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# Urban water management and climate change adaptation: A self-assessment study by seven midsize cities in the North Sea Region

Gül Özerol[a], Nanco Dolman[b], Helge Bormann[c], Hans Bressers[a], Kris Lulofs[a], Mike Böge[c]

[a] University of Twente, Enschede, The Netherlands
[b] Royal HaskoningDHV, Amsterdam, The Netherlands
[c] Jade University of Applied Sciences, Oldenburg, Germany

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ABSTRACT

Cities are experiencing the impacts of climate change through water-related disasters, while the sustainable management of water resources remains crucial for urban climate resilience. Accordingly, frameworks that integrate urban water management with climate change adaptation become increasingly relevant. The Water Sensitive Cities (WSC) framework is built on three pillars that address cities' role as communities and networks, water catchments, and providers of ecosystem services. A major element of the framework is the WSC index, which can be applied to assess cities by using multiple indicators under each pillar. With the objectives of adjusting and testing the WSC index in the context of the North Sea Region through a transdisciplinary knowledge co-production process, this paper presents the results from a self-assessment conducted by seven midsize cities. Insights gained from the comparison of self-assessment results are twofold. Firstly, the cities need to value the benefits of ecosystem services for climate change adaptation, and integrate climate change into other sectors. Secondly, the cities differ regarding the priority of climate change, and even the cities that aspire to be frontrunners have weaknesses. The application of the self-assessment process also creates an exchange and mutual learning platform for cities, and increases their awareness on climate resilience.

## 1. Introduction

Many cities lack the capacity to cope with climate extremes such as droughts, floods and heatwaves (Ferguson, Frantzeskaki, & Brown, 2013; WWAP World Water Assessment Programme, 2017; Leal Filho et al., 2019). In Europe, more frequent and heavier droughts, rainfalls and heatwaves are forecasted or already observable as clear indications of climate change (IPCC, 2014; Smaniotto Costa et al., 2015; Guerreiro, Dawson, Kilsby, Lewis, & Ford, 2018), pushing cities to take action towards adaptation (Carter, 2011). Increases in the frequency and severity of heavy rainfalls, floods, droughts and heatwaves create insurmountable pressure on the quality and quantity of urban water resources in most European countries (Georgi et al., 2016). In the NSR, longer periods of droughts are expected to lead to fluctuating groundwater levels that can damage buildings and ecosystems, whereas droughts and heatwaves can also endanger the quality of urban waters (Quante & Colijn, 2016). Besides climate change, the growing urban populations put an increasing pressure on water resources, since urban areas are one of the main consumers as well as polluters of water globally (WWAP World Water Assessment Programme, 2017), and specifically in Europe (Georgi et al., 2016). Aging water infrastructure, especially the sewage systems, poses another challenge for European cities (Barraque, Isnard, & Souriau, 2017; Pot, 2019). Lastly, the uneven distribution of the effects of climate change poses a challenge for the cities to protect all sections of their communities, especially vulnerable groups such as the elderly, children, women and minorities (Carter et al., 2015; Foster et al., 2019). Although the importance of protecting the vulnerable groups is recognized in European climate adaptation policies (EEA, 2019), the current practice tends to put the burden on individual citizens, for instance through private insurance mechanisms (O'Hare, White, & Connelly, 2016).

One way of dealing with these challenges is implementing physical measures, such as increasing the capacity of the sewage system or the heights of dykes. However, these hard measures also have hard limits given the fact that they often require large-scale investments, which can be financially infeasible, and that multiple utilities, such as water, electricity and gas, have to compete for underground space that is needed for physical infrastructure. Therefore, cities tend to combine multiple measures for climate change adaptation. These measures can include both hard measures, such as green urban spaces, and soft measures, such as incentivizing citizens towards adaptive behaviour (Belmeziti, Cherqui, & Kaufmann, 2018; Sussams, Sheate, & Eales, 2015; Wamsler, 2017). Such measures also build on the notion that cities provide ecosystem services, such as rainwater drainage and recreational values (Bolund & Hunhammar, 1999; Lovell & Johnston, 2009).

In the previous decade, the concept of resilience has become increasingly prominent in addressing climate change adaptation in urban

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areas (Brown, Dayal, & Rumbaitis Del Rio, 2012; Junghans, Kreft, & Welp, 2018; Leichenko, 2011; Meerow, Newell, & Stults, 2016; Ribeiro & Gonçalves, 2019; Stead, 2014). Further, Tyler and Moench (2012) coined the term 'urban climate resilience', which they define based on three elements: systems, agents, and institutions. A resilient urban system is characterized by being flexible to function under different conditions; modular to replace certain parts when needed; and able to absorb sudden shocks and failures. Agents, or actors, of the urban system should be responsive to organize themselves; resourceful by having access to financial or other assets; and have the capacity to learn from past experiences and acquire new skills. Institutions link the systems and agents, provide information on property and use rights, and risks and vulnerabilities, and facilitate the generation, exchange and application of new knowledge. Leichenko (2011) describes three key attributes of urban resilience in the context of climate change. Firstly, climate change is one of many stresses and shocks that cities experience, and its effects often occur in combination with other stresses and shocks, such as population growth and migration, to which the cities should also be resilient. Secondly, a resilient city should demonstrate multiple characteristics, such as flexibility, diversity, adaptive governance, and capacity for innovation and learning. Thirdly, efforts to foster urban resilience should be integrated with broader development plans.

Policies, strategies and actions towards urban climate resilience require a co-production process that involves stakeholders from the public and private sectors, civil society and academia (Muñoz-Erickson, Miller, & Miller, 2017). Wamsler (2017) identifies six steps for such a process: 1) Set-up and starting point of the process, 2) Assessing existing knowledge and the risk context, 3) Identifying potential adaptation options, 4) Selecting adaptation options, 5) Designing the implementation, 6) Designing monitoring, evaluation and learning. A similar concept was described by Bormann et al. (2015) for climate change adaptation in coastal areas. All six steps require bringing together the efforts, capacities and knowledge from different types of stakeholders. This paper focuses on the second step, which forms the foundation of the subsequent steps by identifying the current status of cities, as well as their weaknesses and strengths.

Despite the lack of integrated tools and frameworks to assess urban resilience (c.f. Ribeiro & Gonçalves, 2019; Marana et al., 2019), several approaches that focus on water management and governance have been developed in recent years. These approaches often build on other existing concepts, such as Integrated Water Resources Management (IWRM), Integrated Urban Water Management (IUWM) and Water Sensitive Urban Design (WSUD). For instance, the 'City Blueprint' approach brings together three frameworks (Koop & van Leeuwen, 2015): 1) *The Trends and Pressures Framework* assesses the environmental, financial, and social challenges, on which cities often have no influence. 2) *The City Blueprint Framework* analyses the performance and bottlenecks of IWRM and IUWM, and includes indicators on water services, wastewater treatment, infrastructure, water quality, solid waste treatment, climate robustness and governance. 3) *The Governance Capacity Framework* assesses the status of governance through three categories, namely knowing (awareness, useful knowledge, and continuous learning), wanting (stakeholder engagement, policy ambition, and agents of change), and enabling (multi-level network potential, financial viability, and implementing capacity). By elaborating on specific strengths and weaknesses in multiple water-related (sub)sectors, the City Blueprint approach provides insights into the implementation of IWRM and IUWM in practice.

Another water-oriented approach to urban resilience is the Water Sensitive Cities (WSC) framework (Brown, Rogers, & Werbeloff, 2016; Chesterfield et al., 2016; Wong & Brown, 2009). This framework builds on IUWM and WSUD to integrate the governance, infrastructure and ecosystems dimensions of urban design and resilience under three principles, or "pillars", of action: 1) *Cities as water sensitive communities and networks*: The implementation of integrated solutions requires improved perception of the benefits from decision makers, businesses and the public across multiple levels of governance. This makes collaboration a key requirement. 2) *Cities as water catchments*: The urban water system is often part of a larger water catchment, and the intensive exploitation of the urban landscape results in the decrease of the natural water system to the detriment of the surrounding region. 3) *Cities as ecosystem service providers*: Water resources and infrastructures in urban areas serve multiple purposes and functions, providing ecosystem services. These three principles originate from the 'ecopolis model', which was developed to link sociology to urban planning and to ecology by understanding (Dolman, Savage, & Ogunyoye, 2013; Tjallingii, 1996): 1) *the participating city* – management of actors, 2) *the living city* – sustainable urban areas, and 3) *the responsible city* – sustainable flow management, such as energy, water, waste and traffic. A major element of the WSC framework is WSC index, which consists of seven goals towards becoming a WSC and a total of 34 indicators under these seven goals (Chesterfield et al., 2016).

Lastly, the 'Water Wise Cities' concept builds on four principles that are aligned with the pillars of the WSC framework (IWA, 2016: 1) *Regenerative water services for everyone*: Public health and all current needs are met, while the water quality and quantity are ensured for future needs by producing and using water, energy and materials in an efficient way. 2) *WSUD*: Urban planning is integrated with the protection, conservation, and management of the total urban water cycle. 3) *Basin-connected cities*: Water, food and energy is secured; flood risks are reduced; and activities which contribute to economic health are enhanced. This is reached by connecting the city to a basin. 4) *Water-wise communities*: Key types of actors, i.e., citizens, professionals, policy makers and leaders, behave in a water-wise way. This implies that the actors realise their role in a way to follow the previous three principles.

As seen from the above review, the scientific and grey literature offers several tools and frameworks to support cities in assessing their strengths and weaknesses at the intersection of water management and climate change adaptation, and in improving their resilience. These tools and frameworks often address the needs and characteristics of large cities, which are also the frontrunners of climate change adaptation, and not those of midsize cities, which have a population between 20.000 and 200.000 (Kunzmann, 2009) The applicability of such tools and frameworks in midsize cities is not warranted, given that midsize cities have specific characteristics that differentiate them from large cities (Brown et al., 2012; Junghans et al., 2018; Van der Heijden, 2019). Compared to large cities, the midsize cities have lower number of inhabitants, a smaller geographic scale, less resources available for strategic processes, and a larger connection with and dependency on their surrounding regions and partners (Gonzalez, 2012). With regards to climate resilience, midsize cities face the following specific challenges as compared to large cities (Birkmann, Welle, Solecki, Lwasa, & Garschagen, 2016; Böge et al., 2019; Dolman et al., 2018; Kunzmann, 2009; Özerol et al., 2019):

- A lack of expertise in dealing with climate challenges in an integrated manner,
- Insufficient human resources to develop and implement a comprehensive climate change adaptation strategy,
- Low budget and few opportunities to make large investments for climate change adaptation and mitigation,
- Limited benefit from climate-related research programs and funding,
- Less autonomy due to dependency on or limitations by upper governance levels.

Considering the specific challenges of midsize cities, tailor-made tools are necessary to support cities in making decisions to improve their climate resilience. However, to our knowledge, no such tools exist for midsize cities. By bridging this knowledge gap, the paper aims to create insights from the development and application of a tailor-made tool for midsize cities based on the pillars and indicators of the WSC

**Table 1**
Overview of CATCH partner cities and pilot measures.

| City | Country | City area [km$^2$] | Population | Pilot measure |
|---|---|---|---|---|
| Herentals | Belgium | 39 | 27.000 | Designing a green-blue area in a city development area |
| Vejle | Denmark | 144 | 55.000 | Redesign of a playing field for water storage during heavy rainfall |
| Oldenburg | Germany | 103 | 164.000 | Traffic information for road users during heavy rainfall |
| Enschede | The Netherlands | 143 | 158.000 | 'Pinkeltjes Square' - stepping stone in the restoration of a city brook |
| Zwolle | The Netherlands | 119 | 124.000 | Developing a community building strategy and serious game |
| Arvika | Sweden | 11 | 14.000 | Constructed wetlands to reduce the effect of climate change on water quality |
| Norwich | UK | 49 | 140.000 | Community-led technological solutions for flood protection in the city |

framework. As explained further in the next section, the data from CATCH, a collaborative project that is being implemented in the North Sea Region (NSR), is used for this purpose. Among the approaches available in the literature, the WSC framework was chosen to develop the tool. Three features of the WSC framework make it appealing to apply in the NSR context. Firstly, the WSC framework adopts a long-term perspective by taking into account the historical development of urban water management, which is crucial for the forward-looking cities involved in the CATCH project. Secondly, the focus on a desired future as inspiration helps cities in assessing their current situation and developing a climate adaptation strategy, which are also among the objectives of the CATCH project. Thirdly, the pillars and the indicators of the WSC framework provide the cities with a comprehensive view of their water system from political, social, hydrological and ecological perspectives. The WSC index has been developed and applied mostly in Australian cities, which have different climatic conditions and governance structures than the cities in the NSR. Therefore, the application of the WSC index in the NSR requires adjustments considering the availability of water resources, as well as the needs of midsize cities in terms of climate change adaptation. Such adjustments include a larger focus on heavy rainfall events and floods that are forecasted in regional assessments (Quante & Colijn, 2016; Verhofstede et al., 2011). The insights expected from the development and application of the tool are twofold. Firstly, through the assessment by the cities, contextualized knowledge will be co-produced on the current status of midsize cities in the NSR at the intersection of urban water management and climate change adaptation. This knowledge can be useful for midsize cities in making water management decisions that can improve their climate resilience Secondly, the comparison of seven cities will create a nuanced understanding of the similarities and differences between midsize cities in terms of their complex characteristics regarding water management and climate change adaptation. Given the knowledge gaps in urban climate governance regarding medium-N studies and studies that focus on mid-size cities (Van der Heijden, 2019), these insights can guide other midsize cities in the NSR region and beyond in identifying their own strengths and weaknesses regarding climate resilience.

The outline of the paper is as follows: Section 2 describes the background of the CATCH project, and the knowledge co-production process that was followed for developing and applying a self-assessment tool based on the WSC index. Section 3 presents the results of the self-assessment conducted by each city and compares them across the three WSC pillars. Section 4 closes the paper with a discussion of the results and conclusions, as well as future research directions.

## 2. Materials and methods

### 2.1. Background of the CATCH project

CATCH (water sensitive Cities: the Answer To CHallenges of extreme weather events) is a project that is being implemented between 2017 and 2020 within the scope of the EU Interreg NSR Programme. The main goal of the project is to develop and apply an integrative, online decision support tool (DST), which includes the self-assessment as the first of its four components. The DST is tailored to the characteristics and needs of midsize cities and can assist them in making the right strategic decisions and formulating their climate adaptation strategies. For this purpose, a transdisciplinary project team has been established by 'practice' and 'knowledge' partners from six NSR countries: Belgium, Denmark, Germany, the Netherlands, Sweden, and the United Kingdom. The practice partners are four local authorities (Zwolle Municipality, Enschede Municipality, Arvika Municipality, Norfolk City Council) and five regional authorities (Värmland County, Province of Overijssel, Water Authority Vechtstromen, Flanders Environmental Agency, Oldenburg and East Frisian Water Association), whereas the knowledge partners, also called the 'DST team', include two universities (Jade University of Applied Sciences from Germany and the University of Twente from the Netherlands) and a subject matter expert from an international consultancy firm (Royal HaskoningDHV).

As shown in Table 1, seven pilot climate adaptation measures are being implemented within the scope of the CATCH project. The cities where the pilot measures are located have been experiencing the impacts of climate change, such as heavy rainfall, increasing frequency and intensity of floods, heat stress and water quality problems. These common experiences of climate change impacts constitute a key motivation for the partner cities to implement pilot measures that provide practical insights in whether and why different climate adaptation actions work in practice, and to learn from each other by collaborating in multinational projects such as CATCH.

### 2.2. Co-production of the self-assessments

For conducting the self-assessment, the project team followed a knowledge co-production process, which adopted a transdisciplinary approach by actively involving academic and non-academic participants throughout the research process (Muñoz-Erickson et al., 2017). Such an approach also entails multiple methods, such as field trips, workshops and office visits for eliciting the multiple types of knowledge possessed by different types of stakeholders and enhancing the ownership of different stakeholders. Drawing on Bracken, Bulkeley, and Whitman (2015), co-production of knowledge within the scope of the CATCH project implies a constant emphasis on the understandability and applicability of knowledge by adjusting the research process to the needs and realities of the practitioners, encouraging them to question the ideas or concepts that are raised in relation to the project and promote their own knowledge, and finally following an iterative process that all partners can learn from each other and develop a common understanding.

Midsize cities in the NSR possess several characteristics that call for paying attention to their specific needs in terms of adapting to climate change. As also experienced by the CATCH partner cities, the authorities responsible for climate change adaptation often lack the capacity in terms of personnel and funds. At the same time, the pressure to deal with climate change is urgent due to the increasing impacts of extreme weather events. With this trade-off between capacity and urgency, the midsize cities need tools that are both easy to use and appealing to create awareness and dialogue among stakeholders. Despite their commonalities, such as being in high-income and politically stable countries, the midsize cities of the NSR have different social, climatic and geographic conditions. Therefore, a common 'language' is necessary that can be used both to communicate about climate change adaptation in NSR cities and to establish a joint basis for tailored-made adaptation strategies for midsize cities. This language starts with developing a joint set of indicators that the practitioners can use to assess the vulnerabilities and strengths of their water system in addressing climate change adaptation.

The project team co-produced the self-assessments by using the WSC framework as a conceptual basis and applying three collaborative methods: partner visits, partner meetings, and document reviews. From each practice partner, at least two participants, who were responsible for water management and/or climate adaptation actions in their organization, contributed to the planning and conducting the partner visits and partner meetings. As explained further below, these experts were also interviewed during the partner visits; contributed to the development of the indicator set; and carried out the scoring of the indicators.

Partner visits took place between January and September 2018. The DST team visited each city in order to acquire a complete understanding of the past and current water management and climate change adaptation practices in CATCH partner cities, to familiarise with the characteristics of the cities and the pilot measures, which are implemented within the scope of the CATCH project, and to collect data for identifying the specific needs of the partner cities. The visits consisted of interviews and excursions. Standard guidelines were used to shape the agenda of visits and the scope of interviews (Please see Appendix A for the partner visit guidelines, and Appendix B for interview questions). As summarized in Table 2, a total of 49 respondents were interviewed, including representatives from CATCH partners as well as other stakeholders, such as regional authorities, housing organizations, private companies and non-governmental organizations. The practice partners decided on the type and number of the interviewees depending on their involvement in water management and/or climate adaptation actions. During each partner visit, the host partner also organized an excursion that included a visit to the pilot site and other locations in the city, which were considered important for water management and/or climate change adaptation. The interviews and excursions provided additional perspectives that helped creating a complete picture of the current status of each city and their pilot measure.

Four partner meetings were held between November 2017 and September 2018. These meetings were attended by one to three representatives from each project partner and aimed to create a collaborative, transdisciplinary platform to co-produce the self-assessments and elaborate on the overall progress with the project. During each partner meeting at least one session was dedicated to the WSC framework and self-assessments. Before the second and third partner meetings, which respectively took place in March 2018 and June 2018, the practice partners prepared their reflections on the self-assessment, such as the availability of data to assess the indicators, the relevance of the indicators for their city and pilot measure, the difficulty level of the indicators, the usefulness of the indicators in emphasizing their key concerns, etc. Each practice partner presented their inputs during the partner meetings, and further discussed in plenary sessions and dedicated workshops. Partner meetings also provided the practice partners with the opportunity to explain, justify and adjust the scores that they gave for the self-assessment indicators.

To enrich and verify the data collected by partner visits and meetings, the knowledge partners also examined documents, such as practice partners' reports, policy papers, regulations, and reports from earlier projects. These documents helped to generate a comprehensive overview of the policy and practice about climate change adaptation and urban water management in the partner cities, and more broadly in the NSR. As presented in Section 1, publications from peer-reviewed and grey literature were also examined. When adjusting the WSC indicators to the NSR conditions, relevant policy documents such as the EU Water Framework Directive (EC, 2000) and the EU Floods Directive (EC, 2007) were taken into account in terms of their requirements in cities and the implications of these requirements on the pillars of the WSC framework.

### 2.3. Self-assessment indicator set

Within the scope of the WSC index, 'benchmarking' refers to a process and a tool for identifying the vulnerabilities and strengths of cities across the three pillars of the WSC framework (Chesterfield et al., 2016). Due to the understanding that benchmarks are often used for ranking according to scores, CATCH partners and the project advisory group, which includes international experts from the NSR, raised concerns about the usefulness of the term 'benchmarking'. In order to emphasize the knowledge exchange that is created among the project partners and with broader audiences, and upon the recommendation of the advisory group, the project team decided to use the term 'self-assessment' instead of 'benchmarking'. Since this decision was made in the second year of the project, several project documents, such as the guidelines for partner visits (Appendix A) refer to 'benchmarking'.

The indicators included in the WSC index (Chesterfield et al., 2016) were used as the starting point to develop the self-assessment indicators tailored for the NSR conditions. The knowledge partners prepared a draft set of indicators, which was reflected upon by the practice partners in three rounds:

1 Practice partners evaluated the potential indicators in terms of clarity, relevance and data availability. Based on this information, the knowledge partners narrowed down the list of indicators for each of the three WSC pillars, and they prepared a draft scoring scheme.
2 Each practice partner scored the indicators and made a draft assessment, using the scoring scheme, and they identified reflections in terms of the added value of each indicator. During the second and third partner meetings, the partners met discussed the possible gaps and issues with the scoring of the indicators. Using the input from

**Table 2**
Overview of interviews conducted during partner visits.

| City | Interviewed stakeholders | Number of interviewees |
|---|---|---|
| Zwolle | Zwolle Municipality, Province of Overijssel, Water Authority WDO Delta, Bouwfonds Property Development | 11 |
| Enschede | Enschede Municipality, Water Authority Vechtstromen, Domijn Housing Corporation, University of Twente | 5 |
| Oldenburg | Oldenburg and East Frisian Water Association, Regional Development Office Weser-Ems, Departments of the Oldenburg Municipality (Nature Conservation and Environmental Protection; Urban Development and Land Use Planning; and Traffic Control) | 6 |
| Norwich | Norfolk City Council, National Flood Forum, and two households affected by recent floods | 6 |
| Vejle | Vejle Municipality, Wastewater Company, ØsterBo Housing Association, EnviDan Consulting and Engineering Company, Chief Resilience Officer | 8 |
| Arvika | Arvika Municipality, Värmland County, the church that owns the land of the pilot measure, two local politicians | 9 |
| Herentals | Herentals Municipality, Flanders Environmental Agency, Heritage Agency, Province of Antwerp, Municipal Commission of Spatial Planning | 8 |

**Table 3**
Steps of the self-assessment process conducted by CATCH partners.

| No. | Description of the step | Timing |
|---|---|---|
| 0 | Knowledge partners present the WSC framework; practice partners make first estimations about their positioning on the three pillars | During the 1 st partner meeting (November 2017) |
| 1 | Knowledge partners develop a draft set of indicators for the NSR based on the WSC index | Between the 1 st and 2nd partner meetings |
| 2 | Practice partners provide input on the draft set of indicators in terms of clarity, relevance and data availability | |
| 3 | Knowledge partners narrow down the set of indicators based on the inputs of practice partners and prepare the scoring scheme | |
| 4 | Practice partners carry out an initial scoring and reflect on indicator descriptions | |
| 5 | Practice partners present the initial results of self-assessment, and all partners identify the gaps and issues to be addressed | During the 2nd partner meting (March 2018) |
| 6 | Knowledge partners finalize the scoring scheme and share with the practice partners | Between the 2nd and 3rd partner meetings |
| 7 | Practice partners reach an internal consensus regarding indicator scores and the justification of scores | |
| 8 | Practice partners present their self-assessment results and discuss with all partners | During the 3rd partner meeting (June 2018) |
| 9 | Practice partners finalize self-assessment scores | Before the 4th partner meeting (September 2018) |

these discussions, the knowledge partners finalized the list and descriptions of the indicators.

3 In consultation with the knowledge partners, each practice partner finalized the scoring of the indicators. Practice partners presented their scores and final reflections during the fourth partner meeting.

Table 3 summarizes the steps of the self-assessment process. Steps 4–9 of the process will be repeated in 2020, i.e., towards the end of the CATCH project, in order to assess the possible improvement of partner cities on the WSC index as a result of the implementation of pilot measures.

All CATCH practice partners used a common set of indicators to carry out the self-assessment. To develop the list of indicators in each pillar and to assign the indicator scores, all the indicators included in the WSC index were used as the starting point and a co-production process was carried out by the practice partners. The key principle behind this process was to develop a set of indicators that the practice partners considered relevant for their city and pilot measure, and they also had the necessary data and expertise to assess the indicator. The final list of self-assessment indicators is presented in Table 4 and the detailed self-assessment scoring scheme is provided in Appendix C.

The project team considered adding city-specific indicators to take into account the local context of the pilot measures, most of which were being implemented in a single neighbourhood or a district. However, since the pilot measures are very different from each other, the effort for developing such specific indicators was not seen as worthwhile by the partners, and thus such indicators were not developed. Furthermore, using a common set of indicators ensured that each partner city compared itself to the three pillars of the WSC framework, and enabled identifying comprehensive mutual exchange and learning opportunities across seven cities.

For scoring the indicators, a numerical scale from 1 to 5 was used, where 1 implied an extremely negative judgment (undesired level), and 5 indicated an extremely positive judgment (desired level). Each score has a description, for which a draft text was proposed by the knowledge partners and finalized through deliberation with the practice partners. These descriptions guided the practice partners to provide their own scoring. Whenever quantitative data was available, the indicator descriptions were quantified according to that data. For instance, regarding the indicators C3.2, C3.3 and C3.4, the data that had to be collected according to requirements of the EU Water Framework Directive (EC, 2000) were used to score the indicators. Similarly, the indicator C2.1 was scored according to the data available due to the requirements the EU Floods Directive (EC, 2007). As the nature of most indicators is more qualitative than quantitative, most of the scores are inevitably informed and reasoned judgments of the practice partners

**Table 4**
Self-assessment indicators for midsize cities in the NSR.

| WSC pillar | Code | Indicator title |
|---|---|---|
| Cities as water sensitive communities and networks | C1.1 | Organizational capacity for climate adaptation at the city level |
| | C1.2 | Water as a key element in city planning and design/redesign |
| | C1.3 | City-level integrative arrangements across sectors |
| | C1.4 | Stakeholder participation in water and climate adaptation at the city level |
| | C1.5 | Leadership, long-term vision and commitment by the city-level administration |
| | C1.6 | Level of flood risk awareness of the population |
| | C1.7 | Organisation of emergency management |
| | C1.8 | Regulations to reduce potential flood damage in the city |
| Cities as water catchments | C2.1 | Availability and use of flood hazard and flood risk maps for areas at risk |
| | C2.2 | Areas to temporally store water in the city without expected damage |
| | C2.3 | Measures to increase infiltration |
| | C2.4 | Status of infrastructure for water supply |
| | C2.4.1 | Maintenance of infrastructure for water supply |
| | C2.5 | Status of infrastructure for wastewater |
| | C2.5.1 | Maintenance of infrastructure for wastewater |
| | C2.6 | Status of infrastructure for flood protection |
| | C2.6.1 | Maintenance of infrastructure for flood protection |
| Cities as ecosystem services providers | C3.1 | Attention to the needs and protection of vulnerable groups |
| | C3.2 | Healthy and biodiverse habitat |
| | C3.3 | Protection of surface water quality and flow regime |
| | C3.4 | Protection of groundwater quality and groundwater levels |
| | C3.5 | Activation of connected urban green and blue space |
| | C3.6 | Vegetation coverage at the city level |

and their stakeholders. Nevertheless, the final scoring of each indicator could be justified by the descriptions that are provided for each score and the additional reasoning made by the practice partners, whenever possible, and all partners were aware of the subjectivity of the scores. Several practice partners reflected on this during the scoring process, for instance by highlighting the areas where they can collect data in the future to quantify the scores in a more objective way. Given the common understanding that the scores would not be used to compare the cities' success or performance, the partner cities mainly used the scoring process to diagnose their status and learn from each other's weaknesses and strengths on the multiple dimensions of urban climate resilience.

In order to reach an average score for each indicator and pillar, a decision had to be made regarding the weights of the indicators. The option of using different weights for different cities and/or pilot measures was considered to reflect the relative importance of the pillar for different CATCH partners. However, it was concluded that such a weighing would complicate the justification of indicator weights and final scores. Therefore, equal weights were used for all indicators.

## 3. Results

By going through the co-production process explained in the previous section, the self-assessment scores of the seven CATCH partner cities were calculated and analysed. We present the results of these self-assessments, first for each city, and then at the overall level for each WSC pillar. The score for each indicator represents the final value provided by the corresponding practice partner of the given city. Table 5 presents the overview of the scores. In line with the preference of the partners, the names of the cities are anonymized.

### *3.1. City-level self-assessments of WSC indicators*

#### *3.1.1. City A*

City A made diverse assessments for 21 indicators, while they preferred not to assess two indicators: C2.1 (*Availability and use of both flood hazard and flood risk maps for areas at risk*), and C2.6.1 (*Maintenance of infrastructure for flood protection*). The reason for not assessing the indicator on flood hazard and flood risk maps was that City A is not identified as a high-risk flood area by the national authority that is responsible for the EU Flood Directive, although the city experienced a severe flood in year 2000. Among the three pillars, the city assessed the pillar on ecosystem services as the weakest, especially regarding indicator C3.3 (*Protection of surface water quality and flow regime*), which was scored with 1. The other two pillars were assessed relatively higher, with many scores of 3 and 4, while one indicator, C1.6 (*Level of flood risk awareness of the population*) was scored with a 5, which is attributed to the flood in 2000 and the subsequent construction of a flood barrier.

#### *3.1.2. City B*

Similar to City A, City B scores relatively better in the first two pillars, with lower scores in the pillar on ecosystem services. Three indicators in this pillar were scored with a 2, namely C3.1 (*Attention to the needs and protection of vulnerable groups*), C3.4 (*Protection of groundwater quality and groundwater levels*), and C3.5 (*Activation of connected urban green and blue space*). The city didn't give a specific score to the indicators C3.2 (*Healthy and biodiverse habitat*) and C3.3 (*Protection of surface water quality and flow regime*), as they differed in different parts of the city and also in the outer areas of the city. The only indicator that was scored with a 5 is C2.1 (*Availability and use of both flood hazard and flood risk maps for areas at risk*), demonstrating that the city has up-to-date flood hazard and risk maps, which are published and regularly used for decision making processes.

#### *3.1.3. City C*

The self-assessment results of City C are consistent with City A and B given the relatively lower scores for the pillar on ecosystem services. City C assessed two indicators in this pillar with a score of 1. These indicators are C3.1 (*Attention to the needs and protection of vulnerable groups*), and C3.3 (*Protection of surface water quality and flow regime*). Among the indicators in the other two pillars, only one indicator, C1.6 (*Level of flood risk awareness of the population*) was assessed with a score of 2, which is attributed to the fact that there is no data on public awareness, but at the same time there have been no major floods in City C. The remaining scores range between 2.5 and 4. Similar to City D and City E, the city of City C didn't assess any of the indicators with a score of 5, indicating being receptive to improvement in all the indicators.

**Table 5**
Overview of the self-assessment scores of CATCH partner cities.

| *Code* | *City A* | *City B* | *City C* | *City D* | *City E* | *City F* | *City G* | *Average/indicator* | *Average/pillar* |
|---|---|---|---|---|---|---|---|---|---|
| C1.1 | 3 | 4 | 3 | 3 | 3 | 4.5 | 3 | 3.36 | 3.42 |
| C1.2 | 3 | 4 | 3.5 | 2 | 2 | 4 | 4 | 3.21 | |
| C1.3 | 3 | 4.5 | 3 | 3 | 3 | 4 | 3 | 3.36 | |
| C1.4 | 4 | 5 | 3 | 3 | 2 | 4.5 | 3 | 3.50 | |
| C1.5 | 3 | 3.5 | 3.5 | 2 | 2 | 4 | 4 | 3.14 | |
| C1.6 | 5 | 3.5 | 2 | 3 | 3 | 4 | 4 | 3.50 | |
| C1.7 | 4 | 2.5 | 3.5 | 3 | 4 | 5 | 5 | 3.86 | |
| C1.8 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3.43 | |
| C2.1 | NA | 5 | 4 | 4 | 2 | 4 | 5 | 4.00 | 3.65 |
| C2.2 | 3 | 3 | 3 | 3 | 1 | 3 | 4 | 2.86 | |
| C2.3 | 3 | 4 | 2.5 | 3 | 3 | 3.5 | 5 | 3.43 | |
| C2.4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 4.29 | |
| C2.4.1 | 4 | 4 | 3.5 | 3 | 4 | 5 | 5 | 4.07 | |
| C2.5 | 4 | 4 | 3.5 | 3 | 4 | 4 | 5 | 3.93 | |
| C2.5.1 | 4 | 4 | 3 | 3 | 4 | 4 | 5 | 3.86 | |
| C2.6 | 4 | 4 | 4 | 3 | 1 | 3 | 3 | 3.14 | |
| C2.6.1 | NA | 3 | 4 | 3 | 1 | 3.5 | 5 | 3.25 | |
| C3.1 | 4 | 2 | 1 | 3 | 2 | 4 | 2 | 2.57 | 2.88 |
| C3.2 | 2 | NA | 3 | 3 | 1 | 3.5 | 3 | 2.58 | |
| C3.3 | 1 | NA | 1 | 3 | 3 | 4.5 | 3 | 2.58 | |
| C3.4 | 4 | 2 | 3 | 3 | 3 | 5 | 4 | 3.43 | |
| C3.5 | 4 | 2 | 3.5 | 3 | 4 | 3 | 4 | 3.36 | |
| C3.6 | 2 | 3 | 2 | 3 | 2.5 | 2 | 5 | 2.79 | |

### 3.1.4. City D

The pattern of the self-assessment scores of City D differs from most of the other CATCH cities. Overall, all three pillars were assessed with similar scores, most of them with a score of 3. Two indicators in the pillar on communities and networks were scored with a 2, namely C1.2 (*Water as a key element in city planning and design/redesign*) and C1.5 (*Leadership, long-term vision and commitment by the city-level administration*). These low scores for both indicators demonstrate a clear lack of attention to water and climate change adaptation at the city level. The highest scores were 4, which was given only to two indicators, namely C2.1 (*Availability and use of both flood hazard and flood risk maps for areas at risk*) and C2.4 (*Status of infrastructure for water supply*).

### 3.1.5. City E

City E assessed all three pillars with a diverse range of scores, having similar scores for all three pillars, with the third pillar having slightly lower scores. The city scored four indicators with a score of 1, two of which were assessed at the city level, i.e., C2.2 (*Areas to temporally store water in the city without expected damage*) and C3.2 (*Healthy and biodiverse habitat*), and two at the pilot level, i.e., C2.6 (*Status of infrastructure for flood protection*), and C2.6.1 (*Maintenance of infrastructure for flood protection*). These scores demonstrate ample room for improving the water storage capacity and the habitat. On the other hand, the low scores for the two indicators on flood protection infrastructure are attributed to the problems with flood protection from rainfall, which is also the core of the CATCH pilot measure in City E.

### 3.1.6. City F

The self-assessment pattern of City F is also diverse, given its scores that range between 2 and 5. Similar to most other cities, City F scored low in the pillar on ecosystem services, although its scores are relatively higher in other pillars. No indicators were scored with a 1, and only one indicator was scored with a 2, namely C3.6 (*Vegetation coverage at the city level*), which is also in the pillar on ecosystem services. For each pillar, City F scored at least one indicator with a 5, having a total of four indicators scored with 5. These four indicators are C1.7 (*Organisation of emergency management*), C2.4 (*Status of infrastructure for water supply*), C2.4.1 (*Maintenance of infrastructure for water supply*) and C3.4 (*Protection of groundwater quality and groundwater levels*).

### 3.1.7. City G

Compared with other CATCH partner cities, City G assessed the total of 23 indicators with relatively higher scores. Similar to City F, no indicators were assessed with a 1, and only one indicator in the pillar on ecosystem services was assessed with a score of 2. However, it was a different indicator, namely C3.1 (*Attention to the needs and protection of vulnerable groups*). Again, similar to City F, the City G, which is in a different country, assessed several indicators with a score of 5. These included one indicator each in pillars on community and networks, namely C1.7 (*Organisation of emergency management*), and ecosystem services, namely C3.6 (*Vegetation coverage at the city level*), and 7 out of 9 indicators in the second pillar on water catchments, indicating a very high strength in data and infrastructure management.

## 3.2. Comparative analysis of self-assessment results per WSC pillar

The average score for each pillar was calculated by dividing the total of the scores by seven. Cities A and B did not give any scores to some indicators. For these indicators the average score was calculated based on the six individual scores. When the average scores for the three WSC pillars are compared, we observe that the pillar “cities as catchments” has the highest average score (= 3.65), followed closely by the pillar on communities and networks (= 3.42), and the pillar on ecosystem services has the lowest average score (= 2.88).

### 3.2.1. Cities as water sensitive communities and networks

The lowest score in this pillar is for the indicator C1.5 (*Leadership, long-term vision and commitment by the city-level administration*), with a score of 3.14, and the highest score is for the indicator C1.7 (*Organisation of emergency management*), with a score of 3.86. The indicator with the lowest score shows the need for mainstreaming water and climate change adaptation measures and goals into other sectors, and for implementing integrated projects. When the individual scores of the cities are compared, it is noticeable that none of the cities assessed themselves with a score of 5, whereas the individual scores range between 2 and 4.

In every CATCH partner city, various stakeholders with diverse interests are involved in urban water management and climate change adaptation. However, the involvement of the private sector, such as insurance companies and housing corporations, is seen as lower than expected. Climate change is considered as a problem in the public domain, pushing the responsibilities to the governmental authorities, especially at the local level. The exception is City D, where a private insurance system makes the citizens responsible to take their own measures and to cover the damages. In all cities, the comprehensive stakeholder network ensures that all responsibilities are allocated to one or more stakeholders, and the distribution of responsibilities is perceived as clear and acceptable. Some partners express the need for transferring more tasks to municipalities, which is the case in most of the cities. This transfer is, however, seen as difficult to achieve. Further, there is limited formalization and customization of participatory tools according to the needs and expectations of different type of stakeholders.

Another common weakness in this pillar is that climate change is not perceived as a high priority issue. Due to funding and personnel constraints, climate change adaptation is often part of larger water-related projects, and initiatives remain as ad-hoc or at pilot level. Here, the two exceptions are the cities F and G. City G has a dedicated team, with members from different climate-related sectors and departments, and a budget for climate change adaptation. In City F, climate change is part of the city's resilience programme. Additionally, in several cities (e.g., A, B and E) major floods that occurred in the past few decades triggered action towards climate change adaptation. Given the historical context of the NSR countries, floods are perceived as the primary climate challenge, often linked to heavy rainfall, whereas heatstress and drought are emerging issues, especially after the relatively warm and dry summer of 2018. The lack of prioritizing climate change is also demonstrated by the fact that none of the CATCH partner cities has a climate change adaptation strategy, nor clear goals about climate change adaptation. Cities that are relatively advanced in this regard are City F, where climate change is part of the city's resilience programme, and City G, where a climate change strategy is under preparation.

The assessment results confirm the findings from the review of previous literature that midsize cities are dependent on higher governance levels for urban water management and climate change adaptation. At the same time, the CATCH partners differ in terms of their role regarding climate change adaptation in their cities. Three partners are municipalities and thus the main local authority in their city (i.e., B, F and G). Two partners are local or regional authorities that are responsible for climate change adaptation in the respective cities (i.e., C and D). Finally, two partners are local authorities, and depend on other stakeholders, including the municipality, for their climate change adaptation actions and other decisions in their cities (i.e., A and E).

### 3.2.2. Cities as water catchments

The lowest scored indicator in this pillar C2.2 (*Areas to temporally store water in the city without expected damage*), with a score of 2.86, and the highest scored one is C2.4 (*Status of infrastructure for water supply*), with a score of 4.29. The low average level of the indicator on temporary water storage is due to the fact that one city (City E) assessed itself with 1, another city (City G) with 4 and the rest with 3. Overall, the comparison of the scores in this pillar show the need for increasing the options to temporarily store water e.g., in multifunctional used areas, both for flood and drought situations, and for improving the regulations and incentives to implement such measures.

Indicator C2.4 (*Status of infrastructure for water supply*) has the highest average score among the 23 indicators. For this indicator, cities F and G assessed themselves with 5, and the others with 4, indicating a relatively low need for improving the water supply infrastructure. Similarly, the other indicators on the status and the maintenance of the infrastructure are relatively high, which implies that there is no perceived urgency or pressure on the cities regarding infrastructure investments or maintenance. This observation is consistent with the underlying idea of the first three stages of the WSC framework that describe the evolution of the water system to provide essential services. Cities in the NSR have historically heavily invested in single-purpose systems, and consequently the maintenance of these systems. Like in the NSR, many developed cities lack 'cities as water catchments' practices with regards to the successful implementation of IWRM and climate adaptation.

The scores for indicator C2.1 (Availability and use of flood hazard and flood risk maps for areas at risk) depict a mixed picture. Partly due to the existence of comprehensive actor networks, in all the cities the water and climate data and knowledge are scattered among various organizations. This does not necessarily constitute a problem, as long as mechanisms for sharing data and knowledge exist. However, in several cities, there are concerns on how to share risk-related, sensitive information with the public, e.g., the flood risk maps, due to the possible effects on land prices. However, the implementation of the EU Floods Directive (EC, 2007) requires the accessibility of flood hazard and flood risk maps for all flood risk areas across Europe.

### 3.2.3. *Cities as ecosystem services providers*

With an average score of 2.88, this pillar shows ample room for improvement in ecosystem services that are relevant for water management and climate change adaptation in cities. The lowest score is for the indicator C3.1 (*Attention to the needs and protection of vulnerable groups*), with an average score of 2.57, and the highest score is for the indicator C2.4 (*Protection of groundwater quality and groundwater levels*), with an average score of 3.43. We also observe that two other indicators, namely C3.2 (*Healthy and biodiverse habitat*) and C3.3 (*Protection of surface water quality and flow regime*) have an average score of 2.58, which is very close to the lowest level.

Indicator C3.1 that focuses on the needs and protection of vulnerable groups against the negative impacts of climate change has the lowest average score among the total of 23 indicators. This finding is consistent with the impressions shared by the practice partners during the definition of the indicator, as they communicated that there was relatively low awareness and data regarding the needs of vulnerable groups. Another key weakness regarding this pillar is that the monitoring and evaluation of the results and impacts of climate adaptation actions in midsize cities are limited, mainly due to lack of prioritization and funds. Experimentation with several measures, such as green roofs, is taking place in the cities E, F and G. However, the cities lack the oversight as to which measures work and which do not. Given also the lack of clear monitoring and evaluation criteria, the cities experience difficulties in valuing and quantifying the economic, social and environmental benefits of investments made for climate change adaptation.

The results in this pillar correspond well with the impression obtained during the partner visits, revealing that in the past, water management issues have been mainly approached through engineering solutions across the NSR. The concept of ecosystem services has not yet received sufficient attention by the responsible authorities. Setting a higher priority on strategic climate change adaptation requires putting more emphasis on the integrated management of water resources. Indicators of ecosystem services can contribute to such assessments and help to identify integrated and tailored solutions.

## 4. Discussion and conclusions

In tackling water and climate challenges, large cities are typically the epicentre of attention from both political and scientific perspectives, whereas the importance of midsize cities is also acknowledged. This paper presents the results from a self-assessment study that takes into account the specific needs and characteristics of midsize cities. The indicator set used for the assessment is based on the WSC index, which was adjusted to the conditions of urban water management and climate change adaptation in the NSR. Self-assessment results indicate a strong status in all three pillars of the WSC framework. However, the scores are relatively lower for the pillar "cities as ecosystem services providers" as compared to the other two pillars. This low assessment also implies a common need of the cities to identify and value the different social, environmental and economic benefits of climate change adaptation measures. The benefits of urban ecosystem services are well-documented. For instance, CJC Consulting (2005); Stratus Consulting (2009); Hartig, Mitchell, de Vries, and Frumkin (2014), and Ten Brink et al. (2016) show the monetary net benefits with regard to health costs, improved air quality, reduced temperatures, stress reduction, improved social cohesion, and increased real estate value. However, cities often face multiple obstacles regarding the valuation of these benefits, such as the lack of data, methods and expertise for quantification of benefits; the lack of awareness by the decision makers and citizens; low stakeholder engagement; financial constraints; and fragmentation among multiple sectors (Ervin et al., 2012; Kandulu, Connor, & MacDonald, 2014; Baró, Haase, Gómez-Baggethun, & Frantzeskaki, 2015; Kabisch, 2015; Kremer et al., 2016).

With regards to the pillar "cities as communities and networks", the assessments show positive results in terms of stakeholder involvement, whereas there are common challenges, for instance integrating climate change adaptation across existing policy sectors and making climate change adaptation a priority at the city-level. These findings confirm the results of global studies on urban climate governance (Aylett, 2015; Van der Heijden, 2019).

While the cities score on average the highest for the pillar "cities as water catchments", this pillar also has the largest range of the scores that the partner cities gave to themselves. Such a large range indicates that the midsize cities vary in terms of their capacity for the management of data and infrastructure. This result can also be explained by the subjective scores of the indicators on infrastructure status and maintenance, which might have been perceived and judged differently in different cities. In future applications of the self-assessment, such indicators can be scored by assigning them quantitative measures, such as the percentage of leakage in the water distribution system, to each score. This quantification process, however, should also be tailored to the accepted standards of water infrastructure in the participating cities.

The assessment results highlight several issues, some of which are common, and some are differing among the cities. Similarities are mainly in terms of the high number of stakeholders involved in climate change adaptation and the resulting comprehensive network, the lack of clear criteria to monitor and evaluate climate adaptation actions, and the difficulty of valuing the ecosystem services and the benefits of adaptation measures. The cities, and sometimes the authorities which represent them in the CATCH project, also differ in several aspects. For instance, as argued for all midsize cities, the cities involved in the CATCH project share the common feature of being dependent on higher governance levels. However, the project partners differ in terms of their authority for making decisions at the city level. The partner cities also differ in terms of the priority given to climate change as a policy problem or a strategic issue. This result shows that being a frontrunner city in climate change adaptation has multiple dimensions, and even though all the midsize cities involved in the CATCH project aspire to be frontrunners, each of them has both weak and strong aspects, as demonstrated by their varying indicator scores. The self-assessment exercise provided the cities both the opportunity to identify these aspects at indicator and pillar levels for their own city, and it raised their awareness on the similarities and differences of other midsize cities, without feeling a pressure of high scores or competition with other cities. Several partner cities identified opportunities for further exchange on specific challenges or opportunities that they jointly identified during the self-assessment process. In this regard, the key contributions of the self-assessment do not result from reaching accurate indicator scores and comparing them across cities, but rather from an increased awareness of the partner cities, and the exchange and mutual learning platform that the assessment process provides with the partners on the multiple dimensions of urban climate resilience.

For future applications of the self-assessment by the cities in the NSR and beyond, the scoring process can be enhanced by collecting quantitative data that can facilitate the assignment of scores and by involving a broader range of stakeholders. It should however be noted that both of these improvements require additional financial and human resources, which are key constraints for midsize cities. The application of the self-assessment in other cities, especially in the global south (cf. Bichai & Cabrera Flamini, 2018; Leal Filho et al., 2019), is identified as the final future research direction to validate its relevance to urban climate resilience.

## Declaration of Interest

Authors declare no conflict of interest.

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