A preliminary assessment of urban water security in Ulaanbaatar, a semi-arid region in Mongolia.

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Abstract

Water security is one of the biggest challenges of the 21st century. Understanding context-specific challenges and opportunities around this issue is key to improving water systems globally. This paper explores the current state of urban water security in Ulaanbaatar, Mongolia's capital city. Ulaanbaatar is home to more than 40% of the country's population and 60% of its national GDP. The city is located in the Tuul River basin and relies almost entirely on groundwater aquifers of the Tuul River for its supply of clean drinking water. In recent years, socio-economic stressors resulting from rapid urbanisation and environmental pressures have intensified the levels of degradation of the Tuul River and intensified the risks of water insecurity for the population of Ulaanbaatar. This study combines quantitative and qualitative methods to provide a preliminary assessment of water security at the urban level. This paper presents an urban water security index for the dimensions of water supply and sanitation, water productivity, water environment, water-related disasters and water governance. The findings and discussion are supplemented with information from key informant interviews. This paper concludes by highlighting the important limitations that exist in terms of data availability for an urban scale assessment. The results suggest that important water security inequalities also prevail within the Ulaanbaatar city-region itself which are often masked by using average scores in assessments of this sort.

Keywords: water-security, Ulaanbaatar, Mongolia, Tuul River, urbanization, ger-districts, water access, governance

1. INTRODUCTION

Access to safe drinking water and sanitation are universal human rights. They involve the internationally recognized commitments to availability, accessibility, affordability, quality and safety as well as cultural acceptability of water resources [1]. However, despite the global dedication to advancing the Sustainable Development Goal (SDG) 6 and ensuring the availability and sustainable management of water and sanitation for all [2], water resources continue to face unprecedented stress globally [3]. Water resources have a crucial social, economic, environmental and cultural value yet the rate at which freshwater resources are becoming depleted or highly contaminated has only increased globally over the past years and the situation is projected to continue aggravating over the next few decades [4].

Attention to water issues has received substantial and growing attention in academic and policy circles [5] [6]. More recently, awareness of the critical intersection between urbanization and water security has also grown [7]. Over half of the world's population already lives in urban areas and this proportion is expected to rise to two-thirds of the world's population by 2050 [8]. Rapid urbanization creates serious challenges for the provision of safe drinking water. The United Nations World Water Development Report (2023) has estimated that 2.4 billion people living in urban areas, up to half of the world's urban population, could experience water scarcity by 2050 [9]. This is particularly true for peri-urban areas that may not be connected to the central water infrastructure [10] [11]. These communities may experience what Adeyeye et al. [12] refer to as "water marginality". This idea is closely linked to the concept of water security, or lack thereof in this case.

Water security can be generally understood to be the condition of having an availability of water which is sufficient in quantity and quality to support human requirements, livelihoods and ecosystem dynamics [12]. A diverse range of tools and frameworks have emerged over the past decades which attempt to operationalize the concept of water security. These assessments are based on the selection and categorisation of a set of indicators to create a simple water security index based on a weighted aggregate score from these indicators [13] [14] [15]. A key limitation with these assessments to date has been that they have mostly been restricted to the national or basin scale. Albeit useful, these aggregate measures mask important sub-national and local disparities in water security [15] [7]. Only a few recent studies have applied the operationalization of water security to local contexts focusing on the assessment of water security in urban centres [15] [6] [7] [11].

This paper aims to contribute to this growing body of literature by providing an assessment of urban water security in Ulaanbaatar, Mongolia. To the best of the author's knowledge, this is the first assessment of this kind for Ulaanbaatar to date. Furthermore, this assessment includes the dimension of water governance which has traditionally been neglected in most water security assessments [6] [15]. This work brings together an operational urban water security assessment with key informant and stakeholder interviews to better understand the ongoing challenges and opportunities that exist in Mongolia's capital city of Ulaanbaatar with regard to urban water security.

The objectives of this study are twofold:

1) To construct a simple preliminary operational urban water security index for Ulaanbaatar based on previous frameworks adopted from the literature.
2) To supplement the results from the index with a discussion on contemporary challenges and limitations drawing from informant interviews.

The following section discusses the concept of urban water security; its definitions, key aspects and limitations. Next is a description of the study site of Ulaanbaatar. This paper then proceeds to outline the methods used to construct the urban water security index and the valuable use of key informant interviews. The aggregate results for each dimension and the index overall are then presented, followed by an in-depth discussion of the findings and their limitations.

This assessment is presented here as preliminary. This is due to the ongoing challenges associated with data availability which considerably limit the construction of a comprehensive index at the urban level for Ulaanbaatar. The study also therefore aims to highlight the need for more robust measuring tools and systematic data collection throughout the city. Nevertheless, this assessment provides a valuable starting point to discussing the critical challenges facing Ulaanbaatar's water sector.

2. UNDERSTANDING URBAN WATER SECURITY

2.1. *The contested definitions of 'water security'*

Generally speaking, water security refers to the sufficient availability of freshwater in terms of both quantity and quality at the right time and place [6]. However, the concept of water security is broad and has been taken up in a broad range of disciplines and contexts [5]. There is no single, universally accepted definition for water security.

Definitions and applications of this term have varied across disciplines, regional contexts and over time [16].

The Global Water Partnership (GWP), an international network established in 1996 to promote the use of integrated approaches to water management, provided an early definition of water security in the year 2000. They stated that it was the condition in which "every person has access to enough safe water at an affordable cost to lead a clean, healthy, and productive life while ensuring that the natural environment is protected and enhanced" [17]. In 2013, UN-Water proposed an updated working definition of this concept which has served as a benchmark for international organizations to define and conceptualize water security over the past decade. Water security was defined as "the capacity of a population to safeguard sustainable access to adequate quantities and acceptable quality of water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" [18].

Over the years, other definitions of water security have emerged from the academic and scientific literature [19]. These have incorporated the key dimensions of the UN and GWP definitions but have provided context-specific adaptations. Grey and Sadoff [20], for example, emphasize the potentially destructive impact of water in their definition through the consideration of 'water-related risks'. Aboelnga et al. [14] notice that few water security definitions apply to the urban level and so develop a working definition that encompasses the understanding of context-specific synergies and trade-offs between systems which apply to urban water security. Definitions have also varied geographically depending on local risks, needs and perceptions. In the Middle East and North Africa (MENA) region, for example, water security has been closely aligned with national security concerns given the increasing freshwater demand in an unstable geopolitical context [21] [22].

Nevertheless, despite the range of definitions and applications that exist for water security there are some fundamental themes that have remained critical components of this concept. Hoekstra et al. note that the literature on this issue has generally focused on welfare, equity, sustainability and water-related risks [16]. Similarly, Bakker [19] has argued that the fundamental elements of water security are environmental sustainability, collaboration between stakeholders and the interdependence of both material infrastructure and immaterial decision-making institutions. The Global Water Partnership has highlighted social equity, environmental sustainability and economic efficiency as three vital related and interdependent dimensions of water security [17].

Another key component of water security is that it incorporates and extends key aspects of the integrated water resource management (IWRM) framework [5] by, for example, emphasizing the linkages among sectors and between ecosystem dynamics and human health [19]. The IWRM principles and objectives of promoting holistic and decentralised approaches to water management [23] are embedded in the concept of water security so IWRM constitutes another vital component of water security at all scales [17]. It is for this reason that the assessment uses the degree of implementation of the IWRM plan for Ulaanbaatar as an indicator of water governance.

Whilst water security is a somewhat elusive concept for which a number of definitions and applications have emerged over the past decades, it remains a fundamental concept in international development. This paper seeks to contribute to discussions around this theme by focusing on water security in the urban context of Ulaanbaatar, Mongolia.

2.2. The urban focus of water security

The urban focus on water security draws attention to the particular challenges that urban spaces face and the practices and opportunities that exist in these spaces in relation to improving or enhancing water security.

Whilst the category of "urban" may imply a clear distinction between this and perhaps a "rural" form of water security, this understanding is misleading as clear-cut distinctions between rural and urban areas rarely exist. As Wratten [24] suggested, it is more accurate to view the urban-rural divide as a continuum rather than a rigid dichotomy as rapid urbanization may lead to the expansion of peri-urban areas which share both rural and urban attributes, institutions and processes [25] [26]. Ranganathan & Balazs [27] argue that this hybrid space may be better conceptualized as the "urban fringe". This discussion illustrates that defining an urban scale is in itself a challenge.

Despite these conceptual challenges, local assessments on water security at the city/regional scales have proven to be very useful in highlighting sub-national variations in water security and identifying specific challenges and opportunities. According to Hoekstra et al. [16], urban water security differs from the general concept of water security because it is affected in unique ways by other processes such as urbanization, climate change, economic growth or political structures, making it an especially complex and dynamic phenomenon.

Urban water security assessments emerged from an understanding that in order to better comprehend decision-making structures and develop effective adaptation strategies, finer scales of analysis to those of the national or basin level, were required [19] [14]. This study defines the urban scale of analysis according to the current administrative boundaries of the city of Ulaanbaatar which includes both urban and peri-urban *ger* district geographical areas, its inhabitants and consumers of the city's water resources.

3. STUDY SITE: ULAANBAATAR, MONGOLIA.

3.1. City profile

Ulaanbaatar is Mongolia's capital city. The population of Ulaanbaatar is around 1.6 million [28] which represents nearly 50% of the country's total population [29]. Due to its high altitude (about 1,350 metres above sea level) and continental location, Ulaanbaatar experiences extreme seasonal variations in temperature. The climate is generally classified as semi-arid and the city marks a boundary between humid continental and subarctic climates, with steppe zone to the south and forest-steppe to the north of the city.

The city has experienced particularly rapid urbanization over the past two decades following the transition to a market economy [30] [31]. Ulaanbaatar's population was less than 0.8 million in the year 2000 and over 1.4 million in 2017 [29] [32]. During this time, the capital's population has grown by 70% [33] and *ger* districts have proliferated in the city's surroundings. *Gers* are the traditional nomadic settlements which are shaped as round tents/yurts. Historically, these have been the mobile settlements of nomadic herders but over the past 30 years, there has been a rapid growth of permanent residential *ger*-districts in the outskirts of the Ulaanbaatar and other Mongolian cities [34]. *Ger* districts are currently home to one-third of the country's population [34] and around 60% of Ulaanbaatar's urban population [35]. Centralized piped water infrastructure does not extend to *ger* districts in Ulaanbaatar. These areas rely instead on public water kiosks which serve between 900 and 1,200 people each [36] and independent hand-dug wells [37].

3.2. Water resources in Ulaanbaatar.

Mongolia as a whole has a relatively high endowment of internal freshwater resources [29] [38] despite the fact that 90% of its territory is classified as arid to moisture deficient [39]. Nevertheless, the uneven spatial distribution of both surface and groundwater resources coupled with pollution outbreaks associated with mining, other industrial activities and sewage discharges [40] has resulted in the emergence of highly localized water scarcity hotspots [29] [41] [42].

One of the regions experiencing high water stress is Ulaanbaatar, which Nakayama et al. [42] recently identified as being at severe risk of water insecurity. Ulaanbaatar's growth and expansion, coupled with increasing water demand and higher risk of water contamination from industrial activities and unregulated sewage discharge makes it a particularly concerning water insecurity hotspot [40].

Ulaanbaatar relies almost exclusively on groundwater aquifers for its water supply [32], which account for approximately 82% of the total water use in the city [41]. The Tuul

River flowing through the city is the primary source of recharge to the alluvial aquifer beneath it [28] (Figure 1). The Tuul River Basin experiences the highest water withdrawal rates of all river basins in Mongolia, nearly 100 million m^3 per year [29]. The Tuul River basin includes 65.5% of the Ulaanbaatar city area and provides a total of 641 million m^3/year of potential exploitable groundwater resources [43].

Figure 1. Map showing the location of Ulaanbaatar and the Tuul River flowing through the city.

Beyond the ongoing challenges around water access and availability, climate change projections are expected to put further stress on these resources. Mongolia has been identified as one of the countries most vulnerable to the impacts of anthropogenic climate change but the effects will be mixed [29]. Climate models predict a gradual increase in precipitation and greater seasonal variability but drought events are also expected to become more frequent and prolonged [29] [44]. Surface evaporation in the Tuul River increased by 153 mm between 1961 and 2008 and warm season precipitation decreased by 51mm during the same period [43]. A recent study of the Tuul River's ecohydrological processes confirmed that groundwater levels have been in decline over the past twenty years [28]. Nakayama et al. [42] estimate that groundwater levels throughout the basin declined by 0.7m on average between 2000 and 2018. However, a much greater decline was observed in Ulaanbaatar where groundwater level declined by 3 – 15m during the same period as a result of rapidly increasing urban water use since the year 2000.

3.3. Institutional landscape of water resource management in Ulaanbaatar.

Mongolia's 2012 Water Law emphasized Mongolia's a commitment towards IWRM [43] [45]. A critical component of this legislation was the strengthening of the River Basin

Administrations (RBAs) which are responsible for the management and monitoring of water resources at the basin-scale [29]. There are currently 21 operating RBAs across Mongolia [41]. The RBA responsible for the Tuul River basin is the Tuul River Basin Administration (TRBA). RBAs are supervised by the Ministry of Environment and Tourism and work alongside other local and regional actors such as the municipal Water Supply and Sewerage Authority (USUG).

Both basin and national scale water security assessments have been undertaken recently in Mongolia. The Basin Health Report Card for the Tuul River [46] was the first of its kind in Mongolia. It assesses a range of indicators at the basin level and concludes that the Tuul is the most polluted river in Mongolia. In 2020, the Asian Development Bank conducted a water security evaluation for Mongolia at the national scale. The final report reinforced the unequal distribution of water resources and highlighted Ulaanbaatar as a severe water insecurity hotspot [29]. However, assessments of water security at the urban level are limited [37] [47] [48]. This study aims to address this data gap by constructing a preliminary urban water security index for Mongolia's capital city drawing from a range of publicly accessible government data and secondary literature.

4. METHODS

4.1. Constructing the urban water security index.

This study applies the operational water security assessment developed by Babel and Shinde [13]. Babel and Shinde's [13] framework follows a well-established method in the literature which involves three key steps in the operationalization process [17]. First, relevant dimensions of water security are identified. Second, indicators that reflect the key characteristics of each dimension are selected. Finally, a process of measuring, scoring and combining indicators results in a combined normalized aggregate score for water security at a given scale. This framework has more recently been adapted to assess water security exclusively in urban contexts [6] [15]. By applying this same framework to the urban level, this study aims to provide a similar assessment for the context of urban water security in Ulaanbaatar, Mongolia.

4.1.1. Identifying the dimensions

The key dimensions used in this study are the same as those employed by Babel et al. [15]. These key dimensions are water supply and sanitation, water productivity, water environment, water-related disasters, and water governance.

4.1.2. Selecting the Indicators

For each dimension, a series of different indicators have been selected, each measured through a specific quantifiable variable (Table 1).

Insofar as possible, similar indicators to those used by Tarigan & Mahera [6] for Jakarta's urban water security assessment have been used in the index model for Ulaanbaatar (Table 1). The data collection process involved an extensive literature review of official government documentation, peer-reviewed academic research articles and the review of datasets from organizations such as the World bank and Asia Development Bank. A variety of sources were reviewed to find the same or similar indicators as those used by Tarigan & Mahera [6] that were available for the city scale of Ulaanbaatar and the section of the Tuul River that flows through this city. When this was not possible, alternative indicators from the list suggested by Babel and Shinde [13] were used instead. Table 1 shows the dimensions, indicators and variables used for this assessment.

Table 1. Dimensions, indicators and variables used. Table adapted from Babel et al. [15] with indicators available for Ulaanbaatar, Mongolia.

Dimension	Indicator	Variable
Water supply and sanitation	Availability	Groundwater use (%)
	Accessibility	Proportion of people connected to the centralized water supply (%)
Water productivity	Economic value of water	Water productivity (USD/m3)
Water environment	State of natural water bodies	Surface water quality (%)
	Groundwater quality	Nitrate concentration in groundwater (mg/L)
Water related disaster	Status of water bodies	Proportion of water bodies that have dried out compared to baseline status (%)
	Flood factor	Average annual economic loss from flooding (USD$)
Water governance	Overall management of the water sector	Implementation of IWRMP (%)
		Surface water monitoring (%)

The variables *groundwater use*, *surface water quality*, *proportion of water bodies that have dried out compared to baseline status*, *implementation of IWRMP* and *surface water monitoring* were obtained from the Basin Health Report Card for the Tuul River [46]. This report divides the Tuul River into six distinct 'Regions' and for this assessment only the results for Region II, that which includes Ulaanbaatar, have been used. Prior to including this data in the assessment, the Acting Head of Water Management and Planning Division at Tuul River Basin Authority was consulted. She confirmed that this was the most up-to-date information on the different sections of the river. She mentioned that, unfortunately, the raw data had been lost in a software failure so were no longer accessible but confirmed that these percentages were accurate reflections of the original data.

The *proportion of people connected to the centralized water supply* was obtained from the recent study undertaken by Batdelger et al. [40]. Estimates for the *average annual* *economic loss from flooding* in Ulaanbaatar are obtained from the Central Asia Regional Economic Cooperation Program 2022 report [49].

No *water productivity* measure was available for Ulaanbaatar city region so this was calculated by dividing GDP in constant prices by the annual total water withdrawal. This is the same calculation used by the World Bank to calculate water productivity at the national level. Mongolia's GDP (constant 2015 US$ GDP) is close to $13.75 billion [50]. It has been suggested that Ulaanbaatar is responsible for around 60% of this GDP [43] [46]. This implies that the value of GDP produced in Ulaanbaatar is $8.25 billion. The Asian Development Bank 2020 report on Mongolia's water resources [51] states that the Tuul river basin has the highest extraction rates of all river basins in Mongolia with most of the water being used for domestic and industrial use in and around Ulaanbaatar. The annual total extraction rate is nearly 100 million m^3/yr [51].

An average nitrate concentration in groundwater was obtained from the study by Batsaikhan et al. [37]. They calculate average concentration for three regions of the city. Here we use the values from 'Group 2' which represents the alluvial aquifer that sits directly beneath the main city area. A key limitation of this variable is that the distribution of NO_3 concentrations varies significantly across the city. Sewage discharge in *ger* areas, for example, has led to significantly higher nitrate concentrations in the more uphill periphery of the city.

4.1.3. Scoring and aggregating indicators.

The real measurement for each indicator is then normalized in the range 1 ('poor') to 5 ('excellent') to facilitate the interpretation. This can be done using a variety of threshold figures and references from the literature (Table 2).

Table 2. Reference values used to normalize the variables.

Dimension	Indicator	Variables	Reference values					Reference
			1	2	3	4	5	
Water supply and sanitation	Water availability	Groundwater use (%)	<20	20-<40	40-<60	60-<80	80-100	TRBA (2019)
	Water accessibility	Proportion of people connected to the centralized water supply (%)	<25	25-50	50-75	75-99	>99	WHO (2021)
Water productivity	Economic value of water	Water productivity (USD/m3)	<40.45	40.45-113.27	113.27-255.85	255.85-486.11	>486.11	WB (2023)
Water environment	State of natural water bodies	Surface water quality (%)	<20	20-<40	40-<60	60-<80	80-100	TRBA (2019)
	Groundwater quality	Nitrate concentration in groundwater (mg/L)	100<	50<	25- ≤ 50	10-≤ 25	≤ 10	Eurostat (2018)
Water related disaster	Status of water bodies	Proportion of water bodies that have dried out compared to baseline status (%)	<20	20-<40	40-<60	60-<80	80-100	TRBA (2019)
	Flood factor	Average annual economic loss from flooding (US$ millions)	2-3.5	1-2	0.5-1	0.2-0.5	0.1-0.2	CAREC (2022)
Water governance	Overall management of the water sector.	Implementation of IWRMP (%)	<20	20-<40	40-<60	60-<80	80-100	TRBA (2019)
		Surface water monitoring (%)	<20	20-<40	40-<60	60-<80	80-100	TRBA (2019)

Each score is then interpreted according to the descriptions by Babel et al. (2020) (Table 3).

Table 3. Interpretation of the water security index (WSI). Source: Babel et al., 2020 [15].

WSI	Condition	Description
< 1.5	Poor	The city is highly water insecure. It faces several water-related issues. There is a lack of proper institutional management and preparation for future water challenges.
1.5 - < 2.5	Fair	The city is water insecure from the perspective of some dimensions. It faces some water-related issues. The basin needs some improvement in the institutional management and preparation for future water challenges.
2.5 - < 3.5	Good	The city is reasonable water secure in terms of most dimensions. It faces relatively few water-related issues. The basin has some form of institutional management and has some plans to tackle future water challenges.
3.5 - < 4.5	Very good	The city is quite water secure in terms of most dimensions. It faces very few water-related issues. The basin has proper institutional management and good plans to tackle anticipated future water challenges.

≤ 4.5	Excellent	The city is highly secure in terms of all dimensions. It has no water-related issues. The basin has excellent institutional management and it is fully prepared to tackle the anticipated future challenges.

Once each indicator has been given a score between 1 and 5, a total average score for each dimension can be calculated. For this, equal weighting of indicators is applied (Figure 2). The average scores for each dimension are then combined to calculate a total average score for all five dimensions and interpreted according to the description of each score (Table 2).

Figure 2. Diagram showing water security scoring method for each indicator and the combined average for each dimension. The flow chart applies to all dimensions.

4.2 Key Informant Interviews

Valuable insights on Ulaanbaatar's water systems and contemporary policies were obtained through in-depth, semi-structured interviews with key informants whose professional experience is directly linked to Ulaanbaatar's water sector. Participants were recruited using a non-probability, purposeful snowballing sampling method. The criteria for participation was their direct involvement in Ulaanbaatar's water systems through, for example, decision-making and policy, advocacy or education. A total of 12 key informant interviews were undertaken with participants representing a diverse set of backgrounds and experiences. These included government officials, representatives of local government agencies, private sector professionals and researchers from the Mongolian Academy of Sciences. Most interviews were conducted in English and in the case that participants felt more comfortable speaking in Mongolian, a local translator was employed. The translator, who was fluent in both the local language and English, assisted in conveying and interpreting the responses of the participants.

5. RESULTS

5.1. Water supply and sanitation.

5.1.1. Groundwater use

The percentage result for the groundwater use indicator for Region II is 55%. This corresponds to a 'good' classification with a score of 3 in this assessment.

5.1.2. Proportion of people connected to the centralised water supply (%)

The percentage of Ulaanbaatar's population that is connected to the central water supply infrastructure is approximately 60% [40]. This indicator scores a 3 on the scale to indicate that the proportion of people with access to safely managed drinking water services is 'average', according to the World Health Organization's classification [52] and 'good' according to the classification used in this assessment [15]. This score is higher than the classification of Mongolia as a whole which is 'poor' [52].

5.2. Water productivity (GDP/m^3)

Water productivity for Ulaanbaatar region is estimated at around 82.5 GDP/m^3. This value sits within the parameters of the second lowest category set of the World Bank Data bank. Therefore, this indicator obtains a score of 2 ('fair').

5.3. Water environment

5.3.1. Surface water quality (%)

The value for surface water quality is 36% which gets a score of 2 ('fair') for being within the boundaries set by the report for the second-lowest category of the Tuul River Basin Report Card [46].

5.3.2. Groundwater quality (mg/L)

The median value of nitrate concentration in groundwater for Group 2 is 15.8 mg/L [37]. A concentration of 15.8 mg/L corresponds to a value of 4 (‘very good’), the second-best group in terms of low nitrate concentration.

5.4. Water related disasters

5.4.1. Proportion of water bodies that have dried out compared to baseline status (%).

The result of this variable for Region II is 51% [46] which corresponds with an ‘good’ score of 3.

5.4.2. Average annual economic loss from flooding (million USD)

The average annual economic loss from flooding in Ulaanbaatar is around $2.51 million [49]. In the 2022 Country Risk Profile report by the organization, average annual economic loss from flooding is already divided into 5 categories with the poorest category between the range of $2 million and $3.5 million [49]. Given that the economic loss for Ulaanbaatar is approximately $2.5 million, it may be placed in the highest category which would correspond with a 1 (‘poor’).

5.5. Water governance

5.5.1. Implementation of IWRMP (%)

The implementation of the IWRMP for Region II is given a value of 73% which is quite high and scores a 4 as it can be classified as ‘very good’ [46].

5.5.2. Surface water monitoring (%)

The value for surface water monitoring is lower at 41% and so scores a of 3 ('good') on the 5-point scale [46].

5.6. Combined Results

Based on the assessment and classification criteria, Ulaanbaatar is classified as a medium-low water security. The combined average score of 2.7 (Table 4) indicates that the overall water security index for Ulaanbaatar can be classified as "good" according to the classifications by Babel et al. [15] (Table 3). However, 2.7 is close to the lower end of this category and the overall score masks important differences between indicators. It is therefore important to consider each dimension carefully in the discussion of these results.

Table 4. Variable results and corresponding scores and averages.

Dimension	Indicator	Variable	Result	Score	Average
Water supply and sanitation	Availability	Groundwater use (%)	55%	3	3
	Accessibility	Proportion of people connected to the centralized water supply (%)	60%	3	
Water productivity	Economic value of water	Water productivity (USD/m3)	82.5 GDP/m^3	2	2
Water environment	State of natural water bodies	Surface water quality (%)	36%	2	3
	Groundwater quality	Nitrate concentration in groundwater (mg/L)	15.8 mg/L	4	
Water related disaster	Status of water bodies	Number of water bodies that have dried out compared to baseline status (%)	51%	3	2
	Flood factor	Average annual economic loss from flooding (USD$)	2.51 million USD	1	
Water governance	Overall management of the water sector	Implementation of IWRMP (%)	73%	4	3.5

	Surface water monitoring (%)	41%	3
Average score			2.7

6. DISCUSSION

According to the criteria used for this preliminary assessment, no dimension of water security in Ulaanbaatar can be classified as ‘very good’ or ‘excellent’. *Water productivity* and *water-related disasters* are the worst performing dimensions with an average score of 2, classified as ‘fair’ [15]. Water governance is the highest scoring dimension with an average score of 3.5. These results are visualized in Figure 3.

Figure 3. Pentagram showing the scores for each dimension.

6.1. Financial loss in Ulaanbaatar’s water sector.

Water productivity, the variable used to reflect economic water security, was calculated by dividing GDP in constant prices by the annual total water withdrawal using GDP data from 2021. This is significant because following the onset of the Covid-19 pandemic, GDP growth slowed down. However, the cost of providing water services to the city’s population increased as a country-wide policy to temporarily suspend consumer tariffs for services such as water was put into place. Representatives from USUG highlighted that they consistently operate at a financial loss. They explained this is because the domestic provision of water is very expensive but consumer water tariffs are heavily subsidized by the government. This leads to municipal authorities collecting very little revenue for their day to day operations. On top of this, the temporary suspension of tariffs during the pandemic put further strain on the organization. A government official who used to work in the Ministry of Environment and Tourism emphasizes that this is not an isolated case, there has traditionally been a lack on investment in the water sector in

Ulaanbaatar. The general lack of funding and high water supply infrastructure and maintenance costs has been consistently flagged amongst local water experts as the main reasons why economic water security is of high concern in Mongolia's capital.

6.2. Intensifying flood risk

As for water-related disasters, flooding is a major issue in Ulaanbaatar particularly during the summer months as 90% of annual rainfall is received in the Tuul River Basin between June and August [28]. Participants agreed that flood risk is exacerbated by poor urban planning which has only deteriorated over the years as more construction is taking place immediately adjacent to the river.

According to Article 22.2 in the 2012 Law of Mongolia on Water [53], special protected zones should be established at least 50 meters from the river banks and no construction in this area should be allowed. However, construction in Ulaanbaatar over past few years has not respected this law and buildings are still being constructed adjacent to the river. One participant highlighted that this is an illegal practice and suggested that corruption of local officials by the powerful construction companies is most likely taking place. Additionally, rapid and unplanned construction has led to a significant reduction in green space which exacerbates the risk of flash floods during storms. These urbanization trends are ongoing and so participants suggested that the expected trend is even greater flood risk in the near future.

In fact, at the time of writing the first draft of this paper, the author witnessed the severe flooding that took place in Ulaanbaatar after heavy rain fell in the city on July 1st. On July 8th, the Tuul River reached a depth of 288cm, 28 cm above the dangerous flood level [54]. Local news articles pointed highlighted the severity of this flood and notes that it resulted in the complete flooding of seven locations along the river which have temporarily lost access to electricity affecting a total of around 128,000 citizens directly [55]. These events reinvigorated the discussion around flood preparedness and mitigation in the city but much of the policy implementation on this issue is still limited.

6.3. Water marginality in *ger* districts.

Water supply and sanitation as well as water environment received average scores of 3 which reflect a 'good' level of water security for those dimensions. Nevertheless, both these dimensions rely on average data which masks important disparities across the city. In particular, significant inequalities in water supply and quality exist between areas with apartment buildings supplied by the central water pipeline and *ger* district households that rely on hand-dug wells and public water 'kiosks', small distribution centres where water stored in a large tank is used to fill up people's private containers, for their water supply [56]. The lack of water infrastructure and poor water quality compared to other areas of the city leads to what can be described as a state of 'water marginality' [12] [27] in *ger* districts. This idea refers to an involuntary position and condition in which water infrastructure is limited and investment is prioritized elsewhere.

The disparity in terms of water supply between apartments and *ger* areas is captured by the fact that only approximately 60% of Ulaanbaatar's population is connected to the centralized water supply [40]. Water consumption in the *ger* districts is also lower and residences pay more per liter due to the high maintenance costs of the water kiosks. On average, a *ger* district resident in Ulaanbaatar uses 7.3 l liters of water per day which is much lower than the average for apartment residents, 291 liters/day [35].

Significant differences between apartment buildings and *ger* areas also exist in terms of water quality. The unplanned expansion of Ulaanbaatar's *ger* districts has increased the risk of water contamination due to the lack of appropriate sanitation and sewage systems [37]. Residents in these areas rely on open-pit latrines which directly discharge untreated sewage into the soil [40]. The sewage discharge percolates through the soil and contaminates the local groundwater which then may flow downwards toward the river, expanding the region impacted [37]. Nevertheless, a noticeable difference in nitrates levels exists between the central supply alluvial aquifer where nitrates level is 1.7mg/L versus 101.3 mg/L in *ger* district areas [37].

A chemist at USUG's central Quality Laboratory explained that there is a lack of public awareness on this issue. She suggested this is due to the ongoing misconception that groundwater is separate from surface water and so it remains clean. Furthermore, she stresses that there is a lack of reliable data on groundwater quality in *ger* districts as this lies beyond USUG's jurisdiction.

There are, however, plans to improve water quality and supply to *ger* areas. A noticeable example is Mongolia's flagship Millennium Challenge Account (MCA) project to improve Ulaanbaatar's water systems [57]. One of the projects involves automating kiosks to make water available any time to residents and reduce the operating costs of delivering water via truck to these kiosks. Furthermore, USUG has ongoing projects to connect kiosks to the central water pipeline. However, the infrastructure for this is very costly and they may face land ownership challenges if residents don't agree for the construction work to go ahead in their plots. So, whilst projects to improve water security in *ger* areas are necessary and indeed underway, ongoing challenges to implement these fully results in an ongoing state of water marginality for communities living in the urban fringe.

6.4. Good policy but poor implementation.

Another recurring theme throughout the interviews concerned the contrast between water policy and regulation on paper against everyday implementation challenges. Water governance is the highest scoring dimension of the index with a 'very good' score of 3.5. This is because Mongolia's water laws, policies and regulations follow international best practices and standards closely. However, challenges arise when it comes to implementing and enforcing these high standards. Three main themes were identified as limiting the different institutions from effective policy implementation and enforcement. These are lack of funding, lack of human resources and institutional fragmentation.

For example, one of the variables used in the index is the implementation of the IWRM plan. The Tuul River Basin Authority is an implementing agency whose main role is to design, implement and evaluate the IWRM plan. The latest phase of the Tuul River's IWRM plan was completed in 2021 and an extensive internal review of the process has taken place adhering to the UN's best practices on the process. However, the acting head of Water Management and Planning Division of the organization flagged during our interview that the institution lacks significant funding and human resources. She mentioned that they do not currently have a budget to undertake the activities laid out in the IWRM plan which were not completed by 2021, and that obtaining the financial support from the local government can be challenging. She also pointed out how the lack of funding and investment in the water sector is affecting their ability to employ skilled professionals. "You can see there are a lot of tables in here but I'm alone, we are supposed to have five people in the division but currently I'm the only person working in here…" says as she points around the empty room.

Furthermore, representatives of the Basin Authority, USUG, MCA and the WB in Ulaanbaatar all stressed that challenges arise due to the high degree of institutional fragmentation in the water sector. Water is an issue that cuts across sectors, institutions and spatial scales [7]. Although water policy generally falls under the jurisdiction of the Ministry of Environment and Tourism up to 10 different ministries may become involved at the same time for any single water related project. On top of this, there are different local implementing agencies that have different responsibilities, work on different timescales and budgets. This institutional fragmentation leads to lengthy and, at times, uncoordinated implementation. For example, an employee of the MCA noted that delays in their projects often had to do with the project's approval process. For an activity to get approved it first need to be reviewed by two or three different ministries and once this process is complete it then needs to pass a special committee with other members of government.

Overall, participants agreed that advances in policy coherence through better inter-agency communication could greatly improve policy implementation. Simultaneously, they noted that funding would also be crucial to ensure that policy is effective not only on paper but in practice too.

6.5. Limitations and directions for future research.

This paper has provided an overview of urban water security challenges in Ulaanbaatar. However, the water security index in this paper should be taken as a preliminary assessment which can be used to inform further research.

Due to poor data availability, especially when looking exclusively at the city region as the scale of analysis, this study relied heavily on secondary literature. Although the variables accurately reflect their corresponding dimensions and, when asked, the participants agreed that they were useful and accurate, more should be done to collect primary data and make this publicly accessible. When asked about the challenges around accessing data, two key issues were raised by the participants. The first is simply the lack of data given limited funding or measuring tools for this. The second was some existing data not being publicly available due to national security concerns. Water is considered to be a strategic resource and water laws are embedded in Mongolia's national security strategies so some information, especially on groundwater wells, is highly classified.

Relying on secondary literature also means that this index is static and can only reflect the current urban water security situation in Ulaanbaatar. Using primary data instead that could be collected on an annual basis would allow for a greater replicability of the index and record changes in the different dimensions over time. The suggestion for future researchers is that they use this study to identify areas of special concern and try, in so far as possible, to collect primary data that could support their own assessments and include more variables for each dimension.

7. CONCLUSION

This study has focused on urban water security in Ulaanbaatar, Mongolia's capital city. It has put together a water security index at a more local scale which identifies key challenges for the city's water sector. In doing so, it is the first study to use this particular security index method in Ulaanbaatar. These findings were discussed drawing from information gathered through key informant interviews undertaken during fieldwork in Ulaanbaatar. Table 5 summarizes the main findings of this paper.

Table 5. Summary of main findings.

Main Findings
1. Data unavailability creates important limitations for accurately assessing water security in Ulaanbaatar and its change over time. 2. There is a lack of investment in Ulaanbaatar's water sector which limits the operational capacity of local implementing agencies. 3. Flood risk is very high and intensifying, increasing the annual economic loss from flooding in the city. 4. Water marginality prevails in the city's *ger* districts which have limited water infrastructure and are at higher risk of water contamination from sewage runoff. 5. Legal frameworks and policy standards are very high in Ulaanbaatar but their implementation and enforcement is complicated by lack of funding, limited human resources and institutional fragmentation.

To date, academic literature on water security across disciplines has been critiqued for poorly integrating the needs of policy-makers and practitioners [19]. This study has aimed to address this gap by working with local water sector experts to identify the more pressing water security challenges. More research on this topic is critical for Ulaanbaatar as rapid urbanization and worrying climate change projections create an uncertain future for urban water security. Undertaking finer scale assessments of water security is crucial to better understand context-specific concerns and opportunities, particularly in the context of intensifying anthropogenic climate change.

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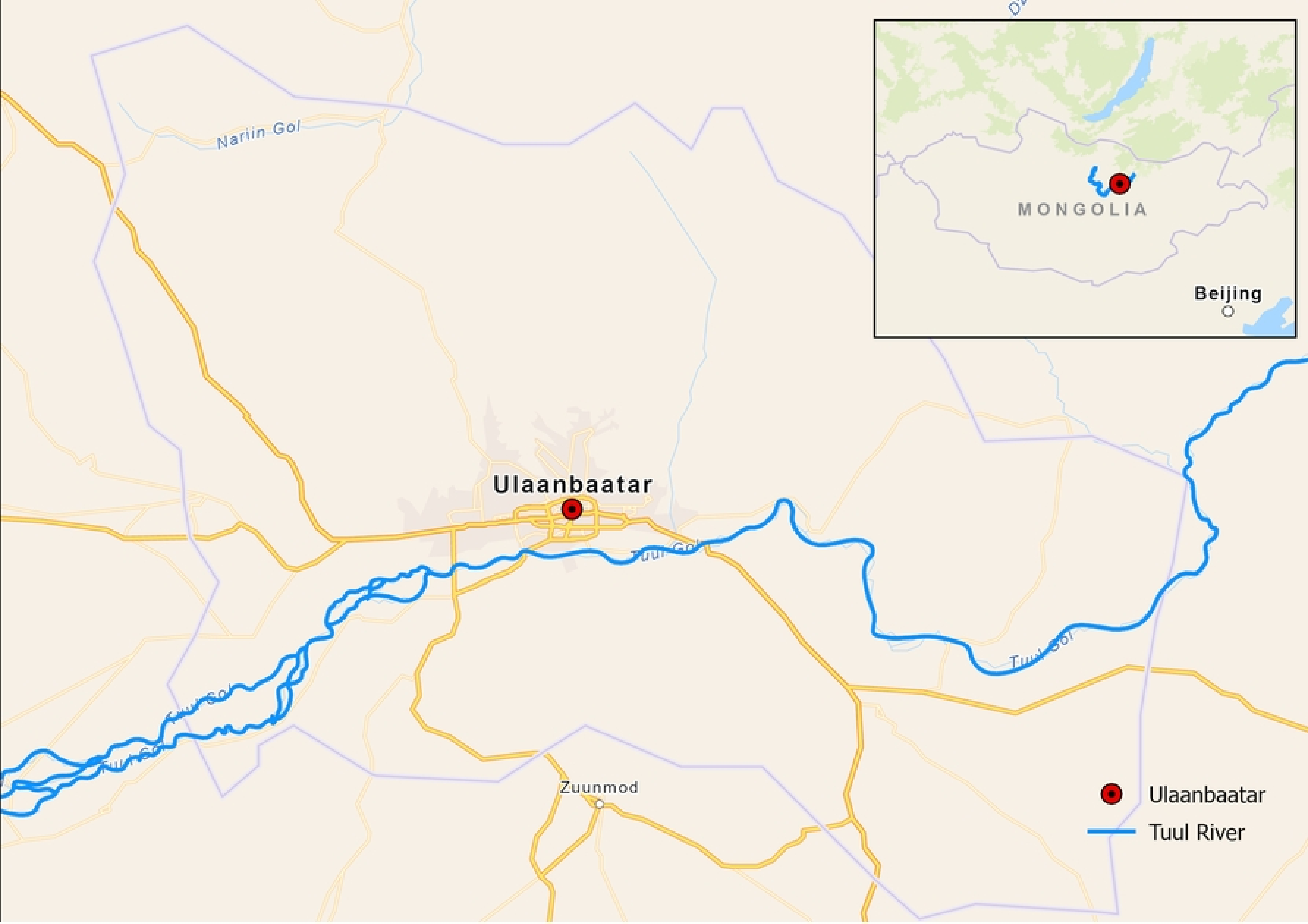
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Figure 1

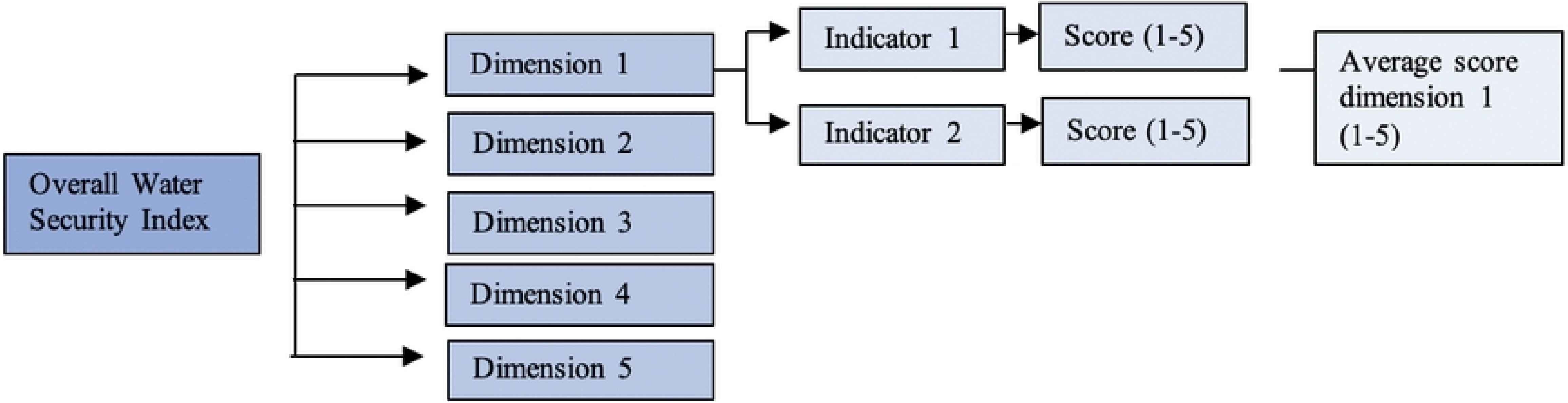
Overall Water
Security Index
Dimension 1
Dimension 2
Dimension 3
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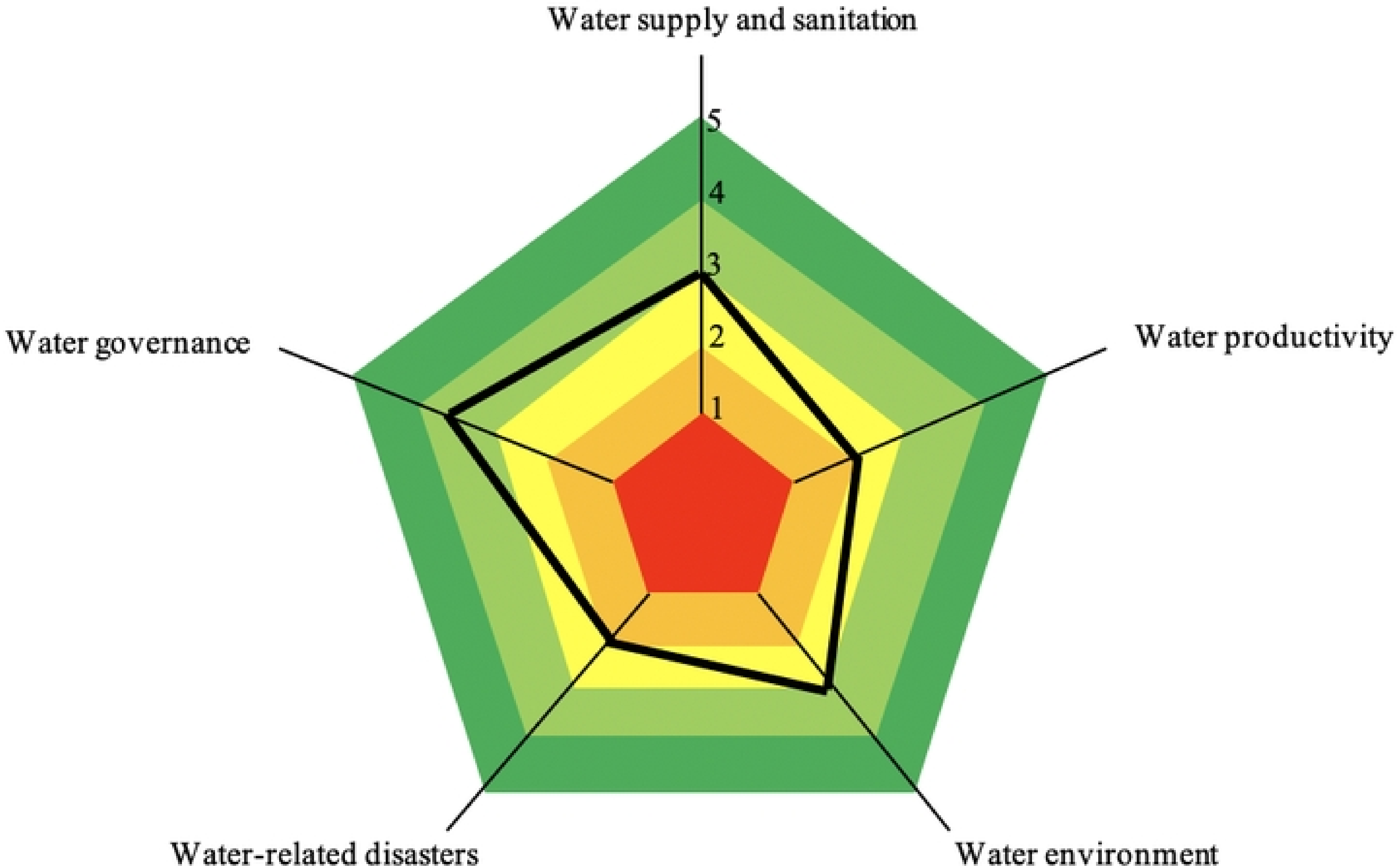
Figure 2


Water supply and sanitation
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Water productivity
Water governance
Water-related disasters
Water environment

Figure 3