Addressing, Assessing and Improving Water Security

Subjects: Public, Environmental & Occupational Health | Water Resources | Engineering, Environmental

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Water security is about managing too much, too little and/or too polluted water. Water security is about the increasing importance of sustainable management of water resources, drinking water and human well-being and protection of life and property from water-related disasters. Water security is about the health of ecosystems and economic development. A groundwork of this broad and multi-faceted concept is presented to facilitate understanding, measuring and improving water security.

Keywords: water security ; assessment ; sustainable development ; policymaking ; water governance ; innovation ; climate change

1. Water Security Definitions

Water security was first articulated as a policy challenge at the World Water Forum in 2000 in the United Nations (UN) Ministerial Declaration of The Hague on Water Security in the 21st Century and it has remained on the agenda of international organizations since then [1]. The Ministerial Declaration led to wide use of the term in global policy, development and science agendas over the past 20 years and developed into a multi-dimensional concept that has widely differing interpretations [2]. Definitions have proliferated, generating both convergence and confusion about the concept and options for measuring and managing water security [3]. Detailed analyses on how water security is defined by different authors can be found in the literature [3][4][5]. Well-known and accepted water security definitions, such as the one proposed by the Global Water Partnership [6], Grey and Sadoff [7] at the World Water Forum in 2006, UN-Water [8], UNESCO [9] and OECD [10] (for definitions, please refer to Supplementary Materials), vary in origin, scale and emphasis, engagement with issues and concepts and the way they address different dimensions (**Figure 1**). This suggests that consensus on the definition of water security, while important, is unlikely (**Figure 2**).

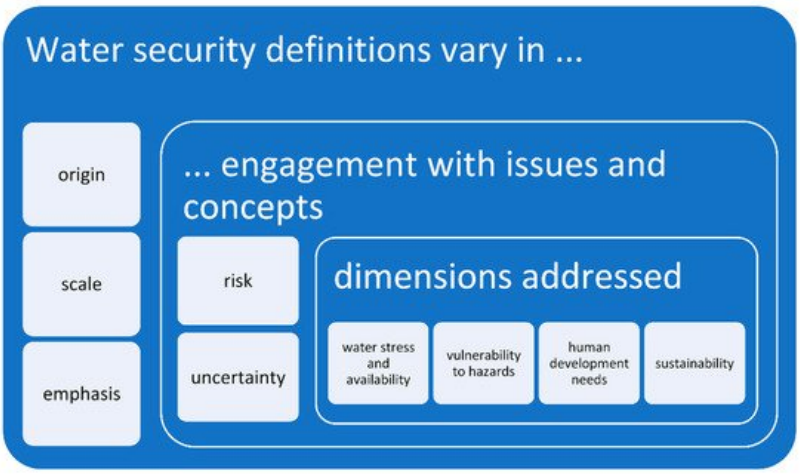

Figure 1. Water security definitions.

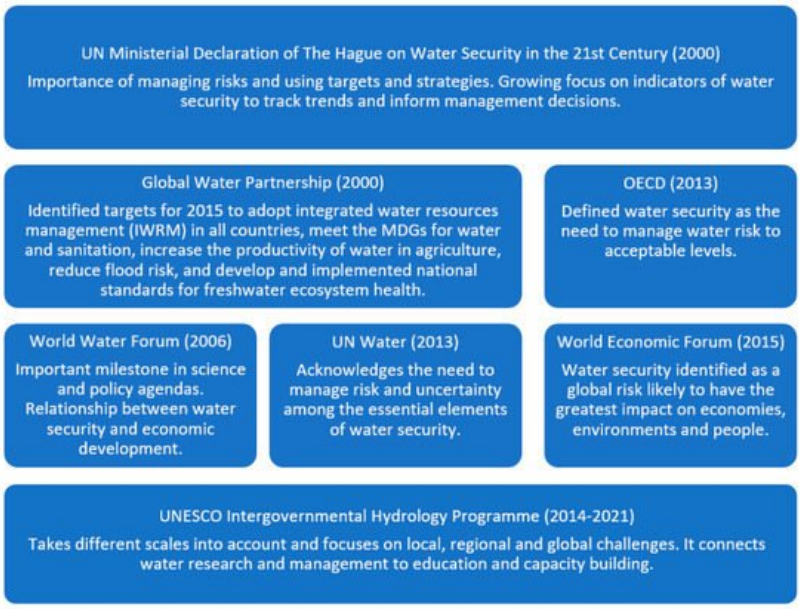

Figure 2. Water security: risks [11][12].

Nonetheless, an effort to adopt a holistic definition can enrich and broaden studies around water security. Therefore, we suggest the adoption of the UN definition (**Figure 3**). However, it should be noted that such an all-encompassing definition presents disadvantages, such as the difficulty of operationalising it and in identifying a suitable set of indicators that might be used to measure the current situation and changes over time [12].

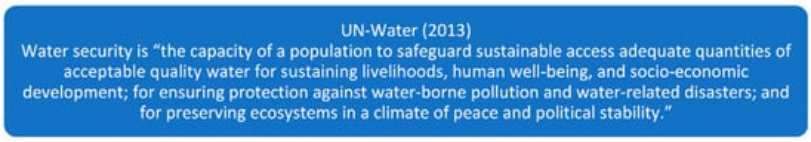

Figure 3. UN-Water [8] definition.

2. Water Security Assessment

Assessing water security allows understanding of the current situation and identifying challenges and areas that need attention. It is an essential step to prioritise and address issues, inform planning and implement and monitor water security actions. It is, therefore, crucial to know how to evaluate water security.

2.1. Overview

From the academic, private and governmental and non-governmental organizations, frameworks, approaches and tools have been developed over the years aiming to assess and study water security on different scales.

Because water security is a wide notion and a fairly recent one, many tools developed over the years assessing concepts such as *water resilience*, *water insecurity*, *water sustainability*, *water governance* provide evaluation for aspects encompassed by the concept of water security. Although designed for different notions, these evaluation methods are often complementary. Van Ginkel et al. [13] compared the results from their water security assessment framework to the assessment outcomes of two other well-known index systems: the Sustainable City Water Index from Arcadis [14] and the City Blueprint from KWR [15]. Their results showed good correspondence despite conceptual differences [13].

Examples of different frameworks assessing water-related concepts are presented in **Figure 4**. This figure does not present an exhaustive list of the existing frameworks, but simply provides an illustration of the diversity of concepts and assessment methods around water issues.

Figure 4. Examples of frameworks for assessing different water related concepts: Water security [16][17]; Water governance [18][19]; Water sustainability [14][15]; Water resilience [20][21]; Water risk/insecurity [22][23] and Utilities performance [24][25].

2.2. Scales and time dependence

From the household to the global scale [6], water security is a local, regional, national and global issue. Due to water security having a broad definition, it has been interpreted over the years at different scales.

The boundary of a framework can be assumed at different levels and contexts, changing the focus of the water security assessment. Nevertheless, these boundaries are not absolute and as scales are connected, the aspects included for different scales can also be associated or shared. Examples of frameworks designed for different scales are presented in **Table 1**.

Table 1. Water security assessment: scales of application.

Scale	Examples and considerations
Global	**Global water security assessment was carried out by Vorosmarty et al. [26], considering human and biodiversity perspectives: drivers and impacts related to catchment disturbance, pollution, water resource development and biotic factors were quantified at a global scale. Gain et al. [27] also provided a global assessment using the Global Water Security Index, using indicators based on SDG 6.**
National/ Country	**Usually encompassing all four dimensions from the UN definition [28], frameworks such as the National Water Security Index [29][30] from the Asian Development Bank, the Water Security Scorecard [31] from the Australian Water Association and others developed by scholars such as Dou et al. [32], Marttunen et al. [33], Su et al. [34], Lautze et al. [35] look at water security at a national scale. The National Blueprint Framework [36], although not designed for water security specifically, provides indicators to measure progress on SDG 6.**
Basin/ Watershed	**With a focus on water quantity aspects such as availability, utilisation and scarcity resources, frameworks at this scale also bring attention to climate change aspects and governance since watershed or basins do not follow administrative boundaries of cities or states, with concerns over the surface and groundwater quantity and quality at this scale often requiring transboundary cooperation. Works developed by scholars such as Babel et al. [37], Yin et al. [38], Xiao et al. [39], Norman et al. [40], Jia et al. [41] provided frameworks for basins of watersheds. Notably, the use of hydrological models is often used, providing valuable predictions.**
Regional	**An intermediate between the city and national context, studies at a regional scale usually follow administrative boundaries of regions or provinces, sometimes comprising several basins and smaller regions. Encompassing not only urban areas but also areas of different land uses, considerations around agricultural activities, ecological and environmental aspects are present. Scholars such as Liu et al. [42], Li et al. [43], Zhang et al. [44] provided regional evaluations.**
City/ Urban	**The urban level frameworks tend to incorporate many aspects regarding availability, access and reliability of water services, governance, water hazards, etc. One of the key dimensions of the National Water Security Index by the ADB [29], notable frameworks such as the City Blueprint Approach (KWR) [15], Sustainable City Water Index (Arcadis) [14] and the City Water Resilience Index (ARUP) [20] are city-specific. As are works from scholars such as Van Ginkel et al. [13], Jensen et al. [12], Ghosh et al. [45] and Romero-Lankao et al. [46].**

Scale	Examples and considerations
Community	**At this scale, frameworks show concern with management strategies, governance and other social aspects. The Canadian Water Sustainability Index (CWSI) [47] was developed to assess the well-being of communities with respect to water. The WaterAid [48] framework highlights the importance of a participatory process involving the community. Authors such as Wutich et al. [49], Shrestha et al. [50], Norman et al. [40] and Dickson et al. [51] considered communities as the scale to assess water issues.**
Household/ Individual	**Focus on essential needs (access to water and sanitation) and aspects related to health and hygiene, social and gender inequality, emotional stress and food security are present at this scale. One key dimension of the National Water Security Index by the ADB [29], and sometimes described in terms of water insecurity, this level has also been assessed by scholars such as Jepson [52], Hadley and Wutich [53], Wutich [54], Brewis et al. [55], Webb [56] and Tsai et al. [57], among others. The HWISE-RCN by Young et al. [23] is notably investigating experiences, causes and outcomes of water insecurity at the household level.**

The differences in contexts show that water security is a complex problem and a single way to evaluate it would not be adequate to all scales. The spatial scale of water security allows us to focus on specific problems and challenges. Although different levels can be considered they are all connected since improving water security is a response to local, regional and global challenges with multi-level implications.

The study of different scales is also associated with the context in terms of the level of development and specific geographic challenges. The African continent for instance has experienced a rapid urbanization process, linked to migration from rural to urban areas [58] and population growth. This leads to experiences of water stress, scarcity and inequality of water services access in cities. This has fuelled not only studies at the city scale but also at the domestic level to investigate the household experience of water security in urban and peri-urban areas [58][59][60][61].
Along with considerations of spatial scale, the temporal variation is equally important in the interpretation and assessment of water security. Temporal distribution of water resources, seasonal effects, climate change, water governance, seasonal demand and demographic variation, amongst other factors, will influence and change water security in space and time.

The application of an assessment framework, as thorough as can be, will invariably represent a moment (or a snapshot) of the evaluated concept. Therefore, as parameters do change over time in the real world, it is crucial to consider the time dependence of water security. To provide a good picture—or a ‘dynamic picture’—of water security, elements such as long-term droughts, changes in precipitation, flood frequency, temperature fluctuation, demand growth and demographic changes, among many other factors or aspects used for water security assessment, need to be interpreted over time.

The time dependence of water security also calls for an ongoing re-evaluation in a region, city, or community. Water security assessment frameworks should be applied as part of an improvement cycle [48] in order to account for changes brought by interventions or pressures. This allows stakeholders to understand the full potential of actions and the update of priority actions, indicators thresholds and goals providing incentives for improvements and new adjustments.

2.3. Approaches and Methodologies for Water Security Assessment

Due to the complexity and different interpretations of the water security concept, there is no standard evaluation method. There are however many approaches, perspectives and methodologies that can be used to translate water security into metrics or frameworks that can help evaluate and provide information on how to improve it.

Water security assessment may be guided by different perspectives. Focus on specific water security aspects may be guided by the discipline. For instance, in the engineering domain, studies on water security give emphasis to flood protection infrastructure and water supply, while environmental studies will focus on water quantity, quality and hydrological variability [62].

Approaches such as risk-based, systemic, metabolism approach, Pressure-State-Response (PSR), Driver-Pressure-State-Impact-Response (DPSIR) among others (see **Figure 5**), are ways to contemplate the problem of water security and decide on the considerations and aspects for a subsequent evaluation. These conceptual models are not exclusive and are often combined by authors to provide a comprehensive evaluation framework.

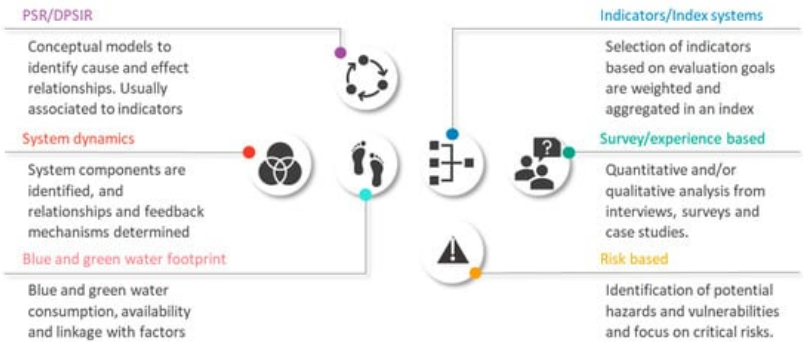

Figure 5. Approaches applied in water security evaluation.

2.4. Water Security Indicators

Very commonly used as a basis for water security evaluation, indicators are often gathered in an index system to convey the different aspects of the concept.

Indicators are sometimes considered under certain dimensions or groups. However, due to the complexity and interconnectivity between different aspects of water security, authors do not always agree on the same categories or even consider the same dimensions of water security. This depends on the scale, context as well as on the definition of water security and methodology adopted. This demonstrates that water security assessment is, naturally, a problem as complex as its definition. A variety of indicators found in the literature, based on the UN definition [63], was divided into four dimensions, as seen in **Figure 6**.

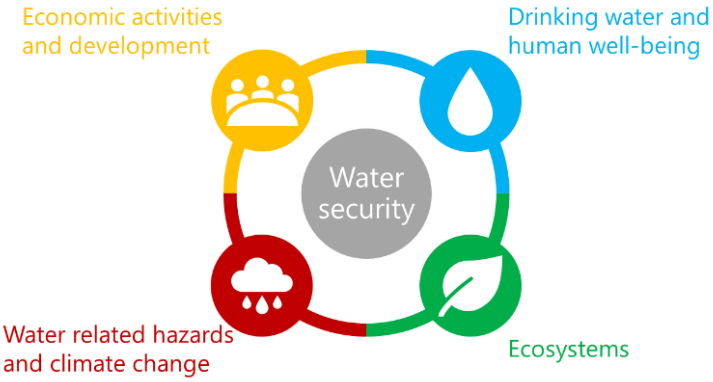

Figure 6. Water security dimensions based on the UN definition [8].

Within the four dimensions from the UN definition, aspects and indicators considered in different water security framework assessments in the literature were divided into categories as seen in **Table 2**. This provides a summary of what can possibly be adopted to measure the different dimensions, illustrating the complexity and amplitude of this concept. As previously stated, the final choice of what to consider in a metric will depend on methodology, scale, perspective, data availability amongst other factors.

Table 2. Water security aspects found in water security frameworks.

Dimension	Categories	Indicator / aspects
Drinking water and human well-being	Water quantity	Water availability, adequate quantity for basic needs, demand and consumption; diversity of sources; precipitation and water balance; water storage; exploitation of resources; water stress and usage efficiency.
	Quality	Quality of water for human consumption (meeting standards); aesthetic, perception and quality acceptability; water treatment practices.
	Access to water services	Access to improved drinking water source; improved sanitation; piped water or water supply connection; accessibility of water points; affordability of services; wastewater collection/sewage connection.
	Infrastructure reliability	Asset management and maintenance; infrastructure condition/age and capacity; reliability (complaints/blockages/interruptions); service level; service continuity (hours of service); water leakage, non-revenue water.
	Reuse/ recycling	Water/wastewater reuse; energy or nutrient recovery; rainwater harvesting; solid waste/recycling.
	Hygiene and public health	Water-related diseases; incidence of diarrhoea; adequacy of water for housework and hygiene; other health problems.
	Wellbeing	Emotional stress, fear, frustration; safety or dispute; deprivation or lost opportunity; recreational opportunities.
Ecosystems	Environment	Surface and groundwater water quality; river health; wastewater generated and adequacy of wastewater treatment; biodiversity; environmental flows; environmental protection actions; pollutants discharge (harmful substances, pollution loading); soil erosion; wildfires; vegetation cover and land use.
	Sustainability	Energy use/efficiency; renewable energy; sustainable natural resources use; sustainable water use; water sensitive urban design.
Water hazards and Climate change	Water-related hazards	Floods (frequency, affected area and population, hazard and vulnerability, protection infrastructure); droughts (frequency/vulnerability/area affected); economic loss; landslides; prevention, preparedness and response; water pollution accidents.
	Climate change	Climate change response; greenhouse gas emissions; salination and seawater intrusion; temperature.
Economic Activities and Development	Economic activities	Water for agriculture, manufacturing; commerce, energy production; broad economic development; water-related business opportunities; food production and demand; water footprint; water use/GDP or GDP/water use.
	Governance	Institutional organization and capacity; accountability and corporate governance; data availability, multi-level and multi-stakeholder participation/engagement; communication and transparency; investment/funding and financial management; legal and regulatory aspects; science, knowledge and innovation; strategic planning; transboundary and international collaboration.
	Socio-economic aspects	Education and awareness; GDP; income/unemployment rate; informal dwellings; population density; social and cultural aspects; urbanization rate.

3. From Paper to Action: Measuring Progress, Achieving Goals and Improving Water Security

Indicators play an important role in describing the complexity of a system, dissemination of information and translating important aspects of a complex system into an accessible format that can be understood and monitored by different stakeholders. As a useful tool to identify critical problems, they have the potential to guide governments and decision-makers in developing action plans and making informed political interventions to tackle areas that need attention in order to improve water security.

From water security assessment, case studies, experiences, observations, consultations, etc., authors in the literature have gathered a range of experiences allowing identification of solutions, suggestions or interventions that could help improve water security. From these, certain actions with the potential to help achieve water security goals have been identified (see **Figure 7**). Sharing these actions is as important as measuring and aiming for water security since the only way to achieve goals and improve water security is going from paper to action and implementing measures.

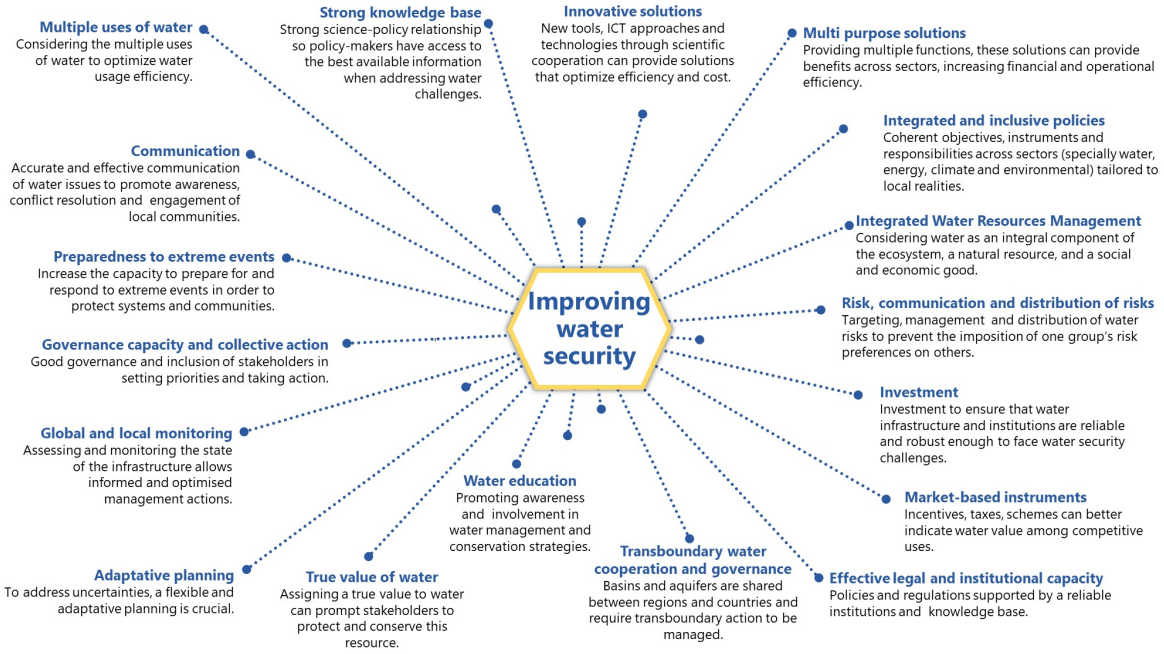

Figure 7. Summary of actions with potential to improve water security.

4. Concluding Remarks

Through different scales and approaches, the evaluation of water-related concepts, in particular water security, is an important step into achieving the SDGs. Although different definitions and frameworks have been proposed in the last decades, research questions around water security, and how to improve it, are still of great relevance. Like the concept itself, water security challenges are multifaceted and facing them depends not only on research and innovation but also on policies, management strategies and governance.

The development of frameworks and the potential to measure water security allows a wider and clearer vision view of water challenges. Investigating water security provides crucial information on this ever-changing, multi-faceted concept, allowing to produce the best possible information on needs and challenges. This fuels research to develop means to better measure and improve water security.

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