The Long Way Around?

The Use of Climate Knowledge in the Mainstreaming of Adaptation in Dutch Municipalities

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Abstract

Climate knowledge plays a key role in adaptation to climate change. However, in the context of the mainstreaming of climate adaptation into existing policy sectors, effective provision of climate knowledge is problematic due to the diversity of actors involved and the limited understanding of how climate knowledge is used and how this affects policy. In the Netherlands, mainstreaming in municipalities started by doing stress tests which map vulnerabilities to climate change. This study investigated how the provision of climate knowledge in stress tests to Dutch municipalities affected the mainstreaming of climate adaptation into municipal policy. It found use of the stress tests to be diverse, with instrumental use in decision-making being complemented by conceptual, strategic and process use. The stress tests affected mainstreaming through two general pathways, each dependent on different factors. In the direct pathway, instrumental use depending on accurate, high-resolution information affected policy goals and instruments. In the indirect pathway, conceptual, strategic and process use, depending on accessibility and interaction, combined to change the problem perceptions and actor involvement. Relevance and credibility were important to both pathways. Which of the pathways predominated depended on how well an adaptation problem fit into existing policy arrangements. The second pathway constituted a long way around but was a necessary detour for problems fitting poorly in existing policy arrangements. Non-instrumental knowledge use played a key role in addressing these problems. While it has so far not been the focus of research into climate knowledge use, accounting for the diversity of ways in which knowledge is used opens up new prospects for enhancing the use and impact of climate knowledge.

Acknowledgements

While doing literature research for this thesis, the acknowledgement sections of dissertations have been a source of inspiration and amusement. It might be because it is the one section free from the restrictions of academic writing, or perhaps it is because of the mental impacts of spending four years on mostly solitary research. Whatever the reason is, acknowledgement sections can be real gems, whether they compare climate change to a duckling dropped in a painting (Boezeman, 2015), comment on the barriers to writing a dissertation on barriers (Biesbroek, 2014) or are for the greater part dedicated to discussing the importance of coffee, which is threatened by climate change (Uittenbroek, 2014). To me, reading these more personal messages created a sense of connection as well as the feeling that there are worse things than working on a thesis for six months.

For my own acknowledgement section, I will tarry no longer and extent my gratitude to some people who much deserve it. I would like to start by thanking my supervisor Kris van Koppen for his help and guidance. His conviction that the student should be the one making decisions about the direction of a thesis and his ability to ask the right questions to further a thought process have been of great value, both to the thesis you are reading and to my own learning process.

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While societies have adapted to their climates throughout history, proactive adaptation to climate change is a very recent phenomenon. Growing acceptance that some degree of climate change is inevitable has led both public and private decision-makers to increasingly consider how the future climate will affect them and how they might adapt to it (Hewitt, Stone, & Tait, 2017; Lourenço, Swart, Goosen, & Street, 2016). Since most climate change is yet to happen, climate knowledge in the form of predictions and scenarios about future climatic conditions plays a key role in informing this process.

Use of climate knowledge in decision-making is generally reported to be low (Jones, Champalle, Chesterman, Cramer, & Crane, 2017; Lemos, Kirchhoff, & Ramprasad, 2012). Over the past decades, the availability and quality of scientific knowledge about climate change have grown (Goosen et al., 2013; Lemos et al., 2012). However, as a review puts it: "promoting the uptake of climate information is only marginally about improving basic climate science" (Jones et al., 2017, p. 268). The use of climate knowledge has been found to depend on a wide range of factors relating to its (potential) users, its producers and their relationship and contexts (Dilling & Lemos, 2011; Jones et al., 2017; Lemos et al., 2012). This recognition has led authors to focus their efforts on the challenge of making useful science usable for decision-makers (cf. Lemos et al., 2012). An important strategy to tackle this challenge is the tailoring of climate knowledge to the needs and context of its users (Lemos et al., 2012; Vaughan & Dessai, 2014).

Climate change affects many different policy sectors. Because of this, a popular approach towards climate adaptation is mainstreaming: the integration of climate adaptation into existing policy sectors (as opposed to creating a new, specialized policy sector). Mainstreaming has been argued to yield several benefits, such as synergies, increased resource-efficiency, increased effectiveness and the promotion of innovation (Dewulf, Meijerink, & Runhaar, 2015; Runhaar, Wilk, Persson, Uittenbroek, & Wamsler, 2018). While critics have noted the risks of reduced attention for the topic and policy dilution (Runhaar et al., 2018), mainstreaming is a common approach to adaptation policy (Massey et al., 2015)

In the Netherlands, efforts towards climate adaptation are concentrated in the Delta Program. While most of this program has a specific focus on water-related impacts, the more recent Delta Plan Spatial Adaptation (*Deltaplan Ruimtelijke Adaptatie;* DPRA) has a broader scope. The DPRA aims to ensure "a climate-proof and water-resilient spatial design in the Netherlands by 2050" (Delta Commissioner, 2018, p. 65). It focuses on four themes: extreme precipitation[1], heat stress, drought and (urban) flooding due to dyke breaches. Concerns related

[1] The DPRA theme is actually called waterlogging, which is the saturation of soil with water. While this is one of the impacts included in the theme, it mostly focuses on flooding due to extreme rainfall. Thus, extreme precipitation is used here as a more accurate translation.

to these themes are to be mainstreamed into policy through a cycle of 'analysis-ambition-action' (Delta Commissioner, 2018). To start this cycle, all levels of government have agreed to do a stress test before the end of 2019. These stress tests map the vulnerabilities of jurisdictions to climate change. The knowledge they provide is to inform the formulation of ambitions and adaptation strategies by 2020.

The Dutch stress tests are an example of the provision of tailored climate knowledge. By mapping the vulnerabilities of specific jurisdictions, the impacts of climate change may become more immediate and actionable to policy-makers. However, they also show that tailoring is challenging in the context of mainstreaming. At the municipal level, which is crucial to spatial adaptation, mainstreaming is to happen among sectors ranging from water management to public health and urban green. This inherent diversity of sectors means that climate knowledge needs to be tailored to a wide range of needs and backgrounds (Boezeman, 2015) as well as support the overall process of mainstreaming.

Furthermore, climate knowledge such as that provided by the stress tests does not directly influence mainstreaming, but only through various types of use by various actors. While there is some recognition that "producers and users are far from homogeneous in the way that they produce and use climate information" (Lemos et al., 2012, p. 289), in most studies the use of climate knowledge implicitly seems confined to its direct application in decision-making. Studies of the use of knowledge and research in other fields have shown this narrow perspective to overlook less straightforward uses of knowledge, as well as more political ones (Nutley, Walter, & Davies, 2007; Weiss, 1977). Likewise, in the case of climate adaptation there has been criticism of the "highly linear and functionalist understanding of decision-making" implicit in much of the literature, which ignores many of the complexities of policy-making (Biesbroek et al., 2015, p. 493). Studying how climate knowledge is used, in addition to whether it is used, is an important step towards addressing these complexities and gaining more insight into the effects of knowledge provision on adaptation policy.

This study aims to contribute to the effective provision and use of climate knowledge by exploring the use climate knowledge and its effects on mainstreaming. The research question guiding the study is: how does the provision of climate knowledge in stress tests to Dutch municipalities affect the mainstreaming of climate adaptation into municipal policy? This question is answered by studying the experiences of ten municipalities with stress tests through interviews and document analysis. While at the moment of writing climate adaptation is only starting to take shape in Dutch municipalities and only time will tell the ultimate effectiveness its mainstreaming, their experiences provide lessons both for policy-makers and for researchers of climate adaptation policy.

Conceptual framework

As argued, the stress tests provide tailored climate knowledge, which through its use by various actors may affect the mainstreaming of climate adaptation into municipal policy. This section presents a framework of how this happens, summarized in Figure 1. Given the frequently reported lack of use of climate knowledge, the section starts by discussing literature on the factors that influence climate knowledge use. It continues by discussing different types of knowledge use in policy-making. These uses affect municipal policy. The effects of interest here, those on mainstreaming, are discussed in the final sub-section.

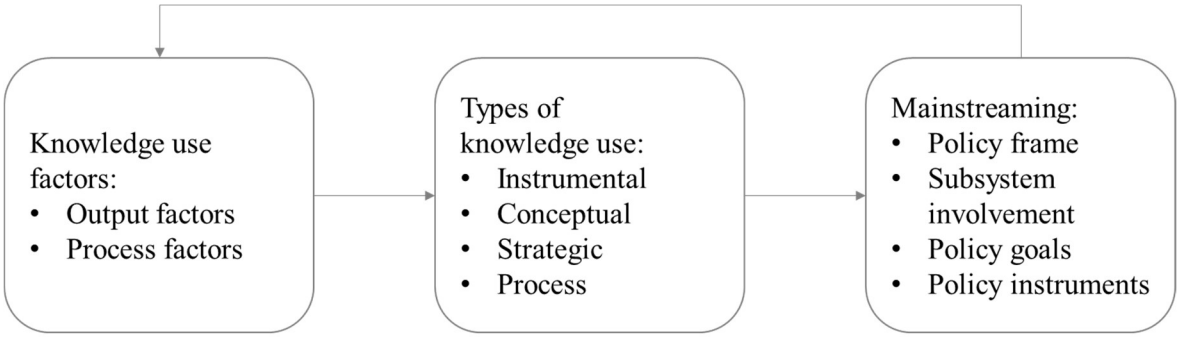

Figure 1. Summary of the conceptual framework.

Knowledge Use Factors

There is a substantive body of research on the factors influencing the use of climate knowledge. Much of this research has focused on the perceived lack of use of this knowledge (Jones et al., 2017; Lemos, Eakin, Dilling, & Worl, 2018), captured in the statement that "despite both the considerable amount of climate change research made available in the past thirty years and evidence that decision-makers … are actively seeking to increase their climate information uptake, there is a persistent gap between knowledge production and use" (Lemos et al., 2012, p. 789). The root of this gap is seen to be a disconnect between the producers of climate knowledge – scientists or other climate knowledge providers – and its users – public and private decision-makers (Boezeman, 2015). While the former may fail to understand and account for the context in which knowledge is to be used, the latter may have unrealistic expectations or a poor understanding of the knowledge (Lemos et al., 2012).

Research has identified a wide range of factors influencing climate knowledge use. These may relate to the characteristics of the knowledge itself (e.g. Dilling & Lemos, 2011; Lemos et al., 2012); to knowledge users and their contexts (Jones et al., 2017; Kirchhoff, Lemos, & Dessai, 2013; Kirchhoff, Lemos, & Engle, 2013); to knowledge producers and their contexts (Dilling & Lemos, 2011; Ernst, Swartling, André, Preston, & Klein, 2019); and to the relationship between knowledge producers and users (Jones et al., 2017; Kirchhoff, Lemos, & Dessai, 2013; Lemos et al., 2012). To set a manageable scope, this study focuses on two of these categories. These are the categories most directly related to the provision of climate

knowledge: output factors, related to the produced knowledge, and process factors, related to the process of knowledge production.

Within the category of output factors, five factors are considered (see Table 1 for relevant literature). The *relevance* of knowledge is unsurprisingly a crucial factor for its use. Relevance can be general, in the sense that knowledge is of interest to a sector, but also very specific, when it is relevant to specific decisions by specific policy-makers. Knowledge also needs to have sufficient c*redibility* to be used, which depends on scientific adequacy but also on the beliefs of users. *Accessibility* includes physical access to knowledge as well as its understandability. The latter is important to climate knowledge due to its often highly technical nature. Especially when adaptation is to be mainstreamed among policy-makers with different backgrounds, it can be expected to be a critical factor. The *accuracy* of knowledge increases its potential value to users. Finally, the *(spatial) resolution* of model results is often reported as a barrier to use at the local level.

Three process factors are considered (see Table 1). The *degree of interaction* has been found to increase knowledge use. Coproduction processes with high degrees of interaction are commonly advocated (see Lemos, Arnott, et al., 2018). Related to this is the *responsiveness* of knowledge producers to the needs, wishes and perspectives of potential users. Finally, the *legitimacy* of the process (as perceived by users) influences willingness to use knowledge. Legitimacy in this case refers to "the perception that the production of information and technology has been respectful of stakeholders' divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests" (Cash et al., 2003, p. 8086).

Table 1. Factors affecting climate knowledge use.

Category	**Factors**	**Sources**
Output factors	Relevance	Cash et al. (2003); Jones et al. (2017); Vaughan (2014)
	Credibility	Cash et al. (2003); Jones et al. (2017); Lemos et al. (2012)
	Accessibility	Jones et al. (2017); Lorenz, Dessai, Forster & Paavola (2015); Vaughan (2014)
	Accuracy	Lemos et al. (2012); Vaughan (2014)
	Spatial resolution	Archie, Dilling, Milford & Pampel (2014); Dilling & Lemos (2011); Jones et al. (2017)
Process factors	Degree of interaction	Dilling & Lemos (2011); Lemos et al. (2012); Lemos et al. (2019)
	Responsiveness of producers	Dilling & Lemos (2011); Jones et al. (2017); Kirchhoff, Lemos & Dessai (2013)
	Legitimacy	Cash et al. (2003); Lemos et al. (2012)

Types of Knowledge Use

While the literature on climate knowledge use has given much thought to the factors that influence knowledge use, less attention has been paid to what it means to 'use' climate knowledge (for an exception, see Wall, Meadow, & Horganic, 2017). In this respect, it can be enlightening to look at earlier research into the use of other types of research or science-based knowledge in policy-making. The argument can be made that climate knowledge is special in some ways, for example due to its highly technical nature or its long time frames. However, literature on climate knowledge use has built on this earlier literature in its conceptualizations of science-policy relations (see e.g. Kirchhoff, Lemos, & Dessai, 2013; Lemos & Morehouse, 2005) and has identified many similar factors relevant for knowledge use.[2]

In general, views on knowledge use in policy-making depend on views on the process of policy-making. In traditional, rational conceptualizations of policy-making, (scientific) knowledge plays a key role in informing decisions, for example by clarifying problems and aiding the comparison of different policy options (for a discussion, see e.g. Stone, 2001). However, later conceptualizations of policy-making have both challenged the centrality of knowledge and broadened the scope of what it means to use knowledge. In views of policy-making as a process of bounded rationality (Simon, 1957), as incrementalism or 'muddling through' (Lindblom, 1959) or as a garbage can filled with problems, solutions and decision-opportunities (Cohen, March, & Olsen, 1972), research-based knowledge may not play a leading role in policy-making and is often simply not considered. Later conceptualizations of the role of knowledge in policy-making, such as in the Advocacy Coalition Framework (Sabatier, 1988; Sabatier & Weible, 2007) and the concept of Epistemic Communities (Haas, 1992), stress the importance of actors and networks. In these models, knowledge does not simply inform policy but instead is an object of contestation as well as a resource in the struggle between networks of actors with different views.

This study bases itself on Nutley et al.'s (2007) distinction between four types of research use: instrumental, conceptual, strategic and process use. These are ideal types and actual knowledge use is unlikely to fit neatly in one of these categories. Still, they are useful for illustrating the variety of ways in which climate knowledge can potentially be used.

Instrumental use refers to the direct application of specific knowledge to a specific decision. This corresponds most strongly to rational views of policy-making and much of the literature on climate knowledge use seems to implicitly adopt this conceptualization, by equating knowledge use to the application of that knowledge in decision-making (e.g. Jones et al., 2017; Lemos et al., 2012). However, research suggests instrumental use of knowledge is relatively rare (Nutley et al., 2007).

[2] Compare for instance the factors reported in box 3.3 in Nutley et al. (2007) to the findings of the review by Jones et al. (2017).

More common is *conceptual use*. This is a broader category, "comprising the complex and often indirect ways in which research can have an impact on the knowledge, understanding and attitudes of policy makers and practitioners" (Nutley et al., 2007, p. 36). It corresponds to the idea of the enlightenment function of research (Weiss, 1977), which proposes that while research rarely has a large immediate impact on decisions, it can have significant long-term effects by informing the views of policy-makers.

Strategic use is the use of research to persuade others or to legitimate or challenge decisions. What distinguishes strategic use from instrumental and conceptual use is that the views of the user itself are not affected. While strategic use is sometimes considered to be improper use of research, an important effect of climate knowledge may well be to demonstrate the relevance of climate adaptation to policy-makers.

Finally, *process use* refers to the effects of the process of conducting research, irrespective of any use of its results. Engaging in research may change the views and behavior of actors. Similarly, the fact that research is undertaken or has just been finished may serve to engage actors who would otherwise not be interested in the results.

Mainstreaming

Use of climate knowledge can affect the mainstreaming of climate adaptation. While the meaning attached to mainstreaming can differ, in general it refers to the integration of climate adaptation into existing policies and practices (Runhaar et al., 2018). It is contrasted to the development of policies or a policy sector dedicated exclusively to climate adaptation (though not all agree with this distinction; see Massey, 2016).

Literature on mainstreaming generally views it as a specific form of the older concept of Environmental Policy Integration (EPI; see e.g. Rauken, Mydske, & Winsvold, 2015; Runhaar et al., 2018; Uittenbroek, Janssen-Jansen, & Runhaar, 2013). EPI refers to the integration of environmental objectives into non-environmental policy sectors, thought to be an important part of sustainable development (Kivimaa & Mickwitz, 2006; Lafferty & Hovden, 2003). Like EPI, the mainstreaming of climate adaptation involves the integration of new goals, such as for Dutch municipalities the management of heat stress, into existing policy sectors. However, it additionally involves adapting to the influence of climate change on existing goals. Limiting vulnerability to extreme precipitation, for example, is not a new goal for Dutch municipal water managers, but climate change affects what measures are necessary to achieve this goal.

At the time of writing, Dutch municipalities had only started to mainstream climate adaptation. This means it was too early to measure its effectiveness, as has been proposed, in terms of outputs and outcomes (Runhaar et al., 2018). A processual view of mainstreaming was likely to provide more insight in the effects of knowledge use. This study uses the conceptualization of Candel and Biesbroek (2016), who propose that integration consists of four dimensions: policy frame, subsystem involvement, policy goals and policy instruments.

The *policy frame* describes "whether a cross-cutting problem is recognized as such and, if so, to what extent it is thought to be requiring a holistic governance approach" (p. 218). *Subsystem involvement* describes the range of actors and institutions involved in the governance of the problem and the density of their interactions. The dimension of p*olicy goals* refers to explicit concern with the problem, captured by the range in of policies in which goals are included and the coherence of policy goals. Finally, *policy instruments* describe the degree to which the problem is addressed by instruments. Important aspects are the range of policies that contain instruments, the existence of procedural instruments to coordinate policies and the consistency of the instruments that are employed.

While these dimensions interact, they do not necessarily move in a concerted manner. Depending on circumstances, change in some dimensions may well precede change in others or happen without those other dimensions changing at all. However, Candel and Biesbroek (2016) do hypothesize change in the dimensions related to policy regimes (policy frame and subsystem involvement) is likely to precede, and lead to, change in the dimensions related to concrete sets of policies (policy goals and instruments).

Methods

Experiences with the stress tests and the mainstreaming of climate adaptation were studied in ten Dutch municipalities between March and June 2019. These municipalities, along with three others which declined participation, were identified through the network of Platform Climate-Proof Together (*Platform Samen Klimaatbestendig*; PSK), an organization created as part of the DPRA to facilitate knowledge-sharing on climate adaptation. Dutch municipalities had agreed to complete a stress test for the four themes of the DPRA by the end of 2019. However, at the time of the study many had yet to start or finish. For this reason, the network of PSK provided a valuable opportunity for identifying relevant municipalities.

These municipalities were selected to be diverse on two characteristics: their size and the point in time at which they did a stress test. Municipal size is important as smaller municipalities have previously been found to be more constrained in their capacity for climate policy (Hoppe, Van der Vegt, & Stegmaier, 2016) and, in a Norwegian study, to be less aware of climate risks (Rauken et al., 2015). On the other hand their smaller staff size could also enable them to implement policy change more quickly (Van den Berg & Coenen, 2012). The moment at which municipalities did a stress test is relevant because it determines how much time they have had for using the results and because the stress tests have been evolving over time. Table 2 provides an overview of the studied municipalities.

The municipalities were studied through a combination of interviews with officials and document analysis. Given the fact that climate adaptation is mainstreamed into diverse policy sectors, relevant differences might exist between these sectors. For this reason, the first official contacted in each municipality, known through the network of PSK, was asked to identify

Table 2. Characteristics of the studied municipalities.

Municipality	Inhabitants	Date of stress test(s)	Officials interviewed
Almere	200.000	2015 & 2016	• Water management • Water policy
Bernheze	30.000	2016	• Water management & policy
Ede	110.000	2018[a]	• Water policy • Water management • Soil & spatial policy • Landscape architecture • Project management
Enschede	160.000	2014	• Water policy • Water design
Goeree-Overflakkee	50.000	2018	• Water management & policy
Neder-Betuwe	25.000	2018	• Water management & policy • Road management
Nieuwegein	60.000	2015 & 2018[b]	• Climate adaptation & water policy • Water management
Rhenen	20.000	2018[a]	• Water policy
Utrecht	350.000	2018[b]	• Water policy • Climate adaptation policy • Urban green policy • Healthy living environment
Zeist	65.000	2018[b]	• Water management & policy

a Ede and Rhenen shared their stress test, though both expanded it based on their own needs.
b Nieuwegein, Utrecht and Zeist also shared their stress test.

officials from other sectors involved in climate adaptation. If these officials seemed likely to yield additional insights, they were also approached for interviews. Appendix A provides the interview guide used for these interviews. Additionally, relevant policy documents were studied. In every municipality, these included at least the results of the stress test and the Municipal Sewage Plan, which addresses extreme precipitation. Other documents were for example vision documents, strategies and additional research reports. Interviews and policy documents were coded using the coding scheme provided in Appendix B.

As Table 2 shows, the majority of interviewees were involved in water management or water policy. This is in line with previous research (Van den Berg & Coenen, 2012) and, given the geography of the Netherlands and the focus on water of the Delta Plan, not very surprising. The background of the other interviewees was diverse, reflecting the varying policy sectors involved in climate adaptation. Not all local officials involved in climate adaptation were

interviewed. In many cases departments were only involved to lower degrees or (especially in smaller municipalities) interactions between departments were so frequent that it was deemed unnecessary to do interviews with all involved officials.

Many municipalities were doing a stress test not individually but collectively within their water cooperation region, which generally included a number of municipalities as well as their water board. As such, several municipalities within this study shared their stress test. On the other hand, some municipalities did multiple stress tests. Municipalities also often did related research, especially the larger ones. Due to rapidly evolving standards, there was not always a clear distinction between stress tests and related research.

Results

This section discusses the use and effects of the stress tests in the studied municipalities. The first sub-section discusses perceptions, use and impacts of the stress tests. The second sub-section abstracts these municipal experiences to the level of knowledge use, discussing for each type of knowledge use its manifestations, the factors relevant to it and its impacts on mainstreaming. The final sub-section builds on this by abstracting yet further and identifying two generalized pathways towards mainstreaming.

The Stress Tests in Dutch Municipalities

While the experiences of municipalities with the stress tests varied, the most pronounced differences were not between municipalities but between the four DPRA themes. After discussing some common aspects related to the process, this sub-section therefore discusses the findings separately for the themes of extreme precipitation, heat stress and drought. The fourth theme, urban flooding, was only studied in four stress tests and was not considered very salient to municipal policy. While this is an interesting finding in its own right, it resulted in a lack of observations, which is the reason it is not discussed separately here.

Common aspects.

Aspects that were common for the themes related to the process of the stress tests. For municipalities doing a stress test collectively, the reason for commissioning it was invariably the fact that they were (or would be) obligated to do so at some point. For municipalities doing the stress tests individually the reasons were more varied. These included previous experiences with extreme weather, the need to update water policies and simple curiosity, as well as concerns about new city development.

The stress tests were done by a wide range of consultancy organizations, which overlapped little. Except for one, these consultancies did not specialize in climate adaptation but were instead more generally active on water, engineering or the environment. Usually the stress tests consisted of three parts: the collection of existing information, modelling and/or

measurements and a workshop to present and discuss the results. The results of the stress tests were presented in reports, but often also in online climate atlases.

Respondents mostly felt the processes of their stress tests were quite interactive. While the stress tests were commissioned by the water departments with usually limited input from others, workshops were considered valuable for explaining the results of the stress tests and validating them using the existing knowledge of officials. The clearest determinant of the responsiveness of consultants was whether a municipality did the stress test individually or as part of a collective. Municipalities commissioning it individually generally felt their aims or circumstances were different from their neighbors and a more customized stress test would thus be more valuable. Regional stress tests resulted in a more standard narrative, though this was often not considered problematic. Issues with legitimacy were mentioned little during the interviews, though it did contribute to use of the stress tests, especially when respondents felt they themselves lacked the expertise to judge the results.

The process of the stress test was often used as an opportunity to stimulate dialogue about the results as well as the wider challenges and the roles of the various sectors in addressing these. This process use was found especially useful to engage otherwise uninvolved officials. Data collection was also sometimes seen as an opportunity to raise awareness, which was then a reason to prefer it over modelling.

Extreme precipitation.

All stress tests studied extreme precipitation. This was not a new topic for Dutch municipalities as they are responsible for managing precipitation, which is one of the primary tasks of their water departments. Precipitation maps generally consisted of the modelled local water level and its effects on buildings and infrastructure in the case of certain rainfall events; sometimes these were statistical, at other times they were specific past events.

The relevance of these results was generally considered to be clear, especially to water managers, although some commented that these events were quite extreme and thus less pertinent. The precipitation maps were seen as easily understandable. They were usually also found credible, although the clearly visible nature of water meant model errors were easily exposed. As one official commented: “especially for water, if it is located in places of which we as municipality say it cannot be located, the trust disappears quickly.” Both the accuracy and the resolution of the stress tests were considered important, but also usually satisfactory. An important issue for the accuracy was the inclusion of sewers in the models. While some water managers, especially in flat municipalities in which precipitation is distributed relatively evenly, felt that simplifying assumptions were acceptable, many stated that not including the sewers results in exaggerated or even unusable results.

Instrumental use of the results for extreme precipitation was common. They were often used to identify problem areas and determine how much water would need to be infiltrated, drained or stored. Reasons not to use the stress tests in this way were concerns about their

accuracy or about the severity of the precipitation events used. Conceptual use was less common. While some water managers were surprised by the severity of the results for extreme precipitation, most they felt their existing views were confirmed. The precipitation events studied were more extreme than previously, but the problem areas were mostly known from prior modelling and practical experience. The results were also used strategically, to increase awareness and raise support for measures to reduce vulnerability. For this use, their extremity was an advantage; as one official commented, “the more blue spots [on the precipitation maps], the better.”

The stress tests affected the policy frame concerning extreme precipitation somewhat, but not fundamentally. While the results did show that reducing vulnerability usually required surface solutions, which also involve other spatial disciplines such as road management and urban green, extreme precipitation remained firmly rooted as a water topic. Likewise, the involvement of other subsystems increased, but the responsibility remained with the water sector. The stress tests did often result in new policy goals and instruments, though mainly within the water sector. Goals such as being prepared for a precipitation event of a specific severity were implemented by linking water measures to existing spatial plans and including them in norms for constructions, agreements with social housing organizations and stimulation programs for citizens. In this way, extreme precipitation was mainstreamed effectively into municipal policy, but without need for fundamental changes.

Heat stress.

All stress tests except for one studied heat stress. Unlike extreme precipitation, this theme was new to municipalities. In the past, heat was not considered a problem. As such, municipalities lacked expertise and sectoral responsibilities were unclear. Stress test maps for heat stress were diverse and showed for example the apparent temperature during hot days, the expected yearly number of tropical nights by 2050 and the distribution of vulnerable elderly people.

The relevance of these maps was far from straightforward. While respondents saw the theme as important, they frequently commented that it was unclear at what threshold heat becomes problematic and what indicators were important (e.g. absolute temperature, relative temperature to the countryside, apparent temperature or night temperature). The accessibility of the results was rated positively. There were more comments about their credibility, but this was not perceived problematic either. The accuracy and resolution of the information were lower than for extreme precipitation, but this was usually not considered a problem, either not yet (as formulating detailed policies was for other reasons not yet feasible) or because the results were to some degree common sense. As one official commented: “I will not wait until the method to map heat has completely crystalized, because you probably end up with the same picture: the downtown is very hot and needs greenery.”

Officials were much more likely to use the results for heat stress conceptually and strategically than instrumentally. To the officials, the results demonstrated, and were useful to

demonstrate, the salience of heat stress as an issue and how it related to the design of neighborhoods, for instance the amount of urban green. Maps were found especially helpful to show this in an intuitive fashion. Instrumental use was considered very difficult, mainly because heat stress was elusive due to the variety of potentially relevant indicators and lack of clear thresholds. As one official explained: "Water is very easy to quantify, you can direct someone 'thou shalt solve this many millimeter of water superficially'; but for heat that is very difficult."

Mainstreaming of heat stress primarily happened in the dimensions of policy frame and subsystem involvement and less in policy goals and instruments. Regarding the first, heat stress was redefined from a non-existing problem to one potentially involving sectors ranging from spatial planning to public health. Actual involvement lagged behind, but also increased. Water managers often had difficulty involving the more social sectors such as public health and responsibilities often remained ill-defined, but involvement increased especially among the spatial policy sectors. Formulating policy goals for heat stress was perceived to be a bigger challenge. The lack of clear goals in turn limited its inclusion in policy instruments: while potential measures were known, there were no standards for when to apply them. As a result, measures against heat stress were mostly limited to no-regret measures also serving other purposes. As a water manager who struggled with the theme explained: "I figured, when we take measures in public space against flooding [due to extreme precipitation], I want us to bring back more green in urban areas. And of course, that is also positive for heat stress."

Drought.

Six stress tests studied drought. In the Netherlands vulnerability to drought is very diverse and depends on geography. So do the impacts of droughts, which range from the direct effects of water shortage (mainly in higher, sandy areas) to land subsidence and damage to the foundations of buildings (mainly in low-lying peatlands). Drought is not a new topic for municipalities and the very dry summer of 2018 had served to demonstrate its relevance in many of the studied municipalities. However, the responsibilities of municipalities were ambiguous; while they had a duty to care for the water table, their responsibilities overlapped with those of homeowners and water boards. Moreover, municipalities stressed that there was little they could do to mitigate droughts.

Drought maps were diverse, showing for example changes in the average lowest water table, land subsidence in peatlands and the vulnerability of buildings to land subsidence based on their foundations. Respondents generally found these maps relevant, but knowledge gaps regarding for example the type of foundations beneath buildings made the impacts of drought difficult to estimate. A further complication was the fact that while dry periods were predicted to increase in frequency and intensity, climate scenarios varied in their predictions for the overall amount of precipitation. Officials did generally find the predictions credible though, especially given their experiences during the previous summer.

The stress tests saw little instrumental use. On the one hand municipalities lacked options to mitigate drought, while on the other hand the knowledge gaps hindered measures to reduce vulnerability. Conceptual use was more frequent, as the stress tests led diverse actors to consider how the increasing number of droughts would affect them in the future. In this way, the stress tests most strongly contributed to a change in policy frame and subsystem involvement, while integration into policy goals and instruments was rare. While an increasing number of actors perceived droughts as relevant for them, their vulnerability and potential measures often remained unclear. Water managers did implement no-regret measures like increasing water storage and infiltration capacity, but respondents mostly felt there was no real municipal policy against drought.

Knowledge Use, Factors and Mainstreaming

As the previous sub-section shows, there were clear differences between the climate adaptation themes. This sub-section continues by abstracting these findings, discussing for each type of knowledge use its manifestations, the factors relevant to it and its impacts on mainstreaming.

Instrumental use

Instrumental use of the stress test involved its direct application in decision-making, which happened most commonly for extreme precipitation. For this theme, the stress tests were often used to identify problem areas and design measures to address these. Instrumental use for the other themes was rarer, but not absent. In Nieuwegein for example, the stress test showed relatively green and shaded neighborhoods to be (only) 3 to 5 °C warmer than rural areas. This was then formulated as a goal for the entire city. While this goal was not robust enough to directly convert to norms, in the words of an official: “it is a statement, better than nothing.”

Instrumental use was most clearly affected by the relevance, accuracy and spatial resolution of the stress tests. The higher clarity of the relevance of different indicators and the threshold at which they become undesirable or unacceptable was one of the main reasons why results for extreme precipitation were much more likely to see instrumental use than results for heat stress. Sufficiently high accuracy and resolution were important to develop effective and efficient policy. Credibility, responsiveness, degree of interaction and legitimacy were also beneficial, but less clearly so. The accessibility of the results was less relevant for their instrumental use, as actors for whom instrumental use was relevant generally, though not always, had sufficient expertise to understand the complexities of the results.

Instrumental use directly affected the mainstreaming dimensions of policy goals and policy instruments. Policy frame and subsystem involvement were affected less. These dimensions instead affected instrumental use, as higher degrees of agreement on problems, roles and responsibilities facilitated the use of the stress tests in decision-making.

Conceptual use

Conceptual use involved more general learning from the stress tests. This was common for the newer themes and less common for extreme precipitation. For heat stress, respondents found the stress tests valuable for demonstrating its relevance as a policy topic and the influence of various urban planning factors on it. The results for extreme precipitation by contrast yielded comparatively few new insights. While they did sometimes show new vulnerabilities, water managers mostly felt their existing views were confirmed.

Conceptual use was strongly influenced by relevance, accessibility, credibility and the degree of interaction. Officials needed to see the general relevance of results to be motivated to study them. Accessibility was important as conceptual use often took place for topics that were new (at least for the specific official). Maps were seen as an especially understandable and helpful format because of their intuitiveness. Credibility was important as new insights needed to be believed to result in learning. The degree of interaction, especially in the form of workshops, strongly influenced learning by less involved officials. Responsiveness and legitimacy, while also beneficial, were less clearly relevant in the studied municipalities. Finally, the accuracy and spatial resolution of the results were generally not important. While some forms of conceptual use required detailed information, more global results were often sufficient.

Conceptual use primarily affected mainstreaming through the policy frame and subsystem involvement. It helped demonstrate the relevance of climate adaptation, both to the municipality as a whole and to specific subsystems whose involvement was thus stimulated. Conceptual use was generally insufficient, however, to result in strong integration of climate adaptation in policy goals and instruments. While awareness of the relevance of heat stress was for example sufficient to link it to planned spatial projects through multifunctional measures like urban green, respondents generally felt a clear strategy was lacking.

Strategic use

Officials often used the stress tests strategically to create awareness and a sense of urgency and sometimes to influence specific decisions. Strategic use to create awareness was very common and took the form of presentations, information events and dialogue with colleagues, citizens and municipal politicians. These bordered on conceptual use: while one goal was to raise awareness (by stimulating conceptual use by others), another goal was to learn more about the relevance of climate adaptation for other policy sectors and stakeholders. Use to influence specific decisions was less frequent, but also happened. Officials used and sometimes commissioned the stress tests to justify decisions they were already convinced of, such as taking measures to reduce vulnerability to precipitation, reserving time to promote climate adaptation and developing norms for new constructions (which the stress tests do not study).

Strategic use was influenced most clearly by the relevance, accessibility and credibility of the knowledge. Especially when used to raise awareness, clear relevance, easy

understandability and believability were critical. Legitimacy, while less often brought up by respondents, was also important to strategic use. The accuracy and spatial resolution of the results and degree of interaction and responsiveness of the process had less influence.

Strategic use for raising awareness affected the mainstreaming process by changing the policy frame and subsystem involvement. Respondents often considered convincing others of the importance of climate adaptation as their most important challenge. Strategic use of the stress tests to influence decisions also affected the degree to which climate adaptation was mainstreamed into policy goals and instruments. As mentioned however, this type of strategic use was less common.

Process use

In addition to these uses of the results of the stress tests, use of their process was very common. Most officials involved in the commissioning of the stress tests saw them as an opportunity not just to gain knowledge, but also to involve others and stimulate dialogue. Most stress tests included workshops in which the results were discussed with a wide range of officials. These were seen as valuable opportunity for involving people who would usually be more difficult to engage. Occasionally the process of data collection was also used as an opportunity to raise awareness, especially among citizens.

Process use is an odd duck, in the sense that it is not actual use of the knowledge provided by the stress tests. As such, the knowledge use factors are not particularly relevant to it. In the studied municipalities, the effectiveness of process use mainly appeared to depend on the intentions and efforts of the officials responsible for the stress test and the consultants.

Process use of the stress tests mainly affected the policy frame and subsystem involvement. It provided opportunities to collectively discuss the implications of climate change and adaptation for the municipality and to engage a broad range of officials, especially those who would normally not be involved. They were sometimes also used to discuss policy goals and instruments. Given the novelty of climate adaptation for most officials though, this was usually not considered practical.

Pathways Towards Mainstreaming

Taken together, these results help to identify two distinct pathways through which climate knowledge influences the mainstreaming process. As Table 3 shows, the importance of different factors for the various uses of climate knowledge differs. While relevance and to a lesser extent credibility were important to each of these uses, a clear difference can be seen between instrumental use on the one hand and conceptual and strategic use on the other. Accuracy and spatial resolution were important for many forms of instrumental use but mattered much less for most conceptual and strategic use. For these uses accessibility and the degree of interaction were critical, which for instrumental use were less relevant. Responsiveness and legitimacy were found to be generally beneficial, but of less clear importance than the other factors. As

Table 3. The relevance of the knowledge use factors for the different types of knowledge use.

	Instrumental use	**Conceptual use**	**Strategic use**	**Process use**
Relevance	++	++	++	-
Credibility	+	++	++	-
Accessibility	-	++	++	-
Accuracy	++	-	-	-
Spatial resolution	++	-	-	-
Degree of interaction	-	++	-	-
Responsiveness	+	+	-	-
Legitimacy	+	+	+	-

process use is not actual use of the knowledge provided by the stress tests, it was impacted little by these factors, instead depending more on the intention and effort of officials and consultants.

Table 4 shows how the different types of use affected the various dimensions of mainstreaming. Instrumental use had – unsurprisingly – a strong impact on the integration of climate adaptation into policy goals and instruments. It did less to promote changes in the policy frame and subsystem involvement. These were affected more by conceptual, strategic and process use. While these types of use also had the potential to impact policy goals and instruments, their effect on these dimensions was much weaker than that of instrumental use.

Thus, two pathways for knowledge use emerge. In the direct pathway, instrumental use depending on accurate, high-resolution information affected policy goals and instruments. In the indirect pathway, conceptual, strategic and process use, depending on accessibility and interaction, combined to change the policy frame and subsystem involvement. Relevance and credibility were important to both pathways. While the knowledge use factors affected the success of each pathway, which of the two predominated depended primarily on the match between adaptation problems and the policy sectors into which they were mainstreamed. Thus, in the case of extreme precipitation little change to existing policy arrangements was necessary for mainstreaming and the direct pathway dominated. Heat stress and drought fit less well into existing policy arrangements and as a result instrumental use would have been difficult even with more accurate and detailed knowledge. Instead the indirect pathway predominated, as officials attempted to make sense of the problems, their responsibilities and directions for solutions.

Table 4. The relevance of the different types of knowledge use for the four dimensions of mainstreaming.

	Policy frame	**Subsystem involvement**	**Policy goals**	**Policy instruments**
Instrumental use	-	-	+	+
Conceptual use	+	+	+/-	+/-
Strategic use	+	+	+/-	+/-
Process use	+	+	-	-

Discussion

While climate knowledge is central to climate adaptation, mainstreaming creates challenges for the effective provision and use of climate knowledge. This study set out to investigate how the provision of climate knowledge in stress tests to Dutch municipalities affects the mainstreaming of climate adaptation into municipal policy by studying the experiences of ten municipalities. The results show two distinct pathways through which use of the stress tests affected mainstreaming. In the direct pathway, instrumental use depending on accuracy and spatial resolution affected policy goals and instruments. In the indirect pathway, conceptual, strategic and process use depending on accessibility and interaction affected the policy frame and subsystem involvement. Both pathways depended on credible and relevant knowledge. Which of these two predominated depended on the degree to which an adaptation problem fit within existing policy arrangements.

In interpreting these findings, it is important to keep in mind that the studied municipalities were frontrunners. At the time of the study, most Dutch municipalities were in the process of or still had to start doing a stress test. For various reasons, ranging from previous exposure to extreme weather to personal interest, the studied municipalities were ahead of the pack in commissioning a stress test. Use of the stress tests and its effects on mainstreaming may be lower as well as different for municipalities mainly commissioning them because they are supposed to. Moreover, despite attempts to include the views of a variety of policy-makers, the results remain heavily dominated by the perspective of water managers. In understanding the (non)-use of climate knowledge, including the views of more peripheral users could prove of particular value.

That being said, the first pathway corresponds to what literature on climate knowledge use has mostly been focused on: the direct application of climate knowledge in decision-making. The factors influencing this type of use were mostly in line with the literature. Only accessibility and the degree of interaction were not found to be influential, but this may well reflect the relatively high levels of expertise and institutionalization in Dutch municipal water policy.

The second pathway has received less attention from literature on climate knowledge use but is not completely new either. In literature on research use, it is captured in stage models, in which conceptual uses of research are likely to precede and build towards instrumental uses (Nutley et al., 2007). In literature in policy integration, Candel & Biesbroek (2016) similarly argue that shifts in policy frame and subsystem involvement are often a precondition for shifts in policy goals and instruments. In this regard it is telling that the adaptation theme seeing most instrumental use, extreme precipitation, was also the one that required the least degree of mainstreaming, as it mostly fit well within a single, pre-existing policy sector.

The second pathway can be thought of as a process of determining and actively constructing the relevance of climate adaptation issues. While relevance was – unsurprisingly – found to be important to all types of knowledge use, there is a difference between relevance

for instrumental use and relevance for conceptual use. While for conceptual use it can be enough to see the relevance of a problem, for instrumental use the relevance needs to be more specifically defined, in terms of responsibilities, thresholds and potential measures. Conceptual use, especially collectively across policy sectors, helps to build this more specific relevance. This is akin to what Boezeman (2015) calls the taming of climate change: transforming it into a meaningful and 'doable' problem. Through this process, in which non-instrumental uses play a key role, instrumental use is made feasible.

Different adaptation problems require different types of knowledge use, which in turn depend on different factors. These differences matter to the effective tailoring of climate knowledge, both for the effective use of resources and because there are trade-offs between the factors. The increased complexity necessary for improvements in accuracy and resolution may well reduce the accessibility of knowledge. The differences also highlight the importance of iterativity for providing climate knowledge. Iterativity has been proposed as a key mechanism for the production of usable knowledge (Dilling & Lemos, 2011; Lemos & Morehouse, 2005). The different influencing factors and complementary values of the different types of knowledge use suggest one reason why iterativity is important may be the fact that it is crucial to incrementally building relevance for climate knowledge.

Conclusion

Research on climate knowledge use has been rapidly developing over the past decades. Most of this literature has focused on instrumental knowledge use: the direct application of knowledge to specific decisions. This study has focused on different types of knowledge use and their effects on mainstreaming. In doing so, it identified two pathways through which climate knowledge affects the mainstreaming of climate adaptation. In the direct pathway, the direct application of climate knowledge in decision-making influenced the integration of adaptation into policy goals and instruments. In the indirect pathway, conceptual, strategic and process use influenced problem perceptions and actor involvement. While this second pathway constitutes a long way around, it is a necessary detour for problems fitting poorly in existing policy arrangements.

While the first pathway corresponds to what literature on climate knowledge use has been studying, the second one has received little attention. Accounting for the diversity of ways in which knowledge is used creates additional challenges for research, but it also provides more comprehensive insight into the value climate knowledge can have. Especially when adaptation problems do not fit neatly in existing practices and institutions, doing so opens up new prospects for enhancing the use and impact of climate knowledge.

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Appendix A. Interview Guide

Below is a translation from the original interview guide in Dutch. Please note that the guide was used as a topic list suggesting a logical order, rather than as a fixed structure for the interview.

Date:
Municipality:
Respondent:

Disclaimer about recording and use of interview.

Background

Personal

- Current position in municipality

Municipal policy

- What risks does climate change cause in the municipality?
- When did these risks start to attract attention?
- Which actors are currently involved in adaptation policy?
- What are your own current activities surrounding climate adaptation?

Stress Test

Commissioning

- What were the reasons to commission a stress test?
- Who were involved in the stress tests? (e.g. consultant, internal involvement, external involvement)
- Did you have any specific requests for the consultant?

Process

- How was the contact with the consultant? (frequency, responsiveness, trust)
- Did you provide any information for the stress test?
- Was any other information used?

Results

- Did the results meet the expectations? Where there any unexpected results?
- Did you miss information? (relevance)
- Were the results understandable?
- Were the results sufficiently accurate?
- Were the results reliable/credible?

Knowledge Use

Did the results of the stress tests affect your work? Why (not)?

- Was there any direct application in policy? (instrumental use)
- Did the results change your perceptions of climate adaptation? (conceptual use)
- Did the results help to draw attention towards climate adaptation? (strategic use)

Effects on Mainstreaming Into Municipal Policy

- Did the general view of climate adaptation change within the municipality? Whose views? (policy frame)
- Did involvement increase? (contact, coordination)
- Is climate adaptation integrated into more policies? (goals, instruments)
- Are there relevant policy sectors into which adaptation is not (yet) integrated?

Potential Closing Questions

How did, in your view, the stress test affect municipal policy?

In what ways was the stress test valuable or did it lack value?

Are there any other thoughts or comments you would like voice?

Appendix B. Coding scheme

1. Knowledge transformation

Ways in which the notions of climate change and adaptation are transformed during the stress test. Due to a lack of results, this topic was later excluded from the research.

Reduction: the exclusion of aspects of climate change and adaptation, such as impacts and the time period.

Extension: the inclusion of additional aspects of climate change and adaptation.

Rhetorical packaging: arguments made for the importance of climate adaptation and trustworthiness of the knowledge.

Redefinition: changes in the core assumptions or the relations between elements of knowledge.

Modification: more minor changes in the elements or dimensions through which climate adaptation is approached.

Existing municipal knowledge: prior municipal views on climate adaptation included in the stress test.

DPRA knowledge: DPRA views on climate adaptation included in the stress test.

Other (transformation): other quotations related to the transformation of knowledge.

2. Use factors: output factors

Factors related to the results of the stress tests.

Relevance: perceptions of the salience and usefulness of the results.

Accessibility: perceptions of the understandability and usability of and access to the results.

Credibility: perceptions of the credibility of the results, including their reliability.

Accuracy: the accuracy of the results, including their spatial resolution.

Temporal (mis)match: the timescale of the results.

Knowledge gaps: missing knowledge which is perceived as important.

Uncertainty: uncertainties in the results.

Other (output): other quotations related to output factors.

3. Use factors: process factors

Factors related to the process of the stress test.

Degree of interaction: the amount of interaction between the stress test providers and municipal policy-makers

Responsiveness: the perceived responsiveness of the providers to the needs and wishes of the municipality

Legitimacy: belief that the provider's conduct has been unbiased and fair.

Commissioning: context in which the stress test was commissioned, such as the number of external actors involved, the reason for commissioning it and specific questions.

Involved actors: involvement of internal actors in the stress test.
Other (process): other quotations related to process factors.

4. Knowledge use

Different types of use of the stress test.

Instrumental use: direct application of results in decision-making.
Conceptual use: changes in perceptions about (aspects of) climate adaptation, including awareness.
Strategic use: use of results to justify or undermine decisions or raise awareness.
Process use: use of the process of the stress test rather than its results.
Other (use): other quotations related to knowledge use.

5. Mainstreaming

Effects on and state of the integration of climate adaptation into municipal policy.

Policy frame: effects on perceptions of climate adaptation, including its relevance for actors' own work and its need for integrated governance.
Subsystem involvement: effects on the involvement of actors from different policy fields and the density of their interactions.
Policy goals: integration of climate adaptation in policy goals, including the range of policies, their coherence and the existence of an overarching strategy.
Policy instruments: integration of climate adaptation in policy instruments, including the range of policy instruments, their consistency and the existence of procedural instruments for coordination and monitoring.
Other (mainstreaming): other quotations related to mainstreaming.

6. Other

Subsequent research: subsequent research which has been undertaken or is planned.
External involvement: subsequent involvement of external actors (e.g. water board, province)
Knowledge gaps: current lack of knowledge for the mainstreaming of climate adaptation.
Other: anything noteworthy not directly related to the codes above.