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Tailoring Climate Parameters to Information Needs for Local Adaptation to Climate Change

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Abstract: Municipalities are important actors in the field of local climate change adaptation. Stakeholders need scientifically sound information tailored to their needs to make local assessment of climate change effects. To provide tailored data to support municipal decision-making, climate scientists must know the state of municipal climate change adaptation, and the climate parameters relevant to decisions about such adaptation. The results of an empirical study in municipalities in the state of Baden-Wuerttemberg in Southwestern Germany showed that adaptation is a relatively new topic, but one of increasing importance. Therefore, past weather events that caused problems in a municipality can be a starting point in adaptation considerations. Deduction of tailored climate parameters has shown that, for decisions on the implementation of specific adaptation measures, it also is necessary to have information on specific parameters not yet evaluated in climate model simulations. We recommend intensifying the professional exchange between climate scientists and stakeholders in collaborative projects with the dual goals of making practical adaptation experience and knowledge accessible to climate science, and providing municipalities with tailored information about climate change and its effects.

Keywords: adaptation; climate change; municipalities; climate information; extreme weather events; climate parameters; user needs; Germany

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1. Introduction

Climate change adaptation on the local level is of increasing relevance because of the regional variation in the effects of global climate change [1–4]. Local governments are increasingly being delegated responsibility to adapt to climate change because they are key state actors in the implementation of overarching national adaptation strategies, and have to develop, plan, and implement adaptation measures [5]. However, this responsibility is often difficult to implement given that the climate change information and science available are not necessarily easily translated into practical everyday decision-making. By comparison to climate mitigation plans, plans and strategies for climate change adaptation remain uncommon in European municipalities [6]. In the multi-scale, multi-sectoral, and multi-level challenge of adapting to climate change, many often intertwined political, economic, institutional, and technical or scientific obstacles involving different political levels have been identified and discussed that prevent or delay the development of local adaptation plans and strategies and the implementation of measures [7–15]. While many of these obstacles are not climate-specific and may emerge in other fields as well, Biesbroek et al. [11] identify three barriers related specifically and directly to adaptation to climate change: the long time scale of climate change, the reliance on scientific knowledge of climate change, and its inherent uncertainties and ambiguities. From a municipality's perspective, the fact that climate change is an ongoing process implies that adaptation strategies involve developments that reach far into the future, which may lead municipalities to the erroneous conclusion that they can postpone action [16], especially because decisions on the local level often focus on shorter time periods, in many cases, election periods [8,17]. Informational and cognitive barriers also can prevent decision makers from beginning or advancing the adaptation process [18]. A study on flood risk management in two Swedish municipalities [19] indicated that, although the stakeholders are aware of climate change, uncertainties remain about "what to adapt to" because of a lack of knowledge about local effects of climate change. This can result in uncertainty about the elements of an adaptation strategy, and, consequently, retard efforts in the task of municipal adaptation. A survey of municipal stakeholders in the German Baltic sea region also found problems associated with lack of knowledge, as well as uncertainty about regional effects of climate change [20]. In the same context, Lehmann et al. reported confusion about the terms "weather" and "climate", as well as "adaptation", and "mitigation", together with "actor-specific characteristics, as, for instance, limited individual (processing) capabilities" and a "lack of high-resolution data for the local level" ([8], p. 85). Finally, perceptions of climate change on the part of the public [21,22], local authorities [20,23,24], and local officials in specific fields of action [12,19] influence decisions about local adaptation to climate change.

With respect to increasing knowledge, scientifically sound, but tailored, climate information and data are essential for planning adaptation measures in municipalities. Many decision makers expect to obtain precise and small-scale climate projections [20,25]. The European Environment Agency (EEA) [4] underscored the " ... clear requirement for the information relating to adaptation to be tailored to the local level. This also includes the access to downscaled climate change scenarios and their impacts" ([4], p. 64). To develop this tailored information, both the political priority of the topic, as well as communication between knowledge providers and decision makers are crucial [19,24,26].

The resolution of regional climate models has advanced during the last years. Continuously increasing computing capacities allow modeling finer horizontal resolutions up to between 1 and 10 km [27–29]. However, urban planning impact models operate on the scale of urban districts or even below, and require climatological input data at spatial and temporal resolutions not yet available in current standard climate simulations. Nevertheless, the scale gap between regional climate models and local impact models has closed considerably [27]. Furthermore, simulation of longer time periods, and generation of ensembles of regional climate model projections based on different global climate model driving data or different emission scenarios are now possible [28–33]. All of these advances enhance the robustness of climate model simulations, allow the estimation of the range of possible future regional climates, and enable regional assessments of climate change. If local decision makers can access the data in an appropriate way, such data can contribute to an enlarged database for planning and implementation of adaptation strategies and measures. In addition, if these data are considered in different fields of action of climate change adaptation, they can support municipal decision-making.

To date, the parameters evaluated in climate model simulations and incorporated in reports and booklets have been defined based largely on meteorological expertise. These climate parameters include, for example, annual mean temperatures and precipitation, and deduced parameters such as summer days (days with a daily maximum temperature of at least 25 °C) or ice days (days with a daily maximum temperature below 0 °C). These climate parameters are useful in monitoring climate change scientifically. However, climate information inquiries made to the South German Climate Office at the Karlsruhe Institute of Technology—which offers regional climate services that can be described as "science–society interaction revolving around local and regional adaptation and mitigation" [34]—revealed that these climate parameters often do not offer enough information to be useful in specific decisions. Lemos et al. [26] identified three interconnected factors that affect individuals' use of scientific information based on a simple market model, and outline interaction, value-adding, retailing, wholesaling, and customization, as strategies to improve the usability of climate information. The three factors are defined as "the level and quality of interaction between producers and users of climate information; the fit, how users perceive that climate information meets their needs; and the interplay, how new knowledge interacts with other types of knowledge decision makers currently use" ([35], p. 402).

To address the "climate information usability gap" between "what scientists understand as useful information and what users recognize as usable in their decision-making" ([26], p. 789), we present the results of an empirical study in local municipalities in Baden-Wuerttemberg, Germany. We approach municipal adaptation from the perspective of climate science and with reference to the tools of a climate service. Drawing on the conceptual model of transforming climate information from useful to usable, we tested the way in which a regional climate service, as an "interacting actor", could contribute to the usability of climate information for local municipalities. We intend to "add value" to already existing climate model simulations by tailoring, or "customizing" ([26], p. 792), climate parameters from simulations to their needs so that municipalities can use them for decision-making in planning and implementing climate change adaptation.

In our empirical study, which was based on a questionnaire and additional interviews with experts, we investigated the municipalities' needs for climate information to identify the way in which climate science can provide tailored information and data support. To determine the untapped potential in exchanging knowledge and data between climate scientists and local authorities, the second objective of the study was to learn about the information sources in Baden-Wuerttemberg used today.

In Section 2, we introduce the regional context as well as study concept and data collection. We show the results in Section 3, addressing the state of climate change adaptation, the data and information used today, the climate parameters relevant to adaptation and the sensitivity to changes. The results are discussed in Section 4, followed by the main conclusions (Section 5).

2. Materials and Methods

To deduce tailored climate parameters that municipalities need for decision-making in planning and implementation of climate change adaptation, we conducted a survey based on a standardized questionnaire and additional interviews with experts. A prerequisite in identifying and defining tailored climate parameters important for adaptation is that a municipality already considers climate change and its effects. Because we cannot expect this to be true for all municipalities [6], and as various barriers can impede implementation [11], we assessed the state of climate adaptation and implementation of measures first. Consistent with the concept of the Intergovernmental Panel on Climate Change (IPCC), we referred to adaptation as "the process of adjustment to actual or expected climate and its effects" ([36], p. 40), as the study focused explicitly on supporting adaptation to "climate impacts as the major source of vulnerability" ([37], p. 49), and approached adaptation from the perspective of climate sciences. Thus, adaptation is not limited to a future (changed) climate, but also can refer to the variability and extremes in the current climate [16]. We used two approaches to deduce tailored climate parameters for municipalities' climate adaptation: first, direct deduction, which is possible if a municipality can relate the effects of climate change directly to climate variables. The second approach, indirect deduction, considers past weather events that caused problems in a municipality in recent years. Thereafter, a sensitivity assessment with respect to the effect of this change is required to use tailored climate parameters as a basis for the development of adaptation activities in municipalities. Referring to the concept of the IPCC, we defined sensitivity in our study as " ... the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change" ([2], p. 1772). Therefore, we explored which change in a certain climate parameter would require action in a municipality or make adaptation measures urgently necessary or even impossible.

Thus, we investigated the following main research issues: the current state of climate change adaptation in municipalities in Baden-Wuerttemberg, the climate information used today, the climate parameters relevant and desired for adaptation, and the sensitivity to future changes in climate parameters. Thus, the local focus—in our case on municipalities in Southwestern Germany—was essential to investigate adaptation either to the current or future climate because the climate differs considerably between municipalities and urban agglomerations in the different climate regions of Baden-Wuerttemberg.

2.1. Investigation Area

The largest urban agglomerations in the state of Baden-Wuerttemberg in Southwestern Germany are Stuttgart (approximately 620,000 inhabitants) and the surrounding metropolitan area, Karlsruhe in the upper Rhine valley, and Mannheim in the metropolitan Rhine-Neckar region (both of the latter two have approximately 300,000 inhabitants). Approximately 250 cities have more than 10,000, approximately 50 more than 30,000, and nine cities more than 100,000 inhabitants [38].

Baden-Wuerttemberg (Figure 1a,b) is characterized by different landscapes, including parts of the upper and middle Rhine valley (approximately 100 m a.s.l.) and mid-range mountains, such as the Black Forest (Feldberg summit 1493 m a.s.l.) and the Swabian Jura (around 500 m a.s.l.). This orographically complex terrain causes large differences in the regional and local climate. The annual average temperature ranges from 4 °C (Black Forest) to 11 °C (Rhine Valley), and the annual precipitation from less than 600 mm (Rhine Valley) to more than 1500 mm (Black Forest) [39]. Climate change is evident in Baden-Wuerttemberg with respect to daily minimum and maximum temperatures, including heat, as well as heavy precipitation events [40–42]. Baden-Wuerttemberg is highly exposed to extreme meteorological events, including hot and dry summers [43,44], hailstorms [45], and heavy precipitation events [46], and several municipalities in Baden-Wuerttemberg have experienced negative effects of such events during years past. For the future, climate model simulations project a significant warming on seasonal and annual scales, an increase in the frequency, intensity, and duration of heat waves [47,48], and in mean winter precipitation, and a slight decrease in summertime mean precipitation; extreme precipitation events are expected to become more frequent [32].

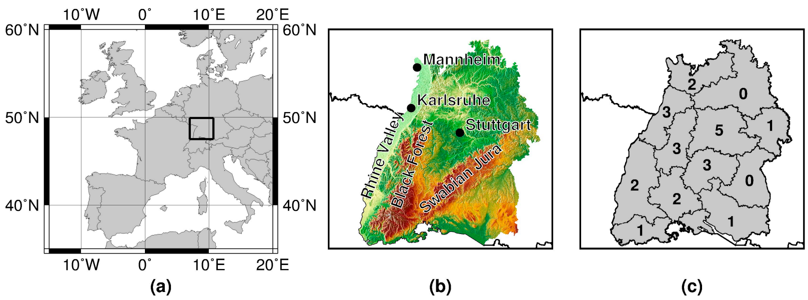

Figure 1. Investigation area. (**a**) location of Baden-Wuerttemberg in Europe (**b**) orography, landscapes and location of the three largest cities (**c**) administrative regions; numbers denote the number of questionnaire responses.

This implies a challenge for municipalities to adapt to long-term changes, as well as to more frequent or more intense extreme local events. The overarching national strategies and frameworks are the German Adaptation Strategy [49], the Action Plan for Adaptation [50], a monitoring report on the German Adaptation Strategy [51], and three planning laws [52]. Several months before the study was conducted, the Federal State adopted a Strategy on Adaptation to Climate Change in Baden-Wuerttemberg (SACC-BW) [53]. This strategy addresses nine fields of action: forestry, agriculture, soil, nature protection, water economy, tourism, health, urban and land use planning, and the economic and energy sectors. In addition, the "climate guide rails" ("Klimaleitplanken") developed in this context describe the future development of approximately 28 climate parameters for these fields of action [54] that are defined predominantly from a meteorological perspective. Under the research program KLIMOPASS [55], the Federal State supports research projects of short duration, such as the study presented here, and development of activities on adaptation and the implementation of SACC-BW in the nine fields of action. In combination with the different regional climates, these recent activities in climate change adaptation make Baden-Wuerttemberg suitable for investigating the way in which existing climate information that climate science believes is useful can be transformed into information that local municipalities can use.

2.2. Study Design

As described above, to investigate our research questions, we conducted a standardized survey and additional semi-structured interviews with experts.

After pre-tests, the final survey questionnaire comprised 26 closed and open-ended questions in four parts. The first contained questions about the state of adaptation in a municipality, the importance of the topic, and present activities in, and barriers to climate adaptation. Focusing on tailored climate parameters, the second part referred to weather events or climate variables that had caused problems in the past or are important to climate change adaptation in the nine fields of action identified in the SACC-BW [53]. Because the study was orientated to these nine fields of action, the climate variables in the final questionnaire included one parameter, air quality, which currently is not a direct output of climate simulations, but is part of the health action field in the SACC-BW. Thus, because compliance with limit values is a municipal task, the study took into account the air quality parameter. Furthermore, we asked for information not yet available on future developments of climate parameters that might be helpful to decision makers. The third part comprised an assessment of sensitivity to climate change to determine to what degree a single climate parameter, i.e., a climate stimulus, must change to require adaptation measures. The fourth and last part covered the location of the municipality and the information sources of the respondents.

We emailed the questionnaire to all of the approximately 180 members of the Association of Cities in Baden-Wuerttemberg ("Städtetag Baden-Württemberg") in spring 2015, together with a cover letter and a leaflet with information about the project, including the idea of providing tailored climate parameters and their sensitivity to support the development and implementation of adaptation on the municipal level. We asked the municipalities to return the completed questionnaires by email or ordinary mail. These were anonymized for further processing, mainly with univariate statistical analysis and analysis of the answers to the open-ended questions.

In addition, we conducted ten semi-structured interviews with experts [56,57] in four municipalities in the spring of 2015 to gain in-depth insights into the process of municipal climate change adaptation. The interviewees were either experts employed explicitly to address the topic of "climate" in (larger) municipalities or persons responsible for all issues of environmental protection (in smaller municipalities) and experts from several offices (for example, forest management, urban green space planning, and winter services) selected according to the nine fields of action of the SACC-BW. The interview protocols were analyzed and structured by the research team, in particular for tailoring usable climate parameters and their sensitivities or sensitivity thresholds.

2.3. Sample and Significance of the Study

In total, 23 questionnaires were included in the analyses. A response rate of nearly 13% is in the same range or even slightly better than that in similar studies, e.g., among political stakeholders in the German Baltic Sea region [20]. Of the 23 questionnaires, eight were completed by smaller municipalities with 10,000 to 30,000 inhabitants, and fifteen by larger municipalities with more than 30,000 inhabitants. This is a response rate of 30% for the larger municipalities, and of 4% for the smaller ones. Despite the relatively small absolute number of responses, the sample was suitable to answer the research questions proposed because the municipalities that participated are located in different regions in Baden-Wuerttemberg, as well as at different heights above sea level. The questionnaire responses cover ten of the twelve administrative regions in Baden-Wuerttemberg (for the regions and the number of participants per regions, see Figure 1c). One response from the Swiss Basel City Canton, which is located just at the border of Baden-Wuerttemberg, has been attributed to its neighboring region. Five municipalities lie at an altitude below 250 m a.s.l., twelve municipalities between 250 and 500 m a.s.l., five municipalities between 500 and 750 m a.s.l. and one municipality above 750 m a.s.l. Hence, they represent different regional climates. Because of the large variation in the numbers of inhabitants, they have different characteristics with respect to personal resources and administrative structures. Thus, generalizations proved to be difficult.

The interviews with experts provided insights into climate adaptation in practice, and its options and barriers in different municipalities. Direct dialogue during these interviews also helped identify weather and climate effects on specific fields of action that were important in particular in deducing climate parameters and their sensitivity. From the perspective of climate science, it also helped illustrate the wide range of applications of regional climate models.

3. Results

In the following, the results of the survey will be described with respect to the state of adaptation, the information used today, the climate parameters relevant to adaptation, and the sensitivity of municipalities. Results from the interviews supported the latter two.

3.1. State of Climate Change Adaptation in Municipalities in Baden-Wuerttemberg

The perceived importance of climate change adaptation varied in the municipalities in Baden-Wuerttemberg. While 10 of 23 municipalities that responded to the questionnaire consider the topic to be "important" or "very important" in their municipality, six rated it as "not important," "hardly important," or "of little importance". In general, climate change adaptation seemed to be more important in larger than in smaller municipalities (Figure 2).

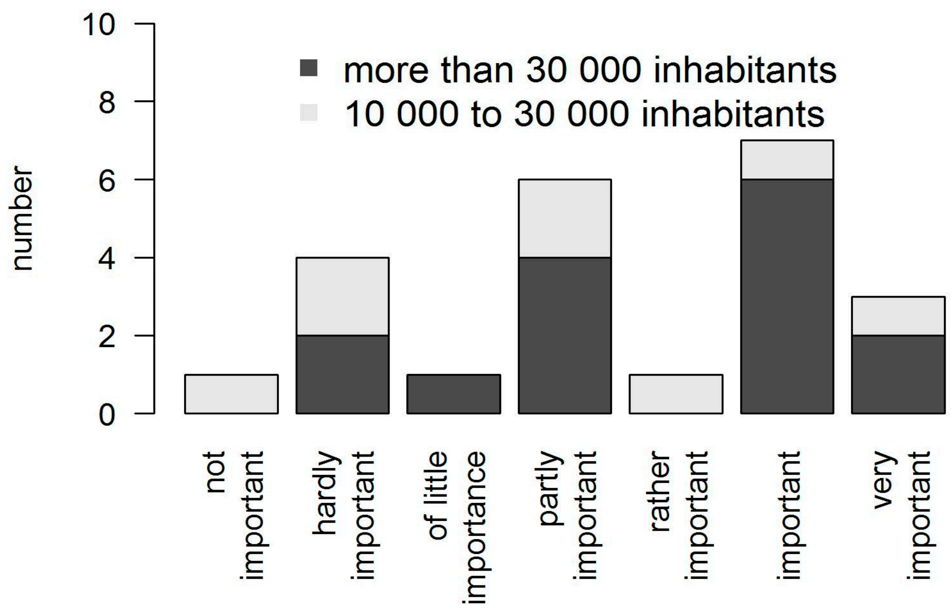

Figure 2. Answers to the question, "How important is the topic 'climate change adaptation' in your municipality?" (n = 23).

Two thirds of the municipalities indicated that they carry out diverse activities in the field of climate change adaptation. These comprise, for example, performing or ordering urban climate analyses and obtaining expert opinions, participating in research projects or working groups on climate and climate change, as well as enhancing public outreach by web presences to increase public acceptance of the topic. Climate adaptation plans exist in almost one third of the municipalities (some in preparation). In some cases, however, these are regional adaptation plans that extend beyond the fields of activity of a single municipality. Concrete implementation of measures consists, for example, of selecting tree species and plants for green areas, drawing up flood protection maps, and upgrading the sewage system. Several municipalities in the early stages of climate adaptation mentioned preliminary investigations or planned adaptation measures. Larger municipalities appeared to carry out both activities more frequently and to engage in more activities per municipality.

Although many municipalities would like to consider climate change in decision-making routines more effectively (14 municipalities chose "stronger" or "much stronger" in answering this question), they mentioned various barriers to doing so (Figure 3). One barrier reported by nearly half of the municipalities is that the topic is relatively new for local administrations. There also are major barriers of an internal nature, including personnel resources, the internal administrative structure, and lack of acceptance on the part of the administration itself. We also concluded from the answers to the open-ended questions that, although municipalities often regard climate adaptation as an important side issue, it covers several fields of action that require additional coordination that often is unavailable. In addition, some municipalities reported a "lack of acceptance in implementation of adaptation measures". With this answer option, we intended to address the possible barrier of a perceived lack of acceptance when measures are implemented, e.g., acceptance by parties involved or affected by measures concerning urban planning or construction plans ("lack of acceptance in implementation" in Figure 3). With respect to data accessibility, a quarter of the municipalities complained that they lacked availability to data and/or, did not know where to obtain them.

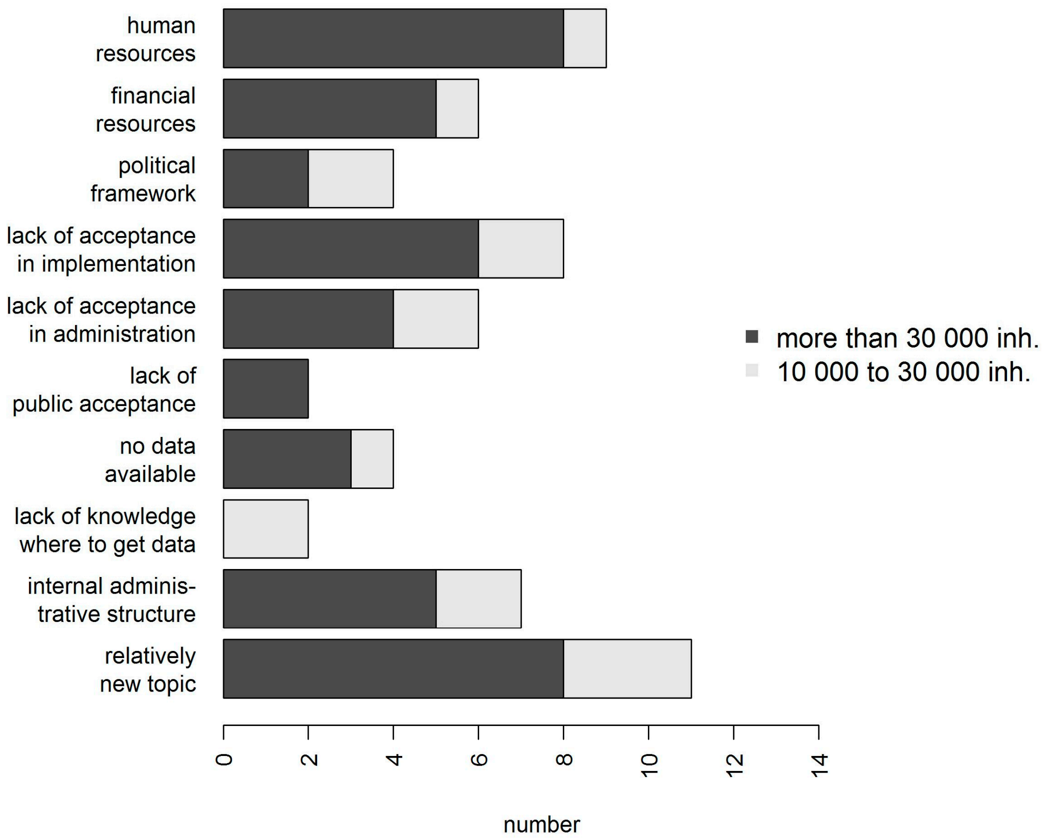

Figure 3. Answers to the question, "If you would like to consider climate aspects in a stronger or much stronger way, which barriers prevent you from doing so?" (number of responses, multiple answers possible, $n = 23$).

3.2. Data and Information Used Today

The municipalities in our sample stated that they use climate data derived primarily from measurement networks of higher authorities, including the State Office for the Environment, Measurements, and Nature Conservation of the Federal State of Baden-Wuerttemberg (LUBW, named by 13 municipalities), and the German Weather Service (DWD, mentioned by 10). Seven municipalities perform their own permanent or temporary meteorological measurements, including measurements of snowfall and ice on streets, and those related to the sewage system, technical operational services, or construction planning. In addition, nine municipalities perform or order analyses of urban climate, air quality, or areas of cold air production. Other climate data sources used include regional climate atlases and analyses, maps of climate functions, or other master plans. Nearly all of these data used refer to the current climate. Respondents mentioned data that refer to the future climate or effects of climate change only occasionally, for example, in one case, a master plan for climate change adaptation.

Different administrative as well as scientific institutions offer information accessible freely, as well as data on climate change and its effects, in most cases on websites or in booklets or leaflets; most municipalities in our survey know and use the information offered by higher authorities on the federal (DWD, Federal Environmental Agency (UBA)) or state level (LUBW). However, according to their responses, they seldom or rarely use climate information offered by scientific institutions and climate services, including the IPCC, universities in Baden-Wuerttemberg, and national and regional climate services. On the one hand, in specific cases, the respondents were looking for short-term weather and air quality forecasts, for example, weather warnings, and ozone and flood forecasts when addressing information sources. On the other hand, they expressed the need for projections of future climate change and its regional effects, for example, future frequency of heat events, development of ambrosia, as well as for best-practice examples in which municipalities comparable to their own are implementing adaptation measures and activities.

3.3. Climate Parameters Relevant to Climate Change Adaptation

Past weather events mentioned in the responses to the open-ended question in the survey about events "having caused problems in the municipality" were heat waves, hot periods, heavy precipitation events, flooding, storms, and dry periods (Table 1). Flooding was included in the list of weather events, because, although it is a hydro-meteorological event, it can cause severe problems. The respondents rated the occurrence of hot periods, as well as of heavy precipitation and precipitation in the summer most frequently as the most relevant to considerations about climate change adaptation. In addition, they listed air quality as one of the most important factors in considerations of adaptation (Figure 4).

Table 1. Grouped answers to the open-ended question, "Which weather events or changes in frequency caused problems at your municipality in the past?".

Number of Answers	Weather Events or Changes in Frequency	Single Events Indicated
11	Heat waves/hot periods/hot days/tropical nights	2003, 2005
9	Heavy precipitation events	Winter 2011, 2013
7	Floods *	June 2013, 1990s
7	Storm (winter gales)	Lothar (December 26, 1999), Wiebke (1 March 1990), Winter of years 2011, 2013
6	Dry periods	2003
4	Hail	June 2013, May 2015
3	Snow	-
2	Stationary temperature inversions	-
2	Thunderstorms	-
2	Cold periods	-

* Hydro-meteorological event, included because of the high number of times mentioned.

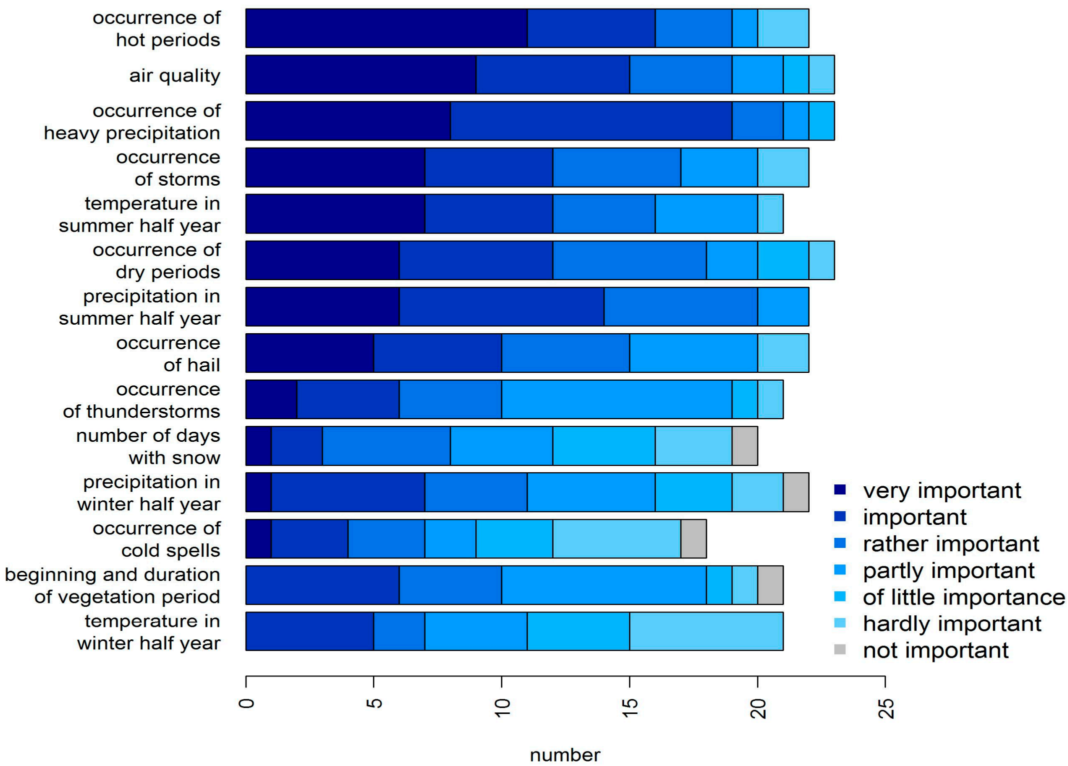

Figure 4. Answers to the question, "How important are the following events and parameters to your considerations relating to adaptation?" (n = 23).

The problematic past weather events mentioned corresponded largely to a municipality's climate adaptation considerations. Many municipalities consider additional weather events or changes in frequency to be important regardless of whether they produced negative effects in the past years. In some cases, however, municipalities deemed weather and climate factors irrelevant, despite problems in the past. In summary, slow-onset events that last a certain time and can cause health impairments, such as heat waves and poor air quality, are highly relevant to climate adaptation considerations. In addition, and as the expert interviews also confirmed, short-term events are important, such as heavy precipitation or storms, which can cause flash floods in settlements, and damage harvests, houses, or infrastructure (Table 2, statement S5). Generally, weather conditions during the summer half year seemed to be more important for adaptation considerations than did those during the winter half year. The regional climate in Southwestern Germany, which has relatively high temperatures in summer and mild winters—particularly in the Rhine valley—most likely is one reason for this. In addition, the responses most likely reflect the remembered experiences of the last several years, e.g., several hot summers.

Despite this, many of the survey respondents had difficulty naming specific climate parameters considered in climate adaptation today. Only some municipalities were able to provide climate parameters they use for current climate adaptation decisions. A quarter of the municipalities answered explicitly that they do not use parameters that can be described numerically, and half of the municipalities did not answer the respective question at all. The climate parameters given by municipalities included:

- Heat warnings by the German Weather Service (including the two warning levels "strong" and "extreme heat stress") in the health sector
- Snowfall and number of frost days for planning winter services or closing of (sports) halls due to snow loads on the roof
- Short-term weather forecasts for heat and precipitation to adjust the irrigation of green areas.

Table 2. Illustrative quotes from interviews with experts to the questions "Which climate parameters do you use?", "Which change of a climate parameter would cause you to plan or implement (more) adaptation measures?", and "Are there climate parameters for which you would like to know the future development?".

	Quotes
	Climate parameters relevant to climate change adaptation
S1	"We use the parameters given by science."
S2	"Urban planning among others requires 'work' with the climate parameters obtained from scientific discussion rather than developing of these parameters."
S3	"So far, we have never thought about individual climate parameters–but this would be interesting."
S4	"Even though we do not know climate parameters, we as a municipality have to do something in the area of climate adaptation. Many thoughts of a municipality may be based on basic developments known for the region, e.g., as a result of the 'guard rails' [54]. Only when we start implementing these measures, will we realize which parameters are needed for prognoses."
	Sensitivity
S5	"Sensitivity is produced when an event occurs: single events sharpen the awareness of both administration and population, as this is when the need for action becomes obvious."
S6	"It's either response to an emergency situation or available funding that trigger actions."
S7	"Generally, the climate adaptation process in cities is not based on fixed parameters, limits, or thresholds, but on general developments to be expected or already observed."
S8	"So far, measures considered or partly implemented have been lacking 'trigger criteria' (when do we have to start implementing measures, which priority do they have?)."

The questionnaire revealed that weather, climate, and its associated parameters play a role in practical applications in different fields of action. Examples include planning winter services, energy costs for heating and cooling, sewage management, selection of tree species for urban forests and the choice of plants for urban green areas. Climate parameters are also relevant in different planning contexts, for example, in drawing up the development plan and when planning green roofs, facades, or rainwater retention basins.

During the interviews, many experts were able to describe current weather effects precisely. It was easier for them to describe effects, either of high-impact weather events or of changes in frequencies of events in the past than to identify directly the climate parameters that could be relevant to the planning and implementation of adaptation. However, some experts were able to specify climate parameters for which they would like to have future projections. If they consider climate issues in their municipality, many rely on personal experiences or general knowledge about climate change in the form of rising temperatures or changes in precipitation (Table 2, statements S4 and S7). For this reason, it was difficult initially to identify their specific data needs. Only a few answers in the questionnaire indicate direct deduction of climate parameters. It was primarily the direct dialogue in the expert interviews that allowed us to deduce tailored climate parameters relevant to practical application in different fields of action directly, although some interviewees considered deducing climate parameters as a new task or even a task for scientists, not them (Table 2, statements S1–S3).

Among the parameters deduced were "standard" climate parameters that have been analyzed already on a regional scale. These include, for example, the number of tropical nights, hot days, hot periods, and the beginning and end of heating periods or vegetation periods. Beyond that, experts also mentioned new parameters that have not yet or rarely been evaluated from current climate models. These include, for example, the number of days per year in which winter services are necessary in the form of salting roads and clearing snow, the number of consecutive dry days between May and September, and the periods with weather conditions favorable for the spread of agricultural parasites, which temperature and humidity influence directly. Table 3 shows a selection of eight of approximately 25 such tailored climate parameters originating from both modes of data collection. Not only the mean values of the 30-year climatological period play a role in these tailored climate parameters, but also the range between extreme values and the inter-annual variability. The possible effect attributable to climate change (Table 3, right column) refers in some cases to adaptation practices and in some cases to climate change impacts. This originates from the explanations of the respondents to the question which climate parameter they desire. As mainly the interviews allowed for defining desired climate parameters, the experts often additionally explained in the dialogue why they desire a certain parameter.

Table 3. Selection of climate parameters desired for local adaptation and their possible effects on municipalities attributable to climate change.

	Desired Climate Parameters	Possible Effect Attributable to Climate Change
(1)	Hot days combined with high solar radiation	Effect on people's well-being; health risks attributable to heat and solar radiation
(2)	Number of hot and dry summers and years between them	Selection of tree species for streets Irrigation necessary for urban green areas Drying out of water bodies
(3)	Dry years	Selection of forest tree species
(4)	Number of consecutive dry days between May and September	Selection of plant species and irrigation of urban green areas
(5)	Days with precipitation in March and April	Change in best time to plant new trees
(6)	Storms and wind gusts	Infrastructure damage, damage to roofs, uprooted trees, high insurance payments
(7)	Cold temperatures with simultaneous precipitation (snow or rain)	Change in number of days when winter services necessary
(8)	Favorable conditions for cherry fruit fly (Rhagoletis cerasi)	Spread of agricultural fruit parasites

With respect to the way in which to provide tailored climate parameters, most survey respondents would prefer to obtain tailored information on specific climate parameters via a website. In addition, they requested datasets that geographical information systems can process. During the interviews, the experts expressed the expectation that this information should also include datasets that are well prepared, reliable, and evaluated for direct application. They also indicated that they need condensed data applicable readily to decision-making and available in a clearly processed form. Furthermore, they suggested that an event should be organized to provide information about the availability and quality of climate data.

3.4. Sensitivity

In the questionnaire responses, several municipalities indicated certain sensitivities to flooding, heat waves, or flash floods attributable to heavy precipitation events, but it was largely difficult or even impossible for the experts to describe their sensitivity in the sense of changes in parameters that would require adaptation actions. At present, they use specific numerical parameters randomly, for which, in addition to the past statistics, they also can estimate a range of possible future developments via regional climate projections. They indicated that an exact definition of sensitivity would require complex statistical evaluations, while decisions for specific adaptation actions rely currently on "subjective" event thresholds. Furthermore, answers to an open-ended question showed clearly that it can be the administrative and legislative framework that define the need for action, as illustrated by the following quote: "Municipalities cannot act alone in areas where measures of increased financial volume have to be implemented, such as flood protection. Municipalities depend on the prompt updating of regulations with respect to the assessment basis (e.g., frequencies of floods, rainfall series, etc.), even more so when measures have to be implemented in accordance with European Union (EU) directives (Water Framework Directive, Flood Risk Management Directive)".

In addition, the in-depth interviews revealed that the process of climate adaptation in municipalities largely is not associated with fixed climate parameters or thresholds (Tables 2, statement S7). Just as often, experiences of past events alone have formed the basis for considerations of climate change adaptation. The experts stated that single extreme events (Table 2, statements S5 and S6), as well as external influences such as project funding, rather than climate impacts, can trigger actions and be the starting point for adaptation (Table 2, statement S6). For the future, often only general projected climatic developments, such as higher temperatures, more hot days, or fewer frost days, are considered. Even if some stakeholders wish to have information on tailored climate parameters to plan and implement concrete adaptation measures, past and future development of these tailored and newly defined climate parameters has not yet been made available. Hence, we lack a basis for the experts' sensitivity assessment (Table 2, statement S8).

4. Discussion

4.1. State of Adaptation in Municipalities Varies

The observation that the state of climate change adaptation differs considerably among the municipalities that participated in our study is consistent with the results of other studies. Our study showed that approximately two thirds of the municipalities engage in activities related to climate change adaptation and one third has an adaptation plan. The latter is consistent with other studies in Germany that found adaptation plans in one third of the cities [6], and showed that one third of the regional planning authorities considered climate adaptation in their regional plans [23]. In combination with the survey result that climate change adaptation is considered a "relatively new topic" in many municipalities in Baden-Wuerttemberg, our study contributes further evidence to Lorenz et al.'s conclusion that, "Despite progress on adaptation at [the] national level [in Germany], adaptation at the local level still seems to be in the early stages" ([58], p. 7). This confirms the "gap between the perceived urgency of proactive adaptation to climate change by scientists and the perceptions of planners" observed in Dutch urban areas ([12], p. 777).

As shown elsewhere (e.g., [8]), lack of personnel resources is a relevant barrier in municipal adaptation. While some larger cities have several persons or offices that handle climate change adaptation, have established working groups on climate change impacts, or have employed persons explicitly responsible for the topic, in smaller communities, a single person is often responsible for all environmental issues. This likely explains in part the varied importance municipalities assign to adaptation. According to Lehmann et al. ([8], p. 87), "the lack of personnel, finances and time" is associated closely with information deficits. Hence, these aspects inhibit adaptation in two ways: the lack of resources prevents municipalities from adapting to climate change directly, and from informing themselves in detail about climate change and its effects. This lack of information then becomes a direct obstacle to adaptation [8]. We also found large differences in knowledge among respondents. Nevertheless, it is possible that they consider climate issues unconsciously or under a different heading, e.g., flood protection, because "climatic factors are often an integral part of environmental and comfort aspects of planning, and therefore, not necessarily perceived to be important in themselves (. . . [and urban planners] often included some climatic considerations in their work without being aware of it" ([59], p. 37). This unconscious use of knowledge must be transferred to explicit considerations in decision-making to institutionalize climate change adaptation in a formal administrative framework. Climate adaptation should become an independent aspect that is explicitly addressed in, e.g., planning processes instead of being just part of other environmental issues. In addition, the systematic implementation of a concept and its mainstreaming in municipalities, for example, ecosystem-based adaptation [60,61], could achieve progress, because "neither adaptation nor ecosystem-based approaches are labelled or systematized in any way" ([60], p. 76) so far.

4.2. Adaptation Often Relies on Previous Experiences

The decisions about climate adaptation measures today often rely on previous experiences, and in many cases, adaptations are considered initially after a single event, when awareness of the need for action increases after an extreme weather event causes damage in a municipality. Such "event-driven risk management" ([19], p. 461) also has been reported in former studies [19,62]. In our study, one example of a single event that triggered action is the summer of 2003. Temperatures were exceptionally high over a protracted period during that summer in Central Europe, and caused high mortality rates [43,63]. Consequently, the city of Karlsruhe in Baden-Wuerttemberg established a working group on climate change and later published a report on climate change adaptation [64] as well as a climate change adaptation strategy [65].

The climate data municipalities use consist primarily of measurements and urban climate analyses, which in most cases refer exclusively to the current climate. The fact that municipalities use analyses of the current climate and documents such as climate function maps or planning recommendation maps more often than climate projections also has been described in previous studies [23,58]. However, municipalities use (online) information sources frequently to obtain information about future climate change, its effects, and concrete measures for adaptation. Several municipalities use information on classical "standard" climate parameters, such as the number of hot days and tropical nights, and the number of days with heat warnings, or number of frost days. At the same time, however, other respondents also wished to have these parameters, even though future projections of these and certain other parameters desired are already available in several climate atlases or similar publications, although they are often provided on a larger horizontal scale (25 to 50 km, e.g., [54,66]). Obviously, to date, municipalities are largely unaware of these information sources.

4.3. Tailored Climate Parameters Can Narrow the Usability Gap

In the "seamless process" ([16], p. 28) of building climate change adaptation on adaptation to the current climate, a combination of data on current and future climates is desirable. This study showed that the capacities of regional climate modeling in providing data that can be used as a basis for adaptation planning are widely unknown, even though ensembles of climate model simulations of high horizontal resolution (less than 10 km) provide a tool to assess the range of possible future developments and the associated uncertainties for tailored climate parameters. Earlier studies revealed that climate projections have rarely been used so far in urban planning in Germany because of inappropriate data. In detail, respondents consider scientific robustness of the data, their obvious relevance to planning actions [23] and spatial resolutions appropriate for the local level and as input data for impact models are lacking [8].

It was clear that experts in administrative bodies expected to receive, preferably, a definite and fixed reference as a basis for decision-making. A discursive policy analysis in Germany that focused on the relation between administrative actors and uncertain scientific knowledge also found this to be the case [67]. In our study, their request for data that were processed, aggregated, evaluated professionally, and ready to be integrated into decisions reflected this. Municipalities expressed their wish for GIS (geographical information system) data repeatedly—in addition to information on a website and in a booklet—for information on the future development of tailored climate parameters. This underscores the importance of direct transferability of climate information into planning processes to improve the usability of climate information.

Although lack of data was not the barrier mentioned most frequently in the responses, transforming useful into usable knowledge [26] by evaluating already available climate model simulations in a user-oriented way promises to increase the value of municipalities' current use of data. In this context, the perceived novelty of the topic offers an opportunity to support municipal adaptation by using tailored climate information at an early stage, as well as providing a database to municipalities that are just beginning to think about adaptation.

Coupling the profound experiences of stakeholders with the tools of climate science by translating weather events or weather-related influences into tailored climate parameters has the significant potential to enlarge the dataset(s) municipalities use in different fields of action. This approach can help narrow the climate information usability gap [26] if climate simulation data thus far unused widely become usable for municipalities. In this way, interaction—one of the three factors that Lemos et al. [26] addressed in their conceptual model—between climate scientists from a regional climate service and stakeholders during the expert interviews was critical. Furthermore, our study enhanced our knowledge about the large range of possible applications and uses of climate model data in municipalities. In doing so, we addressed one of the direct, climate-specific barriers Biesbroek et al. ([11], p. 1124) identified, the " ... reliance on scientific models to identify, understand, and communicate the problem and propose solutions".

The climate parameters that were deduced from experts' experiences were related either to one or more climate variables (e.g., temperature, precipitation). In addition to frequencies of occurrence, durations of certain weather situations are important. These parameters affect people (for example, high temperatures) and influence capital investments or municipal budgets (for example, winter services). Furthermore, the occurrence of events that climate parameters describe can cause property damage (heavy precipitation events, storms) or health risks (heat waves, high pollen levels). For example, knowledge about the direction and intensity of climate change can support decisions in urban planning, although further investigations might be necessary before taking concrete measures. The evaluation of tailored climate parameters for past periods also could underpin municipalities' previous experiences of climate change (for example "we have observed an increasing number of dry periods"). However, some climate parameters desired describe effects of weather events. Such parameters, e.g., flash floods in cities due to heavy precipitation or river flooding, cannot be assessed directly with regional climate models, but require coupling to impact models. Air quality assessments are available already from weather forecasting model data [68,69], but are not yet available widely from climate models for long periods.

4.4. The Concept of Sensitivity Is Difficult to Apply in Municipalities

For the respondents in the municipalities, it was largely unclear which change in a climate parameter requires action or causes damage in their municipalities, for example, what temperature increase will have negative effects on human's health. Although several municipalities exhibited certain sensitivities to extreme events, such as flooding, flash floods, or heat waves, it was difficult for them to assess thresholds for the need for action. The study showed that, from a climate science perspective, asking for thresholds that would imply a need for action is a concept difficult to apply in municipalities.

In addition, the range of possible future developments in climate parameters provided by an climate model ensemble approach does not provide a single number for planning, for example, a projected temperature increase of x,y K. Hence, these uncertainties in climate model projections [70] may be a barrier to making concrete decisions about climate change adaptation [25] and increase the difficulty in defining a threshold for action. Therefore, communication of the uncertainties in climate projections is an important aspect because there is a fundamental discrepancy between scientists' goals to increase knowledge constantly and administrative actors' demand and need for reliable, self-contained, and unambiguous data that they can use in decision-making [67].

4.5. Interaction along Climate Information in Context of Climate Change Adaptation Decisions in Local Municipalities

However, an improved database on regional climate change will not be sufficient to initiate planning and implementation of adaptation measures in municipalities. As indicated in previous studies, the political and organizational framework is even more important [24], as is guidance from higher authorities, mandates, and regulations [8]. In addition, local climate change decision-making is " ... necessarily part of a larger local sustainability challenge" ([13], p. 173). Nevertheless, " ... close collaboration of climate and impact scientists, sectoral practitioners, decision makers and other stakeholders" ([71], p. 273) can increase awareness of the topic of climate change adaptation and the availability of tailored information for decision-making. At this interface of science and society, more projects should be initiated to make practical expert knowledge accessible and detect information needs because personal contact between local authorities and scientists can increase access to information [8]. Research or pilot projects in municipalities contribute to a large extent to the progress in adaptation [60]. The three recommendations in considering urban climate in planning issues also can be applied to adaptation: "Improve awareness, improve communication and argumentation, develop tools and courses suitable for urban planners" ([59], p. 42). Numerous measures for training and capacity building already exist in the form of guidelines, handbooks, and websites. For example, the European Commission initiated Climate-ADAPT, the goal of which is to help users access and share data and information about climate change [72]. The EU-project, RAMSES, as well as the German federal initiatives "deeds bank" ("Tatenbank"), and "city climate guide" ("Klimalotse"), focus on urban climate adaptation measures [73–75]. For example, the latter is an online tool that supports medium-sized and smaller municipalities, in particular, in their decision-making processes with a database that contains approximately 140 suggestions for adaptation measures.

4.6. Limitations of the Study

As mentioned earlier, the relatively small sample size did not allow us to generalize our results to other regions of Germany. While we cannot say that the quite low response rate was attributable to the study design, work overload in the municipalities, or simply their non-interest in participating in a scientific study, the extremely different response rates of smaller (4%) and larger (30%) municipalities may be an indication. Combined with the finding that there are more activities in larger municipalities , the difference in participation rate suggests a self-selection effect in the sample, in that only those municipalities that are already aware of the topic of climate change adaptation participated in the study. At first glance, climate adaptation is neither a common nor a high-priority topic in the daily work of most municipalities in Baden-Wuerttemberg. However, several measures planned or implemented may be related to the adaptation context, even though they are not covered under the heading of adaptation, but are aspects of flood protection or nature and environment protection. As Overbeck et al. ([23] p. 198) indicated, "The fields of work in regional planning in Germany often are not yet considered to be related to climate change and it is not clear to regional planners what can be regarded as adaptation strategy or measure".

With respect to the two approaches taken to deduce tailored climate parameters for adaptation, the questionnaire responses, as well as the expert interviews, showed that indirect deduction of tailored climate parameters from extreme hydro-meteorological events experienced in the past was easier than direct deduction by naming parameters desired. As many of the respondents never had been asked what climate information they desired, the expert interviews proved to be more suitable in identifying users' needs because the more interactive format allowed further explanations and clarifications and thus enhanced the fit to previous knowledge and experiences. From the perspective of a regional climate service, this interactive approach to identifying municipalities' needs for tailored climate parameters proved to be suitable as a case study on the local level. However, such a deliberative and interactive process also requires human and financial resources [13,26], as do the further steps necessary to provide the data desired and its eventual coupling to impact models. This is especially the case if the parameters are tailored to very specific applications relevant in only few municipalities. Nevertheless, the "iterativity between scientists and users of knowledge is critical to the successful production of usable science" ([76], p. 687).

Future studies should test participative methods, for example workshops or focus group interviews, in order to encourage more interaction among the stakeholders. They also should focus on one or a few fields of action in the context of adaptation rather than taking such a broad approach, as this could yield more in-depth results. In addition, the legal and regulatory planning system, in which climate science and local stakeholders interact, should be considered [58] when identifying suitable formats for iterative, dialogue-based approaches.

5. Conclusions

Our survey of municipalities in Baden-Wuerttemberg in Southwestern Germany showed that climate change adaptation is of increasing importance, but that the progress in adaptation on the part of the municipalities differed strongly.

The novelty of the topic and the fact that municipalities, especially smaller ones, do not know where to obtain information and data, offer an opportunity to co-develop tailored information to information needs for local adaptation to climate change. Municipalities have considerable practical experience in, and knowledge of adaptation, as well as a need for information, which can be identified in close interaction and dialogue with climate scientists. At present, regional climate services help institutionalize this dialogue, meet information needs, and provide tailored data with a focus on the specific impacts of climate change on the regional scale [34].

Regional climate models offer reliable data on a regional scale that allow climate information to be tailored to municipalities' needs and thus transform useful climate data to usable information by adding value to the data and customizing the information. The deductive approach described is designed to translate local municipal experiences into tailored climate parameters described by thresholds, durations, or combinations of meteorological variables. Then, these tailored climate parameters can be evaluated with already existing regional climate projections. Therefore, we recommend intensifying the communication of scientific results and developing those results continuously in a user-oriented way. Regional cooperation of municipalities, scientific institutions, and companies should be developed further and collaborative projects that focus on practical application can be an incentive for municipalities to initiate adaptation activities.

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References

1. IPCC. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2013.
2. IPCC. *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*; Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2014.

3. Revi, A.; Satterthwaite, D.E.; Aragón-Durand, F.; Corfee-Morlot, J.; Kiunsi, R.B.R.; Pelling, M.; Roberts, D.C.; Solecki, W. Urban areas. In *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*; Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2014; pp. 535–612.
4. European Environment Agency. *Urban Adaptation to Climate Change in Europe*; EEA Report No 2/2012; European Environment Agency: Copenhagen, Denmark, 2012; Volume 2, pp. 62–94.
5. Wilbanks, T.J.; Romero Lankao, P.; Bao, M.; Berkhout, F.; Cairncross, S.; Ceron, J.-P.; Kapshe, M.; Muir-Wood, R.; Zapata-Marti, R. Industry, settlement and society. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E., Eds.; Cambridge University Press: Cambridge, UK, 2007; pp. 357–390.
6. Reckien, D.; Flacke, J.; Dawson, R.J.; Heidrich, O.; Olazabal, M.; Foley, A.; Hamann, J.J.P.; Orru, H.; Salvia, M.; De Gregorio Hurtado, S.; et al. Climate change response in Europe: What's the reality? Analysis of adaptation and mitigation plans from 200 urban areas in 11 countries. *Clim. Chang.* **2014**, *122*, 331–340. [CrossRef]
7. Dewulf, A.; Meijerink, S.; Runhaar, H. Editorial: The governance of adaptation to climate change as a multi-level, multi-sector and multi-actor challenge: A European comparative perspective Art. *J. Water Clim. Chang.* **2015**, *6*, 1–8. [CrossRef]
8. Lehmann, P.; Brenck, M.; Gebhardt, O.; Schaller, S.; Süßbauer, E. Barriers and opportunities for urban adaptation planning: Analytical framework and evidence from cities in Latin America and Germany. *Mitig. Adapt. Strateg. Glob. Chang.* **2015**, *20*, 75–97. [CrossRef]
9. Klein, R.J.T.; Midgley, G.F.; Preston, B.L.; Alam, M.; Berkhout, F.G.H.; Dow, K.; Shaw, M.R. Adaptation opportunities, constraints and limits. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects.Contribution of the Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2014; pp. 899–943.
10. Reisinger, A.; Kitching, R.L.; Chiew, F.; Hughes, L.; Newton, P.C.D.; Schuster, S.S.; Tait, A.; Whetton, P. Australasia. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Barros, V.R., Field, C.B., Dokken, D.J., Mastrandrea, M.D., Mach, K.J., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2014; pp. 1371–1438.
11. Biesbroek, G.R.; Klostermann, J.E.M.; Termeer, C.J.A.M.; Kabat, P. On the nature of barriers to climate change adaptation. *Reg. Environ. Chang.* **2013**, *13*, 1119–1129. [CrossRef]
12. Runhaar, H.; Mees, H.; Wardekker, A.; van der Sluijs, J.; Driessen, P.P.J. Adaptation to climate change-related risks in Dutch urban areas: Stimuli and barriers. *Reg. Environ. Chang.* **2012**, *12*, 777–790. [CrossRef]
13. Corfee-Morlot, J.; Cochran, I.; Hallegatte, S.; Teasdale, P.-J. Mulitlevel risk governance and urban adaptation policy. *Clim. Chang.* **2011**, *104*, 169–197. [CrossRef]
14. Measham, T.G.; Preston, B.L.; Smith, T.F.; Brooke, C.; Gorddard, R.; Withycombe, G.; Morrison, C. Adapting to climate change through local municipal planning: Barriers and challenges. *Mitig. Adapt. Strateg. Glob. Chang.* **2011**, *16*, 889–909. [CrossRef]
15. Moser, S.C.; Ekstrom, J.A. A framework to diagnose barriers to climate change adaptation. *Proc. Natl. Acad. Sci. USA* **2010**, *107*, 22026–22031. [CrossRef] [PubMed]
16. Burton, I. Climate change and the adaptation deficit. In *Climate Change: Building the Adaptive Capacity*; Fenech, A., MacIver, D., Auld, H., Rong, R.B., Yin, Y., Eds.; Ministry of Public Works and Government Services: Ottawa, ON, Canada, 2004.
17. Laukkonen, J.; Blanco, P.K.; Lenhart, J.; Keiner, M.; Cavric, B.; Kinuthia-Njenga, C. Combining climate change adaptation and mitigation measures at the local level. *Habitat Int.* **2009**, *33*, 287–292. [CrossRef]

18. Adger, W.N.; Agrawala, S.; Mirza, M.M.Q.; Conde, C.; O'Brien, K.; Pulhin, J.; Pulwarty, R.; Smit, B.; Takahashi, K. Assessment of adaptation practices, options, constraints and capacity. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2007; pp. 717–743.
19. Storbjörk, S. Governing climate adaptation in the local arena: Challenges of risk management and planning in Sweden. *Local Environ.* **2007**, *12*, 457–469. [CrossRef]
20. Martinez, G.; Bray, D. *Befragung politischer Entscheidungsträger zur Wahrnehmung des Klimawandels und zur Anpassung an den Klimawandel an der deutschen Ostseeküste*; RADOST-Berichtsreihe 4; Ecologic Institut: Berlin, Germany, 2011.
21. Hornsey, M.J.; Harris, E.A.; Brain, P.G.; Fielding, K.S. Meta-analyses of the determinants and outcomes of belief in climate change. *Nat. Clim. Chang.* **2016**. [CrossRef]
22. Ratter, B.M.W.; Phillipp, K.H.I.; von Storch, H. Between hype and decline: Recent trends in public perception of climate change. *Environ. Sci. Policy* **2012**, *18*, 3–7. [CrossRef]
23. Overbeck, G.; Sommerfeldt, P.; Köhler, S.; Birkmann, J. Klimawandel und Regionalplanung. *Raumforsch. Raumordn.* **2009**, *67*, 193–203. [CrossRef]
24. Demeritt, D.; Langdon, D. The UK Climate Change Programme and communication with local authorities. *Glob. Environ. Chang.* **2004**, *14*, 325–336. [CrossRef]
25. Kropp, J.P.; Daschkeit, A. Planungshandeln im Lichte des Klimawandels. *Inf. Raumentwickl.* **2008**, *6*, 353–361.
26. Lemos, M.C.; Kirchhoff, C.J.; Ramprasad, V. Narrowing the climate information usability gap. *Nat. Clim. Chang.* **2012**, *2*, 789–794. [CrossRef]
27. Hackenbruch, J.; Schädler, G.; Schipper, J.W. Added value of high resolution regional climate simulations for regional impact studies. *Meteorol. Z.* **2016**, *25*, 291–304.
28. Sedlmeier, K. Near Future Changes of Compound Extreme Events from an Ensemble of Regional Climate Simulations. Ph.D.Thesis, Karlsruher Institut für Technologie, Karlsruher, Germany, 2015.
29. Prein, A.F.; Langhans, W.; Fosser, G.; Ferrone, A.; Ban, N.; Goergen, K.; Keller, M.; Tölle, M.; Gutjahr, O.; Feser, F.; et al. A review on regional convection-permitting climate modeling: Demonstrations, prospects, and challenges. *Rev. Geophys.* **2015**, *53*, 323–361. [CrossRef] [PubMed]
30. Junk, J.; Matzarakis, A.; Ferrone, A.; Krein, A. Evidence of past and future changes in health-related meteorological variables across Luxembourg. *Air Qual. Atmoms. Health* **2014**, *7*, 71–81. [CrossRef]
31. Berg, P.; Wagner, S.; Kunstmann, H.; Schädler, G. High resolution regional climate model simulations for Germany: Part 1—Validation. *Clim. Dyn.* **2013**, *40*, 401–414. [CrossRef]
32. Feldmann, H.; Schädler, G.; Panitz, H.J.; Kottmeier, C. Near future changes of extreme precipitation over complex terrain in Central Europe derived from high resolution RCM ensemble simulations. *Int. J. Climatol.* **2013**, *33*, 1964–1977. [CrossRef]
33. Déqué, M.; Rowell, D.; Lüthi, D.; Giorgi, F.; Christensen, J.; Rockel, B.; Jacob, D.; Kjellström, E.; de Castro, M.; van den Hurk, B. An intercomparison of regional climate simulations for Europe: Assessing uncertainties in model projections. *Clim. Chang.* **2007**, *81*, 53–70. [CrossRef]
34. Von Storch, H.; Meinke, I.; Stehr, N.; Ratter, B.; Krauss, W.; Pielke, R.A., Jr.; Grundmann, R.; Reckermann, M.; Weisse, R. Regional climate services illustrated with experiences from Northern Europe. *Z. Umweltpolit. Umweltr.* **2011**, *34*, 1–15.
35. Kirchhoff, C.J.; Lemos, M.C.; Dessai, S. Actionable knowledge for environmental decision making: broadening the usability of climate science. *Annu. Rev. Environ. Resour.* **2013**, *38*, 393–414. [CrossRef]
36. Field, C.B.; Barros, V.R.; Mach, K.J.; Mastrandrea, M.D.; van Aalst, M.K.; Adger, W.N.; Arent, D.J.; Barnett, J.; Betts, R.; Bilir, T.E.; et al. Technical Summary. In *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*; Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2014; pp. 35–94.
37. Basett, T.J.; Fogelman, C. Déjà vu or something new? The adaptation concept in the climate change literature. *Geoforum* **2013**, *48*, 42–53.
38. State Statistical Office (Statistisches Landesamt) Baden-Wuerttemberg (Stuttgart, Germany). Available online: http://www.statistik.baden-wuerttemberg.de/ (accessed on 24 November 2016).

39. State Office for the Environment, Measurements and Nature Conservation of the Federal State of Baden-Württemberg (LUBW). *Klimaatlas Baden-Württemberg*; LUBW: Karlsruhe, Germany, 2006.
40. Zolina, O.; Simmer, C.; Kapala, A.; Bachner, S.; Gulev, S.K.; Maechel, H. Seasonally dependent changes of precipitation extremes over Germany since 1950 from a very dense observational network. *J. Geophys. Res.* **2008**, *113*, D06110. [CrossRef]
41. Albrecht, F.M.; Dietze, B. Langzeitverhalten der Starkniederschläge in Baden-Württemberg und Bayern. In *KLIWA-Berichte 8*; KLIWA: Karlsruhe, München, Offenbach, Germany, 2006.
42. Hundecha, Y.; Bárdossy, A. Trends in daily precipitation and temperature extremes across western Germany in the second half of the 20th century. *Int. J. Climatol.* **2005**, *25*, 1189–1202. [CrossRef]
43. Fink, A.H.; Brücher, T.; Krüger, A.; Leckebusch, G.C.; Pinto, J.G.; Ulbrich, U. The 2003 European summer heatwaves and drought—Synoptic diagnosis and impacts. *Weather* **2004**, *59*, 209–216. [CrossRef]
44. Hoy, A.; Hänsel, S.; Skalak, P.; Ustrnul, Z.; Bochníček, O. The extreme European summer of 2015 in a long-term perspective. *Int. J. Climatol.* **2016**. [CrossRef]
45. Puskeiler, M.; Kunz, M.; Schmidberger, M. Hail statistics for Germany derived from single-polarization radar data. *Atmos. Res.* **2016**, *178–179*, 459–470. [CrossRef]
46. Piper, D.; Kunz, M.; Ehmele, F.; Mohr, S.; Mühr, B.; Kron, A.; Daniell, J.E. Exceptional sequence of severe thunderstorms and related flash floods in May and June 2016 in Germany—Part I: Meteorological background. *Nat. Hazards Earth Syst. Sci.* **2016**, *16*, 2835–2850. [CrossRef]
47. Wagner, S.; Berg, P.; Schädler, G.; Kunstmann, H. High resolution regional climate model simulations for Germany: Part II—Projected climate changes. *Clim. Dyn.* **2013**, *40*, 415–427. [CrossRef]
48. Beniston, M.; Stephenson, D.B.; Christensen, O.B.; Ferro, C.A.T.; Frei, C.; Goyette, S.; Halsnaes, K.; Holt, T.; Jylhä, K.; Koffi, B.; et al. Future extreme events in European climate: An exploration of regional climate model projections. *Clim. Chang.* **2007**, *81*, 71–95. [CrossRef]
49. Die Bundesregierung. *Deutsche Anpassungsstrategie an den Klimawandel*; Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit: Berlin, Germany, 2008.
50. Die Bundesregierung. *Aktionsplan Anpassung der Deutschen Anpassungsstrategie an den Klimawandel*; Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit: Berlin, Germany, 2011.
51. Umweltbundesamt. *Monitoringbericht 2015 zur Deutschen Anpassungsstrategie an den Klimawandel*; Umweltbundesamt: Dessau-Roßlau, Germany, 2015.
52. Bubecka, P.; Klimmer, L.; Albrecht, J. Klimaanpassung in der rechtlichen Rahmensetzung des Bundes. *Nat. Recht* **2016**, *38*, 297–307. [CrossRef]
53. Ministerium für Umwelt, Klima und Energiewirtschaft. *Strategie zur Anpassung an den Klimawandel in Baden-Württemberg*; Ministerium für Umwelt, Klima und Energiewirtschaft: Stuttgart, Germany, 2014.
54. State Office for the Environment, Measurements and Nature Conservation of the Federal State of Baden-Württemberg (LUBW). *Zukünftige Klimaentwicklung in Baden-Württemberg*; LUBW: Karlsruhe, Germany, 2013.
55. Ministerium für Umwelt, Klima und Energiewirtschaft Baden-Württemberg. KLIMOPASS. Available online: https://um.baden-wuerttemberg.de/de/klima/klimawandel/klimawandel-in-baden-wuerttemberg/klimaforschung/klimopass/ (accessed on 17 January 2017).
56. Baur, N.; Blasius, J. *Handbuch Methoden der empirischen Sozialforschung*; Springer: Wiesbaden, Germany, 2014.
57. Flick, U.; von Kardorff, E.; Keupp, H.; von Rosenstiel, L.; Wolff, S. *Handbuch qualitative Sozialforschung: Grundlagen, Konzepte, Methoden und Anwendungen*; Beltz Psychologie-Verlag-Union: Weinheim, Germany, 2012; Volume 3.
58. Lorenz, S.; Dessai, S.; Forster, P.M.; Paavola, J. Adaptation planning and the use of climate change projections in local government in England and Germany. *Reg. Environ. Chang.* **2016**. [CrossRef]
59. Eliasson, I. The use of climate knowledge in urban planning. *Landsc. Urban Plan.* **2000**, *48*, 31–44. [CrossRef]
60. Wamsler, C.; Pauleit, S. Making headway in climate policy mainstreaming and ecosystem-based adaptation: Two pioneering countries, different pathways, one goal. *Clim. Chang.* **2016**, *137*, 71–87. [CrossRef]
61. Roberts, D.; Boon, R.; Diederichs, N.; Douwes, E.; Govender, N.; Mcinnes, A.; Mclean, C.; O'Donoghue, S.; Spires, M. Exploring ecosystem-based adaptation in Durban, South Africa: "Learning-by-doing" at the local government coal face. *Environ. Urban.* **2011**, *24*, 167–195. [CrossRef]
62. Adger, W.N.; Arnella, N.W.; Tompkins, E.L. Successful adaptation to climate change across scales. *Glob. Environ. Chang.* **2005**, *15*, 77–86. [CrossRef]

63. Robine, J.-M.; Cheung, S.L.K.; Le Roya, S.; van Oyen, H.; Griffiths, C.; Michel, J.-P.; Herrmann, F.R. Death toll exceeded 70,000 in Europe during the summer of 2003. *C. R. Biol.* **2008**, *331*, 171–178. [CrossRef] [PubMed]
64. Karlsruhe, S.; Arbeitsschutz, U. *Anpassung an den Klimawandel*; Stadt Karlsruhe, Umwelt-und Arbeitsschutz: Karlsruhe, Germany, 2008.
65. Karlsruhe, S.; Arbeitsschutz, U. *Anpassung an den Klimawandel—Bestandsaufnahme und Strategie für die Stadt Karlsruhe*; Stadt Karlsruhe, Umwelt-und Arbeitsschutz: Karlsruhe, Germany, 2013.
66. Meinke, I.; Gerstner, E.M.; von Storch, H.; Marx, A.; Schipper, H.; Kottmeier, C.H.; Treffeisen, R.; Lemke, P. Regionaler Klimaatlas Deutschland der Helmholtz-Gemeinschaft informiert im Internet über möglichen künftigen Klimawandel. *Mitt. DMG* **2010**, *2*, 5–7.
67. Fröhlich, J. Klimaanpassung im administrativen Diskurs—Das Verhältnis von Verwaltungsakteuren zu unsicherem wissenschaftlichen Wissen. *Z. Umweltpolit. Umweltr.* **2009**, *32*, 325–350.
68. Rieger, D.; Bangert, M.; Bischoff-Gauss, I.; Förstner, J.; Lundgren, K.; Reinert, D.; Schröter, J.; Vogel, H.; Zängl, G.; Ruhnke, R.; et al. ICON—ART 1.0—A new online-coupled model system from the global to regional scale. *Geosci. Model Dev.* **2015**, *8*, 1659–1676. [CrossRef]
69. Vogel, B.; Vogel, H.; Bäumer, D.; Bangert, M.; Lundgren, K.; Rinke, R.; Stanelle, T. The comprehensive model system COSMO-ART—Radiative impact of aerosol on the state of the atmosphere on the regional scale. *Atmos. Chem. Phys.* **2009**, *9*, 8661–8680. [CrossRef]
70. Flato, G.; Marotzke, J.; Abiodun, B.; Braconnot, P.; Chou, S.C.; Collins, W.; Cox, P.; Driouech, F.; Emori, S.; Eyring, V.; et al. Evaluation of climate models. In *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2013; pp. 741–866.
71. Füssel, H.M. Adaptation planning for climate change: Concepts, assessment approaches, and key lessons. *Sustain. Sci.* **2007**, *2*, 265–275. [CrossRef]
72. Climate-ADAPT–Sharing Adaptation Information across Europe, European Climate Adaption Platform. Available online: http://climate-adapt.eea.europa.eu/ (accessed on 24 January 2017).
73. RAMSES. Science for Cities in Transition Home Page. Available online: http://www.ramses-cities.eu/ (accessed on 24 January 2017).
74. Umweltbundesamt. Tatenbank. Available online: https://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/werkzeuge-der-anpassung/tatenbank (accessed on 24 January 2017).
75. Umweltbundesamt. Klimalotse. Available online: https://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/werkzeuge-der-anpassung/klimalotse (accessed on 24 January 2017).
76. Dilling, L.; Lemos, M.C. Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Glob. Environ. Chang.* **2011**, *21*, 680–689. [CrossRef]