act* (Thüringer Landtag 2018). In contrast, although Saxony-Anhalt has no explicit plans for continuous monitoring and reassessment, updated strategies and implementation reports have been published every 2 to 4 years since 2010.

Four states' (25%) strategies show no concrete plans for continuing or reassessing but often call for further research and monitoring of climate change impacts. Saarland and Mecklenburg-West Pomerania have not added or adjusted stand-alone policies for CCA in over a decade. In Lower Saxony, on the other hand, the state parliament gave an Interministerial Working Group the task of presenting progress reports every 2 years. The last report was published in 2015 and includes information on which measures were still planned, in progress, finished, or dismissed as unnecessary or unfeasible (Nds. MU 2015), but since then no reports have followed.

Patterns among state approaches to adaptation

The cluster analysis based on eight central variables of the indicators (see Table 1) identified three similar clusters (see Figs. 1 and 2). Cluster 1, in green, includes four states whose strategies include a legal commitment to CCA, have designated bodies for CCA, set implementation timeframes, and plan for continuous action. Two of these four states are city-states. North Rhine-Westphalia does not have a stand-alone strategy in that adaptation is in a strategy integrated with mitigation, but it also has sector-specific adaptation strategies. States in this cluster can be characterized as having *coordinated, directed strategies* for climate adaptation. In this cluster, the majority of states also have conducted vulnerability assessments, created stand-alone strategies, and formulated binding goals for adaptation. Cluster 2, in blue, is made up of seven states whose strategies often (86%, or 6 of 7 states) designate bodies dedicated to CCA and plans for continuous action. In this cluster, six states have a stand-alone strategy for CCA, but none has binding goals and the majority no timeframe for implementation or no legal commitments. This cluster consists of states with *loosely coordinated, informative strategies* for climate adaptation. Finally, cluster 3, in yellow, includes five states who have no vulnerability assessments (but data on climate impacts), no stand-alone CCA strategies, no timeframe for implementation, no designated authority, and often (20% or 1 of 5 states) no plan

Table 2 An overview of areas of action (sectors) addressed in the state climate change adaptation strategies. "X" means sector is included; n/a means not applicable (states without coastline). Areas of action mentioned in two or fewer strategies were omitted from the table. Some state names have been abbreviated: Mecklenburg West Pomerania (MWP), Baden-Württemberg (BW), Rhineland-Palatinate (RP), and North Rhine-Westphalia (NRW)

Sectors	Brandenburg	Saarland	Schleswig–Holstein	MWP	Saxony	Lower Saxony	Hesse	Saxony-Anhalt	BW	Bremen	Bavaria	RP	Hamburg	NRW	Thuringia	Berlin	Total	Federal
Water management	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	16	X
Coastal risk management	n/a	n/a	X	X	n/a	X	n/a	n/a	n/a	X	n/a	n/a	X	n/a	n/a	n/a	5	X
Human health	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	15	X
Nature/biodiversity	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	15	X
Agriculture	X	X	X	X	X	X	X	X	X	X	X	X		X	X		14	X
Planning and development			X		X	X	X	X	X	X	X		X	X	X	X	12	X
Forestry/forests	X	X	X	X		X		X		X	X	X	X	X	X		12	X
Energy sector		X		X	X	X	X	X	X	X	X			X	X	X	12	X
Economy/industry			X		X	X	X	X	X	X	X		X	X		X	11	X
Soils	X		X		X	X		X		X		X	X	X	X		10	X
Tourism				X		X		X	X	X	X			X	X	X	9	X
Emergency services/disaster protection					X	X	X	X			X		X	X	X	X	9	X
Building/housing					X	X	X	X		X	X			X	X		8	X
Transportation	X	X		X	X	X	X	X						X	X		9	X
Education/research	X					X	X	X					X	X		X	7	
Recreation/culture							X	X		X					X		4	
Fishery				X		X		X						X			4	X

for continuous action. In this cluster, Schleswig–Holstein is the only state with a legal commitment to CCA, in that 2017 *State Climate Act* called for the development of a state adaptation strategy and its implementation (§10, Innenministerium SH), but as of 2021, this strategy does not exist. This cluster is characterized by *uncoordinated, informative strategies* and approaches to adaptation.

Discussion

State strategies for fostering climate adaptation in Germany

Through the analysis of German state CCA strategies based on the five indicators, this paper provides several insights on approaches to adaptation and reveals a number of variations. Table 1 shows that no two state strategies are the same with each state fulfilling different sets of indicators. Findings from the cluster analysis help summarize three general directions states are taking to foster climate adaptation. The minority of state strategies (25%) show *coordinated, directed strategies* (cluster 1) whereas clusters 2 and 3 are more informative and provide less clear direction and lower levels of ambition for state-wide goals and commitments.

Cluster 1 (*coordinated, directed*) shows the highest levels of institutionalization of climate adaptation with clearer, and often binding, goals providing direction for adaptation action. These goals provide directions which are underpinned by legal commitments and the structures in place to coordinate their implementation. Notable in this group is that both Hamburg and Berlin are city-states, which may be an advantage for coordinating and institutionalizing adaptation. These four state strategies are comprehensive in depth and breadth, both temporally and structurally, and the indicators show they are well developed throughout all of the

phases of the policy cycle. Based on the importance of clear authorities, goals, and measures; established institutional structures; and learning mechanisms for continuous action for facilitating CCA (as suggested by, e.g., Olazabal et al. 2019 and Owen 2020), the states in this cluster are most clearly using strategies as instruments for fostering adaptation at state level.

The largest and most internally diverse cluster is cluster 2 (*loosely coordinated, informative*). Compared to the states in cluster 1, these states (≈44% of all states) are more loosely coordinating adaptation with multi-sector strategies and voluntary goals. These strategies are informative and but do not mandate any top-down policies. Bavaria, for example, is a rather representative example from cluster 2 in that its strategies provide ample data, recommended sector goals, and potential measures but have no leading authority for coordinating adaptation and clearly state the overarching goal of helping actors help themselves. Empirical evidence indicates that clear guidance from the central government helps increase local prioritization and support of CCA (Young and Essex 2019). The absence of such clear guidance in some states may later prove to become problematic. Based on the indicators, these strategies themselves are less likely to foster adaptation, but it is possible that other instruments are in place to foster adaptation.

Among the states, cluster 3 (*uncoordinated, informative*) strategies show the lowest levels of institutionalization of adaptation. None has designated authorities and continuous action. Nor do these five states' (≈32% of all states) have stand-alone adaptation strategies. Reasons for this could be different in each state and cannot be explained by this analysis. Explanations could be lack of political will, lack of recognition for coordinated action, or a mainstreaming approach not captured by the assessment of multi-sectoral strategies. Saxony has the most recent plans with adaptation embedded in its Energy and Climate Protection Strategy, but Brandenburg, Saarland, and Mecklenburg-West Pomerania have not developed publicly available strategies for over a decade and have not progressed beyond the identification of climate change impacts for their states. Schleswig–Holstein has a short "road map" for adaptation that documents sectoral and project-based measures but has yet to deliver a stand-alone state strategy. In this cluster, adaptation documents are largely from single ministries (as opposed to state governments or from interministerial bodies). The isolation of adaptation within one department is also shown to be a barrier (Young and Essex 2019). Based on the findings of this analysis, these states' strategies are the least likely to foster adaptation, though other instruments to foster adaptation may be in place.

Consistent among the state strategies are the use of regional climate change data for identifying current and future impacts and the sector-based approach to adaptation (with the exception of Bremen). These approaches model after the federal adaptation strategy and reports, which identify impacts of climate change for different sectors and regions and recommended areas of action. From the analysis of the sectors, it is apparent that "classic" areas for adaptation—water management, nature, human health, and agriculture—are virtually omnipresent in all state strategies. For these topics, horizontal coordination with other states and participation in national networks could help states advance their adaptation planning, yet roughly a third document doing so in their strategies. Common areas for improvement include more attention to social vulnerability and the formulation of measurable goals. Even the states in cluster 1 did not fulfill all of the indicators and sub-codes, i.e., facilitating factors for CCA. Finally, another trend independent of the clusters is weak inclusion of the local level in state strategies. Though several strategies mentioned the importance of local level actor and planning procedures, a stronger emphasis on multi-level action and institutionalized coordination could help further foster adaptation.

State-level policies and multi-level governance of climate adaptation

Climate adaptation scholars acknowledge the importance of multi-level action and diverse, context-specific approaches in adaptation governance (e.g., Adger et al. 2005; Urwin and Jordan 2008; Jurgilevich et al. 2019). Although there is some evidence on the diffusion of climate policies between governments and among levels (e.g., De Gregorio Hurtado et al. 2014; Jordan and Huitema 2014; Heidrich et al. 2016; Kammerer and Namhata 2018), interactions between levels of government and their implications for adaptation are not well understood (Clar and Steurer 2019). For the case of Germany, this analysis offers a first step for further investigations of these interactions between national-, state-, and local-level adaptation strategies and action.

All sixteen states show varying degrees of agenda setting and institutionalization of adaptation, and each of these strategies will have implications for lower levels of government. Municipalities across Germany therefore have different incentive structures and starting points, in terms of information and guidance. Particularly in the cluster of *uncoordinated, informative* strategies, communities are not under pressure to develop and implement adaptation policies and are thus free to act, or not act, as they choose. Larger cities are more likely to have the resources to produce adaptation policies on their own (De Gregorio Hurtado et al. 2014, 2015), but smaller cities and communities in these states may be at a disadvantage. Alternatively, the two states that are not city-states in the *coordinated, directive* cluster have higher ambitions for adaptation but also little power to steer adaptation in sectors with higher concentrations of local level authority (e.g., urban

planning and zoning). The state commitments and goals provide direction and information for adaptation at the local level but are not formulated in a manner that requires lower levels of government to produce their own policies or plans.

More than a decade has passed since the first federal strategy (DAS) and recommendations for states to develop adaptation strategies, yet this analysis demonstrates the diverse stages of progress and varying commitments among the states. While some states are steadily progressing and fostering adaptation, others have not pursued state-wide adaptation strategies. In Germany, the DAS and federal adaptation activities are iterative with progress reports and updates to action plans every 4 to 5 years. Reckien et al. (2018) show that cities are five times more likely to have adaptation plans if there is a national mandate to do so, but there is not yet evidence (to the author's knowledge) of national mandates for state CCA plans and their potential impact on lower levels. This leads to the question if Germany or other federal nations will continue to incentivize and encourage state-level adaptation policies, leading to regionalized deficits, or if at some point, if the federal government will introduce harder instruments and mandate adaptation policies.

Limitations and future research

This framework and analysis are not without limitations. The exclusion of sector-specific policies may also have resulted in the omission of data relevant for the assessment of state CCA strategies. Though some states' current and past versions of CCA strategies were analyzed, the indicators do not capture temporal developments within states' strategies. Furthermore, the qualitative document analysis applied here could not capture relevant data on informal activities or internal documents.

Beyond the indicators within this analytical framework, there are several other factors at play both enabling and hindering adaptation policy and their implementation. Further research should explore which of the state governments implement their strategies more quickly, effectively, or with higher levels of acceptance, and which attributes these more effective policy approaches share. One aim of this research was to lay the foundation for further investigations of causal relationships and interactions with contextual conditions and other levels of policy and their impact on adaptation action, which could provide insights for adaptation policies and planning at multiple levels both within and outside of Germany.

Conclusion

This research analyses and compares state climate adaptation strategies in Germany, based on five indicators: (i) climate impacts and vulnerability assessments, (ii) sectors addressed, (iii) policy goals and commitments, (iv) institutional organization and coordination, and (v) plans for policy adjustments and continuous action, and finds diverging approaches more and less likely to foster adaptation. Three clusters emerged and are described as *coordinated, directed* strategies; *loosely coordinated, informative* strategies; and *uncoordinated, informative* strategies.

By following through on commitments to reassess and further develop CCA strategies and with continued support from the federal government, most German states may have the strategies and structures to foster climate change adaptation. However, the absence of nationally regulated standards for state CCA strategies has thus far resulted in substantial variation in the strategic planning of individual states in Germany. Research on the implementation of the strategies and the impacts of realized measures will be the final assessment of their strategies' coordination and institutionalization of adaptation at state level.

Evidence from the document analysis displays a wide range of levels of commitment and attention to detail throughout various policy phases among the sixteen states. The use of climate change data, the breadth of areas of action, and the creation of oversight committees for CCA coordination are commendable in the majority of states. Comparative analysis has identified common challenges at certain phases of the policy cycle (e.g., agenda setting and passing legislation) and thus highlights gaps that are common barriers to CCA, such as unclear or non-binding goals. The diversity of sixteen policy approaches to similar challenges sheds light on the flexibility inherent in federal polity as both an opportunity and a challenge for adaptation as a multi-level issue. National-level reliance on recommendations rather than regulations does not lead to country-wide progress.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10113-021-01870-3.

Acknowledgements I am deeply thankful for all feedback and comments by Nicolas W. Jager, Meghan Alexander, and Bernd Siebenhüner and the support of the Adapt Lock-in team.

Funding Open Access funding enabled and organized by Projekt DEAL. This research was supported by the Deutsche Forschungsgemeinschaft (Grant Number 396892926).

References

Adger WN (2006) Vulnerability. Glob Environ Chang 16:268–281. https://doi.org/10.1016/j.gloenvcha.2006.02.006

Adger WN, Arnell NW, Tompkins EL (2005) Successful adaptation to climate change across scales. Glob Environ Chang 15:77–86. https://doi.org/10.1016/j.gloenvcha.2004.12.005

Aguiar FC, Bentz J, Silva JMN, Fonseca AL, Swart R, Santos FD, Penha-Lopes G (2018) Adaptation to climate change at local level in Europe: an overview. Environ Sci Policy 86:38–63. https://doi.org/10.1016/j.envsci.2018.04.010

Amundsen H, Berglund F, Westskogh H (2010) Overcoming barriers to climate change adaptation - a question of multilevel governance? Environ Plan C Gov Policy 28:276–289. https://doi.org/10.1068/c0941

Bauer A, Feichtinger J, Steurer R (2012) The governance of climate change adaptation in 10 OECD countries: challenges and approaches. J Environ Policy Plan 14:279–304. https://doi.org/10.1080/1523908X.2012.707406

Berrang-Ford L, Biesbroek GR, Ford JD, Lesnikowski A, Tanabe A, Wang FM, Chen C, Hsu A, Hellmann JJ, Pringle P, Grecequet M, Amado JC, Huq S, Lwasa S, Heymann SJ (2019) Tracking global climate change adaptation among governments. Nat Clim Chang 9:440–449. https://doi.org/10.1038/s41558-019-0490-0

Biesbroek GR, Delaney A (2020) Mapping the evidence of climate change adaptation policy instruments in Europe. Environ Res Lett 15:83005. https://doi.org/10.1088/1748-9326/ab8fd1

Biesbroek GR, Peters BG, Tosun J (2018a) Public bureaucracy and climate change adaptation. Rev Policy Res 35:776–791. https://doi.org/10.1111/ropr.12316

Biesbroek R, Lesnikowski A, Ford JD, Berrang-Ford L, Vink M (2018b) Do administrative traditions matter for climate change adaptation policy? A comparative analysis of 32 high-income countries. Rev Policy Res 35:881–906. https://doi.org/10.1111/ropr.12309

Biesbroek GR, Swart RJ, Carter TR, Cowan C, Henrichs T, Mela H, Morecroft MD, Rey D (2010) Europe adapts to climate change: comparing national adaptation strategies. Glob Environ Chang 20:440–450. https://doi.org/10.1016/j.gloenvcha.2010.03.005

Blättner B, Janson D, Roth A, Grewe HA, Mücke HG (2020) Health protection against heat extremes in Germany: what has been done in federal states and municipalities? Bundesgesundheitsblatt - Gesundheitsforsch - Gesundheitsschutz. https://doi.org/10.1007/s00103-020-03189-6

Bowen GA (2009) Document analysis as a qualitative research method. Qual Res J 9:27–40. https://doi.org/10.3316/QRJ0902027

Bremen (2018) Klimaanpassungsstrategie Bremen.Bremerhaven. Bremen

Bundesregierung (2008) Deutsche Anpassungsstrategie an den Klimawandel. Dtsch Bundesregierung, Berlin, p 78

Bundesregierung (2015) Fortschrittsbericht zur Deutschen Anpassungsstrategie an den Klimawandel. Dtsch Bundesregierung, Berlin, p 275

Clar C, Steurer R (2019) Climate change adaptation strategies at different levels of government. In: Keskitalo ECH, Preston BL (eds) Research handbook on climate change adaptation policy. Edward Elgar Publishing, Cheltenham, pp 310–326

De Gregorio HS, Olazabal M, Salvia M, Pietrapertosa F, Olazabal E, Geneletti D, D'Alonzo V, Di Leo S, Reckien D (2015) Understanding how and why cities engage with climate policy. An analysis of local climate action in Spain and Italy. Tema J L Use, Mobil Environ 8:23–46. https://doi.org/10.6092/1970-9870/3649

De Gregorio Hurtado S, Olazabal M, Salvia M, Pietrapertosa F, Olazabal E, Geneletti D, D'Alonzo V, Feliú E, Di Leo S, Reckien D (2014) Implications of governance structures in urban climate action: evidence from Italy and Spain. BC3 Working Paper Series, 2014–02, Bilbao

Dilling L, Prakash A, Zommers Z, Ahmad F, Singh N, de Wit S, Nalau J, Daly M, Bowman K (2019) Is adaptation success a flawed concept? Nat Clim Chang 9:570–574. https://doi.org/10.1038/s41558-019-0539-0

Dupuis J, Knoepfel P (2013) The adaptation policy paradox: the implementation deficit of policies framed as climate change adaptation. Ecol Soc 18:41. https://doi.org/10.5751/ES-05965-180431

Ebermann V (2020) Entwicklung von staatlichen Strategien zur Klimaanpassung. Springer VS, Lüneburg

Eisenack K, Moser SC, Hoffmann E, Klein RJT, Oberlack C, Pechan A, Rotter M, Termeer CJAM (2014) Explaining and overcoming barriers to climate change adaptation. Nat Clim Chang 4:867–872. https://doi.org/10.1038/nclimate2350

England MI, Dougill AJ, Stringer LC, Vincent KE, Pardoe J, Kalaba FK, Mkwambisi DD, Namaganda E, Afionis S (2018) Climate change adaptation and cross-sectoral policy coherence in southern Africa. Reg Environ Chang 18:2059–2071. https://doi.org/10.1007/s10113-018-1283-0

Ford JD, Berrang-Ford L (2016) The 4Cs of adaptation tracking: consistency, comparability, comprehensiveness, coherency. Mitig Adapt Strateg Glob Chang 21:839–859. https://doi.org/10.1007/s11027-014-9627-7

Ford JD, King D (2015) A framework for examining adaptation readiness. Mitig Adapt Strateg Glob Chang 20:505–526. https://doi.org/10.1007/s11027-013-9505-8

Forum Fed (2021) Federal Countries. 15 Sept 2021. http://www.forumfed.org/countries/

Grecksch K (2013) Adaptive capacity and regional water governance in north-western Germany. Water Policy 15:794–815. https://doi.org/10.2166/wp.2013.124

Häußler S, Hofmann M, Müller M (2020) Regionale Anpassung an den Klimawandel – Ein Überblick mit Empfehlungen für Kommunen in Baden-Württemberg. Standort. https://doi.org/10.1007/s00548-020-00655-w

Heidrich O, Reckien D, Olazabal M, Foley A, Salvia M, de Gregorio HS, Orru H, Flacke J, Geneletti D, Pietrapertosa F, Hamann JJP, Tiwary A, Feliu E, Dawson RJ (2016) National climate policies across Europe and their impacts on cities strategies. J Environ Manage 168:36–45. https://doi.org/10.1016/j.jenvman.2015.11.043

Howlett M, Mukherjee I, Fritzen SA (2019) Challenges associated with implementing climate adaptation policy. In: Keskitalo ECH, Preston BL (eds) Research handbook on climate change adaptation policy. Edward Elgar Publishing, Cheltenham, pp 50–68

Hsu A, Höhne N, Kuramochi T, Vilariño V, Sovacool BK (2020) Beyond states: Harnessing sub-national actors for the deep decarbonisation of cities, regions, and businesses. Energy Res Soc Sci 70. https://doi.org/10.1016/j.erss.2020.101738

Huitema D, Adger WN, Berkhout F, Massey E, Mazmanian D, Munaretto S, Plummer R, Termeer CJAM (2016) The governance of adaptation: choices, reasons, and effects. Introduction to the special feature. Ecol Soc 21. https://doi.org/10.5751/ES-08797-210337

Innenministerium SH (2017). Gesetz- und Verordnungsblatt für Schleswig-Holstein: Ausgabe Nr. 4. Ministerium für Inneres und Bundesangelegenheiten des Landes Schleswig-Holstein, Kiel

IPCC (2014) Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of

Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds). Cambridge University Press, Cambridge, p 1132

Jordan A, Huitema D (2014) Innovations in climate policy: the politics of invention, diffusion, and evaluation. Env Polit 23:715–734. https://doi.org/10.1080/09644016.2014.923614

Jurgilevich A, Groundstroem F, Klein J, Räsänen A, Juhola S (2019) The emergence and institutionalization of national adaptation strategies. In: Keskitalo ECH, Preston BL (eds) Research handbook on climate change adaptation policy. Edward Elgar Publishing, Cheltenham, pp 212–227

Kammerer M, Namhata C (2018) What drives the adoption of climate change mitigation policy? A dynamic network approach to policy diffusion. Springer US

Landtag Nordrhein-Westfalen (2021) Klimaanpassungsgesetz Nordrhein-Westfalen, Düsseldorf

Lesnikowski A, Biesbroek R, Ford JD, Berrang-Ford L (2020) Policy implementation styles and local governments: the case of climate change adaptation. Env Polit 1–38. https://doi.org/10.1080/09644016.2020.1814045

Lesnikowski A, Ford JD, Biesbroek R, Berrang-Ford L (2019) A policy mixes approach to conceptualizing and measuring climate change adaptation policy. Clim Change. https://doi.org/10.1007/s10584-019-02533-3

Massey E, Biesbroek R, Huitema D, Jordan A (2014) Climate policy innovation: the adoption and diffusion of adaptation policies across Europe. Glob Environ Chang 29:434–443. https://doi.org/10.1016/j.gloenvcha.2014.09.002

McNamara M (2012) Starting to untangle the web of cooperation, coordination, and collaboration: a framework for public managers. Int J Public Adm 35:389–401. https://doi.org/10.1080/01900692.2012.655527

Measham TG, Preston BL, Smith TF, Brooke C, Gorddard R, Withycombe G, Morrison C (2011) Adapting to climate change through local municipal planning: barriers and challenges. Mitig Adapt Strateg Glob Chang 16:889–909. https://doi.org/10.1007/s11027-011-9301-2

Mecklenburg-Vorpommern (2010) Studie: "Folgen des Klimawandels in Mecklenburg-Vorpommern 2010". Ministerium für Wirtschaft, Arbeit und Tourismus Mecklenburg-Vorpommern, Schwerin

Mimura N, Pulwarty RS, Duc DM, Elshinnawy I, Redsteer MH, Huang HQ, Nkem JN, Rodriguez RAS, Moss R, Vergara W, Darby LS, Kato S (2014) Adaptation planning and implementation

Ministerium für Inneres und Bundesangelegenheiten des Landes Schleswig-Holstein (2017) Gesetz- und Verordnungsblatt für Schleswig-Holstein, Kiel

Moser SC, Ekstrom JA (2010) A framework to diagnose barriers to climate change adaptation. Proc Natl Acad Sci 107:22026–22031. https://doi.org/10.1073/pnas.1007887107

Msuya J (2021) Opening Remarks. 54th Session of IPCC Secretariat. 26 July 2021, Geneva

Nds. MU (2015) Umsetzungsbericht zu den Empfehlungen der Regierungskommission Klimaschutz. Niedersächsisches Ministerium für Umwelt, Energie und Klimaschutz, Hannover

Nds. MU (2013) Klimapolitische Umsetzungsstrategie. Niedersächsisches Ministerium für Umwelt, Energie und Klimaschutz, Hannover

Nds. MU (2012) Empfehlung für eine niedersächsische Strategie zur Anpassung an die Folgen des Klimawandels. Niedersächsisches Ministerium für Umwelt, Energie und Klimaschutz, Regierungskommission Klimaschutz, Hannover

Olazabal M, Galarraga I, Ford J, Sainz De Murieta E, Lesnikowski A (2019) Are local climate adaptation policies credible? A conceptual and operational assessment framework. Int J Urban Sustain Dev 11:277–296. https://doi.org/10.1080/19463138.2019.1583234

Otto A, Kern K, Haupt W, Eckersley P, Thieken AH (2021) Ranking local climate policy: assessing the mitigation and adaptation activities of 104 German cities. Clim Change 167. https://doi.org/10.1007/s10584-021-03142-9

Owen G (2020) What makes climate change adaptation effective? A systematic review of the literature. Glob Environ Chang 62:102071. https://doi.org/10.1016/j.gloenvcha.2020.102071

Reckien D, Salvia M, Heidrich O, Church JM, Pietrapertosa F, De Gregorio HS, D'Alonzo V, Foley A, Simoes SG, Krkoška Lorencová E, Orru H, Orru K, Wejs A, Flacke J, Olazabal M, Geneletti D, Feliu E, Vasilie S, Nador C, Krook-Riekkola A, Matosović M, Fokaides PA, Ioannou BI, Flamos A, Spyridaki NA, Balzan MV, Fülöp O, Paspaldzhiev I, Grafakos S, Dawson R (2018) How are cities planning to respond to climate change? Assessment of local climate plans from 885 cities in the EU-28. J Clean Prod 191:207–219. https://doi.org/10.1016/j.jclepro.2018.03.220

Reckien D, Salvia M, Pietrapertosa F, Simoes SG, Olazabal M, De Gregorio HS, Geneletti D, Krkoška Lorencová E, D'Alonzo V, Krook-Riekkola A, Fokaides PA, Ioannou BI, Foley A, Orru H, Orru K, Wejs A, Flacke J, Church JM, Feliu E, Vasilie S, Nador C, Matosović M, Flamos A, Spyridaki NA, Balzan MV, Fülöp O, Grafakos S, Paspaldzhiev I, Heidrich O (2019) Dedicated versus mainstreaming approaches in local climate plans in Europe. Renew Sustain Energy Rev 112:948–959. https://doi.org/10.1016/j.rser.2019.05.014

Reusswig F, Becker C, Lass W, Haag L, Hirschfeld J, Knorr A, Lüdeke MKB, Neuhaus A, Pankoke C, Rupp J, Walther C, Walz S, Weyer G, Wiesemann E (2016) Anpassung an die Folgen des Klimawandels in Berlin (AFOK). Klimaschutz Teilkonzept. Hauptbericht. Gutachten im Auftrag der Senatsverwaltung für Stadtentwicklung und Umwelt, Sonderreferat Klimaschutz und Energie (SRKE). Berlin

Runhaar H, Wilk B, Persson Å, Uittenbroek CJ, Wamsler C (2018) Mainstreaming climate adaptation: taking stock about "what works" from empirical research worldwide. Reg Environ Chang 18:1201–1210. https://doi.org/10.1007/s10113-017-1259-5

Russel D (2019) Enabling conditions for the mainstreaming of adaptation policy and practice. In: Keskitalo ECH, Preston BL (eds) Research Handbook on Climate Change Adaptation Policy. Edward Elgar Publishing, Cheltenham, pp 108–124

Smit B, Pilifosova O, Burton I, Challanger B, Huq S, Klein R, Yohe G (2001) Adaptation to climate change in the context of sustainable development and equity, Climate Change 2001: impacts, adaptation, and vulnerability

Smit B, Wandel J (2006) Adaptation, adaptive capacity and vulnerability. Glob Environ Chang 16:282–292. https://doi.org/10.1016/j.gloenvcha.2006.03.008

Stecker R, Mohns T, Eisenack K (2012) Anpassung an den Klimawandel - Agenda Setting und Politikintegration in Deutschland. Zeitschrift Für Umweltpolitik Umweltr 35:179–208

Termeer CJAM, Biesbroek R, Van Den Brink M (2012) Institutions for adaptation to climate change: comparing national adaptation strategies in Europe. Eur Polit Sci 11:41–53. https://doi.org/10.1057/eps.2011.7

Thüringer Landtag (2018) Thüringer Gesetz zum Klimaschutz und zur Anpassung an die Folgen des Klimawandels (Thüringer Klimagesetz). Erfurt

Uittenbroek CJ (2016) From policy document to implementation: organizational routines as possible barriers to mainstreaming climate adaptation. J Environ Policy Plan 18:161–176. https://doi.org/10.1080/1523908X.2015.1065717

Urwin K, Jordan A (2008) Does public policy support or undermine climate change adaptation? Exploring policy interplay across different scales of governance. Glob Environ Chang 18:180–191. https://doi.org/10.1016/j.gloenvcha.2007.08.002

Vogel B, Henstra D, McBean G (2020) Sub-national government efforts to activate and motivate local climate change adaptation: Nova Scotia, Canada. Environ Dev Sustain 22:1633–1653. https://doi.org/10.1007/s10668-018-0242-8

Wenta J, McDonald J (2019) The role of law and legal systems in climate change adaptation policy. In: Keskitalo ECH, Preston BL (eds) Research Handbook on Climate Change Adaptation Policy. Edward Elgar Publishing, Cheltenham, pp 69–90

Young D, Essex S (2019) Climate change adaptation in the planning of England's coastal urban areas: priorities, barriers and future prospects. J Environ Plan Manag. https://doi.org/10.1080/09640568.2019.1617680