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Integrated Water Resources Management in Cities in the World: Global Challenges

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Abstract

Water scarcity and accessibility remain persistently amongst the most prominent global challenges. Although there is a wide agreement among international organizations that Integrated Water Resources Management (IWRM) and water governance are key to overcome water-related challenges, global assessments of the progress made by cities is lacking. This paper for the first time analyses the challenges of water, wastewater, municipal solid waste and climate change in cities. We used empirical studies (125 cities) based on the City Blueprint Approach and developed a statistical estimation model to estimate IWRM performances of another 75 cities. These 200 cities in total represent more than 95% of the global urban population. This comprehensive global picture enables us to evaluate the existing gaps in achieving water-related Sustainable Development Goals (SDGs), in particular SDG 6 (clean water and sanitation) and SDG 11 (sustainable cities and communities). The best performing cities were Amsterdam and Singapore. Unfortunately, most cities do not yet manage their water resources wisely and are far from achieving the SDGs. For instance, targets regarding drinking water supply are still a challenge for many cities in Africa and Asia and challenges regarding sanitation are high in cities in Africa, Asia and Latin America. The same holds for solid waste management, climate adaptation, and people living in informal settlements. In another paper we will address the solution pathways to these global challenges.

Keywords Integrated water management · Water governance · Sustainability indicators · Blue City Index · Estimation model

1 Introduction

International agreements on the need for Integrated Water Resources Management (IWRM) have led to major policy initiatives in many countries. IWRM is widely acclaimed by international organizations such as the International Water Management Institute, the Food and Agriculture Organization, the World Bank and various regional authorities. IWRM is

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defined as a process that promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (UNEP 2022; United Nations 2022). The concept and its application is considered by many as pivotal for achieving the water-related UN Sustainable Development Goals (SDGs; Essex et al. 2020; Pahl-Wostl et al. 2021). As approximately 70% of the population will be living in urban areas by 2050, with the largest growth taking place in cities in Africa and Asia, the pressure for tackling water challenges has shifted to cities (Romano and Akhmouch 2019). Cities have the responsibility for local resources management, land use and urban infrastructures, and therefore can position themselves as arenas for tackling the largest changes (OECD 2015a; Hachaichi and Egieya 2023).

The impact of IWRM in cities can be far-reaching. As urban populations grow, water demands increase, which can substantially exacerbate freshwater scarcity at a regional scale (Koop and Van Leeuwen 2017; OECD 2015a). Cities are, therefore, as vulnerable to water challenges as they are influential in finding management solutions. Due to the pressing nature of climate change, cities are forced to rapidly adapt their IWRM and anticipate long-term climate impact, such as in the case of Cape Town (Madonsela et al. 2019), Sabadell (Šteflová et al. 2018) and Ahmedebad (Aartsen et al. 2018). IWRM has rather universal claims on how water management should be reshaped. This triggers discussions on the ambiguity of IWRM, because it has also been criticized for being too all-encompassing which results in difficulty in providing clear implementations steps (Casiano Flores et al. 2019; Gupta et al. 2013; Medema et al. 2008; Saravanan et al. 2009). Hence, as a next step, cities need to identify which elements of their water management and governance already perform well and which ones need to be improved (Koop et al. 2017; OECD 2015b; Pahl-Wostl et al. 2021).

Despite ample research on IWRM theory and application in many world regions, there are limited indicator-based studies that provide coherent global perspectives that are specifically focussed on IWRM in cities (Engle et al. 2011; Koop and Van Leeuwen 2017). Key impediment of such a focus is the availability of a coherent, meaningful and reliable indicators that can lay out urban IWRM challenges and prospects. It is particularly challenging to ensure that data-poor world regions are not under-represented. The City Blueprint Approach (CBA) has been developed and applied to address this gap and the methodology has been published in this journal (Koop and Van Leeuwen 2015a, b; Koop et al. 2017). The approach uses quantitative water management performance assessments. The outcome – a baseline assessment – can initiate a development and implementation cycle for improving IWRM in the cities.

Early 2021, we completed the assessment of 125 cities in 53 countries (See Supplementary Information). The city's locations are biased towards Europe and China (Chang et al. 2020; Feingold et al. 2018; Koop and Van Leeuwen 2015a; Rahmasary et al. 2019). Because a significant amount of quantitative data are required to complete the CBA, urban populations in data-poor regions of sub-Saharan Africa, Latin America and Central Asia are underrepresented.

The aim of this paper is to provide a coherent outline addressing urban IWRM challenges and prospects across the globe. In order to fulfil this aim, an assessment of the current state of urban water management across the globe is provided. Water management performance is summarized by the Blue City Index (BCI), the geometric mean of the 24 City Blueprint indicators. This will be explained in more detail in the methodology section. To address the gap in city assessments of data-poor regions, a statistical BCI estimation model has been developed which is based on empirical data from 125 cities. Capitals in 75 data-poor countries were selected and their BCIs were estimated. Next, the current water challenges are examined using appropriate SDGs and other relevant indicators. The focus here is mainly on SDG 6 and SDG 11. In this way, a broad diagnosis of urban water challenges across the globe is provided. In another paper we will provide the solution pathways to these global challenges (Koop et al. 2022).

2 Methodology

2.1 The City Blueprint Approach

The CBA assesses the main social, environmental, financial and governance pressures exerted on cities by the Trends and Pressures Framework (TPF; Koop and Van Leeuwen 2021a). These pressures may identify less favourable conditions for a city's water management performance. How cities are managing their IWRM is assessed with the City Blueprint Framework (CBF; Koop and Van Leeuwen 2021b). Where cities can improve their water governance is assessed with the Governance Capacity Framework (GCF; Koop and Van Leeuwen 2021c). An example of a complete analysis with the CBA has been published recently for the city of Windhoek (Olivieri et al. 2022). In this study we apply only the TPF and the CBF. Each city is assessed using 24 indicators for the TPF (Koop and Van Leeuwen 2021a) and 24 indicators for the CBF (Koop and Van Leeuwen 2021b). Each TPF and CBF indicator is standardised to a scale of zero to ten (see Supplementary Information). The indicators, the sources of information, and sample calculations are provided in great detail (Koop and Van Leeuwen 2021a, b).

The TPF is a quantitative approach and is composed of 24 descriptive indicators divided over 4 categories (social, environmental, financial, and governance). Indicators are scored on a scale from 0–10, where 0 means no concern and 10 is high concern.

The CBF deals with the adequacy of the city's water management assessing seven main categories: (i) basic water services, (ii) water quality, (iii) wastewater treatment, (iv) water infrastructure, (v) solid waste (vi) climate adaptation and (vii) plans and actions. The IWRM performance is summarized in the BCI, the geometric average of the 24 indicators of the CBF (Koop and Van Leeuwen 2021b). A low BCI implies that there are many improvement options needed, in for example, the city's wastewater treatment, solid waste treatment and climate adaptation activities. The 24 indicators are visualised in a spider web diagram (Fig. 1).

2.2 Update of the Methodology and Database of Cities

CBA data have been gathered for 125 municipalities and regions in 53 countries over a period of about 10 years. In order to consolidate the databases and to remove temporal inconsistencies and to further simplify and harmonize the methodology, a major review and update took place in 2021. Every effort has been undertaken to verify sources and to find the most recent information available. During this process the original CBA applied since 2015, has been modified as well. Details on the consolidation of the database are provided in the Supplementary Information. The update of the database of cities was the first step in the process which is summarized in Fig. 2.

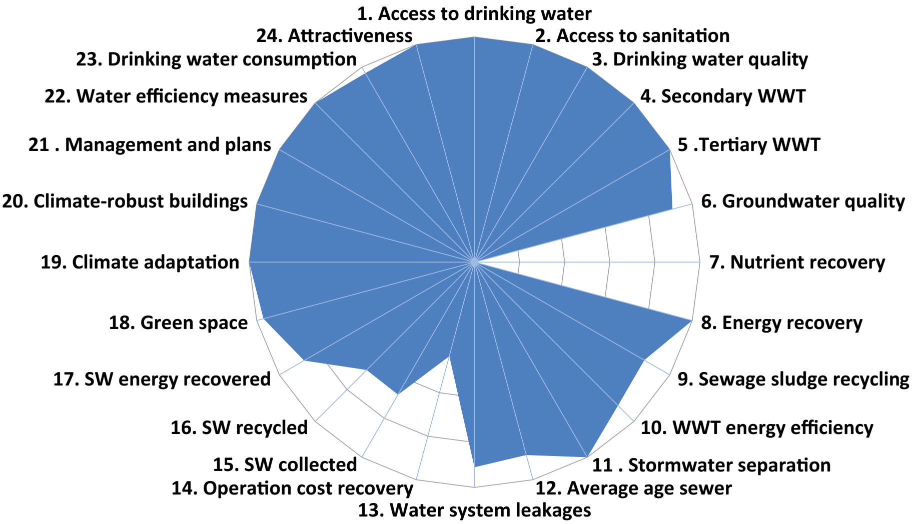

Fig. 1 The 24 City Blueprint performance indicators of Singapore. The indicators score from zero to ten

2.3 Development of a Statistical Estimation Model for the BCI

For the development of the BCI estimation model, a forward stepwise regression analysis approach was adopted using Microsoft Excel to create an expression composed of a limited number of variables representing the indicators. Stepwise regression is a method of fitting regression models in which the choice of predictive variables is carried out to select important variables to obtain a simple and easily interpretable model. Stepwise regression is a process of building a model by successively adding or removing variables based solely

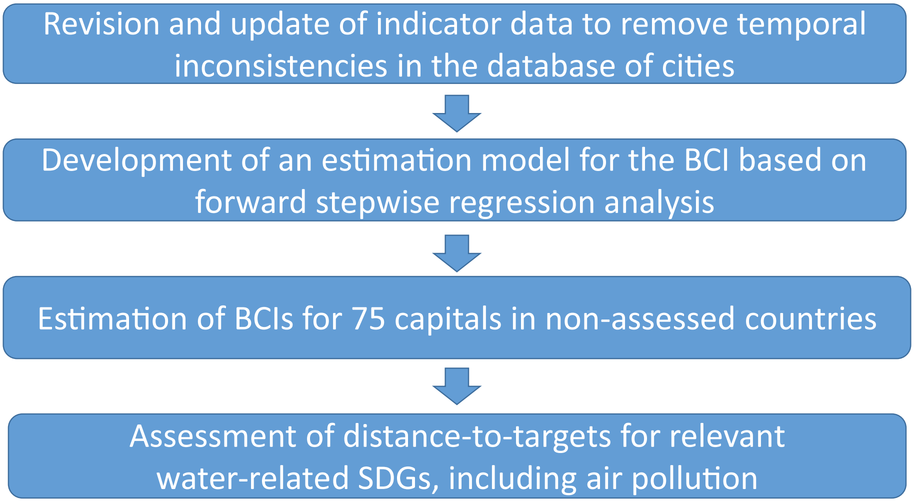

Fig. 2 Schematic illustration of the methods adopted in this study

on the p values associated with the t statistic of their estimated coefficients. It begins with a model that contains no variables and subsequently adds the most significant variables one after the other (Sokal and Rohlf 1981). This methodology was applied three times: using the 24 CBF indicators, using the 24 TPF indicators and using the combined 48 CBF and TPF indicators. The consolidated database of 125 cities was used (see Supplementary Information). For the BCI estimation model, this process was concluded when three easily accessible variables were identified and the prediction intervals reflected a similar variation as observed in the empirical BCI scores observed in countries in which many cities were assessed, such as the Netherlands, Sweden, the USA and China.

Once the equations for each of these three datasets were determined, the equation that resulted in the smallest 95% prediction interval was selected as the estimation model. To be useful, data for each of the CBA indicators in this equation must be readily available for countries globally. As such, the ease of finding data for each indicator was assessed. It was decided for reasons of transparency and replicability to only include indicators that can be obtained from accessible public databases from international organizations.

2.4 Selection of Cities for Applying the Estimation Model

Before applying the estimation model, a list of cities to be evaluated was selected. As the aim of this paper is to provide BCI scores for cities globally to adequately provide global representation, a list was constructed by first selecting countries lacking CBA assessments. To avoid a bias towards urban populations in countries with a negligible portion of the global urban population, countries with greater than 0.5% of the world population were included, while countries with less than 0.02% of the world population were excluded. Then the capital cities of the remaining countries were selected for evaluation. The final sorting was dependent on data availability. The complete list of cities for which the BCIs were estimated (BCI*) using the estimation model can be found in the Results section and the Supplementary Information.

2.5 Challenges in Cities

The challenges in cities across the globe, were calculated on the basis of the empirical and estimated BCI scores and sorted at continental level, i.e., for Europe, Oceania, Asia, North America, Latin America and Africa.

2.6 Challenges in Countries

The CBA can also provide links to a broader set of IWRM goals and international strategies, such as the United Nations' SDGs (Essex et al. 2020; Koop and Van Leeuwen 2017). This is particularly reflected by *SDG 6—Ensure availability and sustainable management of water and sanitation for all*, and by *SDG 11—Make cities and human settlements inclusive safe, resilient and sustainable* (UN General Assembly 2017). Every indicator in SDG 6 and most indicators in SDG 11 are represented by the CBA, ensuring that city assessments using this method will be representative of SDG targets as well. With a target date of 2030 for these SDG goals, it is vitally important to obtain a global assessment of where cities currently stand in terms of achieving these goals (Essex et al. 2020). Unfortunately, these data is not available. As of 2020, only 42% of the 92 SDG environment-related SDG indicators had sufficient data at national level to assess progress in achieving the targets (UNEP 2021a). Thus, in order to broaden the assessment of the global urban challenges, we used a number of water-related and urban SDG indicators (United Nations 2022) for which data were available at national level:

- Achieve universal and equitable access to safe and affordable drinking water for all (SDG 6.1).
- Access to adequate and equitable sanitation and hygiene for all (SDG 6.2).
- Urban population (not) living in slums, informal settlements or inadequate housing (SDG 11.1).
- Urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated by cities (SDG 11.6.1).
- Annual mean levels of fine particulate matter (SDG 11.6.2)

We also included one of the World Bank governance indicators, i.e., government effectiveness (Kaufmann et al. 2010, 2022) and climate adaptation (ND-GAIN 2020) to provide a broader set of indicators. Data for these indicators had to be available for any country and ideally come from the same source. Data sources were selected based on quality, availability and reliability. As such, large data banks such as World Bank and the UN were prioritized. All data except for government effectiveness and climate adaptation was under a percentage of the population either meeting or not meeting the target. The percentage of the population meeting the target was calculated per country based on its total population.

3 Results and Discussion

3.1 The BCI Estimation Model

We developed a simple BCI estimation model for assessing urban water management performances (BCI*), particularly for cities in data-poor regions. The results of the full statistical analyses including all data used are provided in the Supplementary Information. The resulting equation for estimating BCI scores (denoted as BCI*) is shown in the equation below:

$$\begin{aligned}\mathbf{BCI}^{*} &= 4.25 - 0.396^{*}\mathit{TPF}21\ [\mathit{Government\ effectiveness}] \\ &\quad + 0.195^{*}\mathit{CBF}4\ [\mathit{Secondary\ WWT}] + 0.111 * \mathit{CBF}8\ [\mathit{Energy\ recovery}]\end{aligned} \tag{1}$$

One of the most important results of the statistical analysis is the relevance of the Governance effectiveness parameter of the World Bank in predicting water management performance. Governance effectiveness is the most important variable (Multiple R = 0.71 and R Square = 0.50). It explains most of the variation observed in the empirical BCIs, and confirms the results published earlier based on an analysis of only 45 cities (Koop and Van Leeuwen 2015b). Although correlations are not cause-effect relations, the results support the view expressed by Romano and Akhmouch (2019), that if you want to 'fix the water pipes, start with the institutions'. The second most important variable is secondary wastewater treatment. Poor waste water treatment is observed in many cities and contributes to severe surface water pollution. Water infrastructure, and sewers and wastewater treatment plants in particular, are among the most expensive infrastructures in cities (Koop and Van Leeuwen 2017). The logic of this parameter in the estimation model is that only countries with a high gross national income per capita (Koop and Van Leeuwen 2021a) can afford to invest in proper wastewater treatment. Proper collection and treatment of wastewater is also a prerequisite for energy recovery from wastewater, which is the third varable in the BCI estimation model.

The estimation model predicts the BCI* within a range of ± 1.3 (95% prediction interval) from the fully assessed value with a correlation coefficient (R^2) of 0.83. The estimated BCI scores using this model versus CBA-assessed BCI scores are shown in Fig. 3.

3.2 Limitations of the BCI Estimation Model and Its Implications

The 125 cities that were used for the statistical analysis have not been randomly selected. In fact, our work was originally focussed on cities in Europe, that volunteered to participate. Later on cities in other regions were added. Collaboration with scientists in China resulted in the inclusion of all provincial capitals of China to our database (Chang et al. 2020). Hence, the cities used for the statistical analysis for the development of the estimation model have a distribution bias towards Europe and China. Of the 125 cities that were assessed, 67 cities are non-European of which 32 cities are Chinese.

The implications of this bias in the selection of cities on the estimation model are not large. The width of the prediction interval is comparable to the variation of BCIs in countries where multiple cities have been assessed such as in China, the USA, the Netherlands

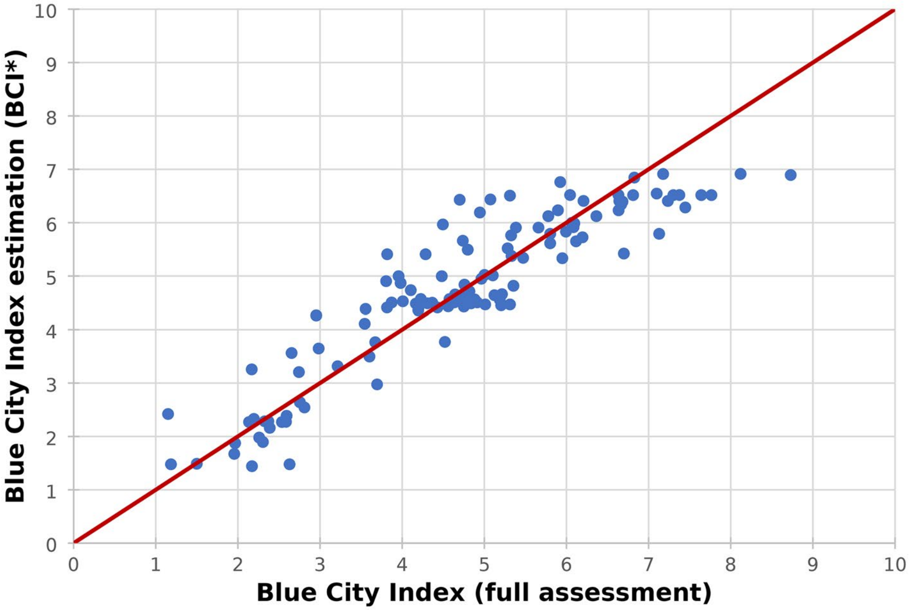

Fig. 3 Three-variable BCI* estimation model based on CBF and TPF, as provided in Eq. (1): **BCI*** = *4.25—0.396*TPF21 [Government effectiveness] + 0.195*CBF4 [Secondary WWT] + 0.111*CBF8 [Energy recovery]*. The plot shows the estimated BCI*s against the fully assessed BCIs for the combined 48 CBF and TPF indicators. The solid red line represent a full correspondence of the estimated BCI* and the actual BCI (Y = X; slope = 1). The applicability domain of the estimation model covers the BCI range of 1 to 6.5 as for BCI values > 6.5 a departure from linearity can be observed

and Sweden. For example the lowest BCI in the Netherlands was for the city of Eindhoven (5.8) and the highest BCI value (8.7) was for the city of Amsterdam.

Above BCI values of 6.5, there is a departure from linearity, resulting in lower BCI* values. This implies that the applicability domain of the BCI estimation model covers the range of 1 to 6.5. For our assessments of the BCI* scores for 75 capitals in this study this has no practical consequences as all BCI* values are in the range of 1 to 5.5 (Table 1). The full data sets of cities, the statistical analyses and the data are provided in the Supplementary Information.

3.3 Application of the BCI Estimation Model

Successful application of the model requires reliable input data for the three indicators selected in the equation: TPF 21 – Government effectiveness, CBF 4—Secondary wastewater treatment, and CBF 8 – Energy recovery from wastewater. Developing the model meant searching for high quality credible data, readily available for any country and ideally coming from the same source (see Supplementary Information). The data input was then converted to a score out of 10, in order to reflect BCI scores which range from 0 (low performance) to 10 (high performance). The process for each indicator is described below.

3.3.1 TPF Indicator 21: Government Effectiveness

Government effectiveness is one of the governance indicators rigorously assessed by the World Bank (Kaufmann et al. 2010; 2022), as established in the guidelines for assessing the TPF indicators (Koop and Van Leeuwen 2021a). The World Bank database provides government effectiveness data for 209 countries (and territories) with the most recent data from 2019. The indicator score of the World Bank varies from -2.5 to 2.5 and has been transformed by a min–max standardization method into scores of 0 to 10 (Koop and Van Leeuwen 2015a). Finally, the scores are converted into “concern scores”, where a score of 0 means a low concern and a score of 10 indicating a high concern for government effectiveness (Koop and Van Leeuwen 2021a):

$$\mathbf{TPF\ 21} = 10 \times \left(\frac{2.5 - Governance\ score}{5} \right) \tag{2}$$

3.3.2 CBF Indicator 4: Secondary Wastewater Treatment

This indicator measures the percentage of the urban population whose wastewater is treated by secondary treatment. The original suggested data source for this indicator in the guidelines for assessing CBF scores is from the OECD (Koop and Van Leeuwen 2021b; OECD 2021). However, these data are limited to OECD countries, many of which have already been assessed by the CBA. As the goal of the model is to estimate BCI* scores for unassessed regions globally, new data sources are required.

An in-depth review revealed two reliable data sources. A joint UNICEF and WHO report (2019) provides data for the proportion of wastewater treated to at least secondary treatment for 65 non-CBA assessed countries. The IB-Net database (IBNET 2021) also provides data for the percentage of collected sewage that receives at least secondary treatment for 51 non-CBA assessed countries.

Table 1 Estimated BCI scores (BCI*) of 75 capitals. Countries are indicated by their ISO country code

Country	City	BCI*	Country	City	BCI*
AFG	Kabul	1.1	LBN	Beirut	1.9
ALB	Tirana	3.0	LBY	Tripoli	1.1
ARE	Abu Dhabi	5.3	LSO	Maseru	3.5
ARG	Buenos Aires	2.5	LTU	Vilnius	5.0
ARM	Yerevan	3.1	MAR	Rabat	3.0
AUT	Vienna	5.4	MDA	Chisinau	3.8
AZE	Baku	4.0	MEX	Mexico City	3.2
BGD	Dhaka	3.2	MKD	Skopje	2.4
BHR	Manama	4.5	MLI	Bamako	2.1
BIH	Sarajevo	2.2	MMR	Naypyidaw	1.4
BLR	Minsk	4.0	MYS	Kuala Lumpur	5.0
BOL	La Paz	2.1	NIC	Managua	2.3
BRA	Brasilia	3.2	NER	Niamey	2.2
CIV	Yamoussoukro	1.9	NZL	Wellington	4.9
COG	Kinshasa	1.0	OMN	Muscat	4.4
COL	Bogota	2.6	PAK	Islamabad	1.7
CRI	San Jose	3.5	PAN	Panama City	2.9
CUB	Havana	3.0	PER	Lima	3.4
CZE	Prague	4.9	PNG	Port Moresby	1.7
DOM	Santo Domingo	2.4	PRY	Asuncion	2.8
DZA	Algiers	2.2	QAT	Doha	4.8
EGY	Cairo	3.3	RUS	Moscow	3.7
ETH	Addis Ababa	1.9	SAU	Riyadh	4.5
GEO	Tbilisi	3.1	SDN	Khartoum	1.0
GIN	Conakry	1.7	SEN	Dakar	2.7
GTM	Guatemala City	1.8	SLE	Freetown	1.7
HND	Tegucigalpa	2.4	SVK	Bratislava	4.7
HRV	Zagreb	3.9	SYR	Damascus	2.1
IRN	Tehran	3.5	TJK	Dushanbe	3.3
IRQ	Baghdad	2.4	TUN	Tunis	4.1
JAM	Kingston	3.3	UGA	Kampala	2.3
JPN	Tokyo	5.5	UKR	Kyiv	3.2
JOR	Amman	5.4	URY	Montevideo	4.1
KAZ	Nur-Sultan	4.2	UZB	Tashkent	3.6
KEN	Nairobi	2.0	VEN	Caracas	1.4
KGZ	Bishkek	3.5	YEM	Sana’a	1.8
KWT	Kuwait City	4.2	ZMB	Lusaka	2.5
LAO	Vientiane	2.6			

Because the data from these two sources are partly overlapping, together they provide data for 85 countries that have not yet been assessed by the CBA. As both sources provide data in percentages, the indicator score could then be transformed for use in the model by using the following equation:

$$\mathbf{CBF\ 4} = \frac{\%\ wastewater\ treated\ to\ secondary\ treatment}{10} \tag{3}$$

3.3.3 CBF Indicator 8: Energy Recovery

The energy recovery from wastewater systems is expressed as CBF Indicator 8 (Koop and Van Leeuwen 2021b). Data for the percentage of wastewater treatment plants where energy recovery systems are installed and operational have been found for eight cities (International Water Association 2018), of which only three have not yet been assessed by the CBA. For these data, the indicator score could be determined using the following equation:

$$\mathbf{CBF\ 8} = \frac{\%\ energy\ recovered\ from\ treated\ wastewater}{10} \tag{4}$$

Aside from this source, adequate data are generally lacking for energy recovery from wastewater systems. Our BCI assessments of cities have revealed that the value of CBF indicator 8 is zero for approximately half of the cities assessed. Published reports support these results, as energy recovery from wastewater treatment is only widely practised in regions with established energy recovery, i.e., Western Europe, North America and Australia (Alvarez and Buchauer 2015; Strazzabosco et al. 2021). Energy recovery is unlikely in countries that possess little or no secondary or tertiary wastewater treatment (Jones et al. 2021; Qadir et al. 2020). Furthermore, energy recovery is costly (as are secondary and tertiary treatment), and countries with low GDPs are unlikely to invest in these technologies (Jones et al. 2021; Van Puijenbroek et al. 2019). Countries with low GDPs and/or no secondary wastewater treatment are likely to have scores of zero for CBF indicator 8.

3.4 A Global Overview of Challenges in 200 Cities

The result of the above analysis is that in addition to the 125 cities already assessed, the BCI* scores for 75 cities were estimated, representing in total 95% of the world population (Table 1, Fig. 4 and Supplementary Information).

The global map illustrating BCI scores indicates that the majority of cities show ample room too improve IWRM. This is further evidenced when examining the BCI scores per continent (Table 2): 145 cities of the 200 assessed have BCI scores lower than 5 and the average score across all continents is 4.1. Even in Europe, with the largest concentration of higher scoring cities, 36% of those assessed scored lower than 5.

3.5 Challenges in Countries

Table 3 provides an overview of the current relative distances to several water-related and urban SDG targets, as well as to other relevant indicators such as government effectiveness and climate adaptation. SDG 6.1 and 6.2 correlate with CBF indicators 1 (access to drinking water) and 2 (access to sanitation), respectively. SDG 11.6.1 corresponds with CBF 15 (Municipal solid waste collected) and SDG 11.6.2 corresponds with TPF 14 (air quality). Finally, TPF 21 (government effectiveness) and CBF 19 (climate adaptation) were included as well to provide broader insights into the challenges.

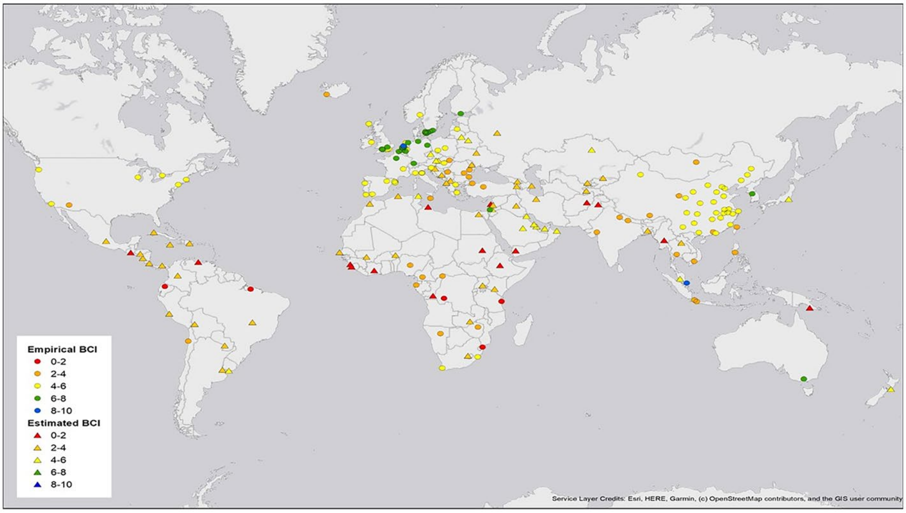

Fig. 4 Global map of estimated BCI* and fully assessed BCI scores for 200 cities. This shows that Latin America, Africa, and parts of Asia generally have BCI scores lower than 4, indicating a great disparity in IWRM. Only Northern Europe shows a distinct cluster of cities scoring higher than 6, whereas Singapore (BCI = 8.1) and Amsterdam (BCI = 8.7) are the only cities with BCI scores > 8

The results of these assessments reflect the observations at city level as presented in Table 2 and Fig. 4. Targets regarding drinking water supply have been met in many countries with the exception of some countries in Africa and Asia. Challenges regarding sanitation are still high in countries in Africa, Asia and Latin America. The same holds for management of solid waste, climate adaptation, the percentage of the urban population living in slums and needs for improving governance effectiveness. Air pollution is a global challenge. Relatively positive scores regarding air pollution are observed for Australia, Canada, Finland, Iceland, Ireland, New Zealand, Norway, Portugal, Spain, Sweden, USA and Uruguay. Globally much work remains to meet these targets, especially with regards to urban solid waste management, waste water treatment, air pollution and climate adaptation.

Table 2 BCI scores per continent. Regional variation of IWRM in cities among continents as measured by the 125 fully assessed and 75 estimated BCI values

Continent	Number of cities	Number of cities with BCI < 5	Cities with BCI < 5 (%)	Average BCI and standard deviation (in parentheses)
Europe	66	24	36	5.3 (1.5)
Oceania	3	2	67	4.3 (2.3)
Asia	75	65	87	4.0 (1.3)
North America	15	14	93	3.5 (1.1)
Latin America	12	11	93	2.7 (1.1)
Africa	29	29	100	2.4 (1.0)
All	**200**	**145**	**73**	**4.1 (1.7)**

Table 3 Distance to targets status for SDG indicators and other relevant targets. For each indicator the total number of people in each country—either the total or urban population—was calculated for which the targets were met. Details of the calculations are provided in the Supplementary Information

No	**Indicator**	**Total or Urban population**	**People meeting the target**		**People not meeting the target**		**Population represented**
			million	%	**million**	%	%
6.1	Achieve universal and equitable access to safe and affordable drinking water for all	Total	6.072	81%	1.380	**19%**	95%
6.2	Access to adequate and equitable sanitation and hygiene for all	Total	4.825	65%	2.628	**35%**	95%
11.1	Urban population (not) living in slums, informal settlements. or inadequate housing	Urban	3.167	75%	1.033	**26%**	77%
11.6.1	Urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated. by cities	Urban	2.973	42%	4.130	**58%**	91%
11.6.2	Annual mean levels of fine particulate matter ($< 10\ \mu g/m^3$)	Total	486	7%	6.967	**93%**	95%
NA	Government effectiveness (> 5.0)	Total	4.988	67%	2.465	**33%**	95%
NA	Climate Adaptation—ND-GAIN Readiness (> 0.5) (ND-GAIN 2020)	Total	1.351	18%	6.077	**82%**	95%

4 Concluding Remarks

This paper aims to provide a coherent outline of IWRM challenges and prospects in cities cross the globe. The 125 empirical assessments and the 75 estimates of the BCI have been used to measure progress on making cities and human settlements inclusive and safe. Additionally, the assessments have been used to determine the current status of the implementation of the greater international water and urban agendas (SDGs 6 and 11). We observe that 145 of the 200 cities assessed or estimated have BCIs below 5, which means that many cities still have to implement advanced wastewater treatment, energy and resource recovery, and climate adaptation measures. Only two cities have BCI scores > 8 (Amsterdam and Singapore). The current state of affairs urges for accelerated improvements: large portions of the global population are far from reaching the SDGs goals, notably related to water, waste and climate change. This further supports the global assessment performed using the CBA, revealing not only relatively low BCI scores in cities around the world, but also significant regional disparities between Europe and Latin America, Africa and parts of Asia. There is a need to focus on the practical implementation of the SDGs for which global availability and accessibility of data is essential (Essex et al. 2020).

As populations continue to grow and urbanisation rates increase, cities must accelerate their development beyond their growth rates to achieve IWRM. This requires long-term strategies, continuous monitoring of progress, adaptive capacity and stable and sustainable financing. As water can be linked, directly or indirectly, to nearly all of the SDGs, addressing water challenges could be the gateway to meeting the targets of the other SDGs as well (Essex et al. 2020; Makarigakis and Jimenez-Cisneros 2019; Van Leeuwen 2020).

Meeting the UN SDGs is a political choice. Data gaps are preventing adequate implementation of the SDGs. It is not possible to manage a process if progress cannot be monitored, and monitoring of progress is hindered if adequate data is not available (UNEP 2021a). To date, funding for SDG 6 targets has been deemed insufficient and the global framework for IWRM shows a poor record of implementation. Unless significant progress is made, it is envisaged that SDG 6 targets will not be met by 2030, which in turn impacts other SDGs (UNEP 2021a).

Finally, our data indicate that the World Bank indicator government effectiveness is the most important indicator in the developed estimation model (see also Supplementary Information). It echoes the relevance of IWRM, and in particular the relevance of good water governance as stated by the OECD that if you want to 'fix the water pipes, start with the institutions' (Romano and Akhmouch 2019). The relevance of effective public–private collaboration for IWRM has been widely acknowledged and plays a major role in cities where most of the challenges of water, waste and climate change reside and solutions for these challenges need to be developed (Beisheim and Campe 2012; Koop and Van Leeuwen 2017; Rahmasary et al. 2020; UNEP 2021b). The longer it takes to start the actions, the more difficult it will be to overcome challenges of water, wastewater, waste and climate change in cities. In another paper we will discuss the global solutions for IWRM in cities (Koop et al. 2022).

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Author Contributions K.v.L., S.K. and D.S. designed the study. C.G created the estimation model and calculated the distance to targets. C.G. drafted the manuscript. I.C and S.W. provided data for the CBF and TPF of cities in China. S.E. suggested improvements for the TPF. D.S., S.E., J.H., S.K. and K.v.L. reviewed the manuscript. All authors discussed the results and contributed to the manuscript.

Data Availability The authors declare that all the data supporting the findings of this study are included in its Supplementary Information.

Declarations

Ethical Approval The authors subscribe to the ethical principles of this journal.

Consent to Participate All authors approved to participate in the efforts to publish this paper.

Consent to Publish All authors approve the publication in this journal.

Conflict of Interest The authors declare no conflict of interest.

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