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TOWARDS DEVELOPING A DOMESTIC WATER SECURITY INDEX FOR SOUTH AFRICA

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Background

The primary input to our water resources is rainwater and South Africa's rainfall is unevenly distributed in time and space. It is estimated that 8% of our water source areas provide 50% of the available water. Combined with climatic patterns, topography, spatial distribution of the population and industries, South Africa is inherently a water scarce country. This is worsened by an increasing shift towards overall lower rainfall and higher evapotranspiration in southern Africa. Locally, our rainfall is highly seasonal and variable in time and space, coupled with a potential evaporation rate that is generally greater than rainfall. South Africa gets most of its water supply from surface storage. Surface storage systems comprise approximately 5 000 registered dams, 3 832 of these are small dams serving farms and municipalities and imported water from Lesotho. The few low-capacity desalinisation plants (brackish groundwater and seawater) are localised. Because of the complexity of our geology, the ground is widely but unevenly distributed. Groundwater is predominantly used in agriculture, rural water supply and some urban supply. Groundwater provides >50 % of the water supply to 36% of all settlements in South Africa. A large proportion of the 36% relies 100% on groundwater resources. Although a small proportion of the overall water system, groundwater provides 100% water security for large parts of the country where surface water source networks are not available. Groundwater use is estimated at 3 000 million m3/a and 4 500 million m3/a is estimated to be still available for exploitation.

Institutionally, water planners always preferred surface water supply systems to the point that 98% of all surface water is now allocated with only a few dam building sites remaining. It is estimated, in the National Water and Sanitation Master Plan (NWSMP), that by 2025 that there will be marginal increases in groundwater supply and incorporating acid mine drainage (AMD) water into the supply mix (Figure 3). Desalinisation will also increase marginally as a percentage of the total water supply. The bulk of the desalinisation will come from coastal seawater units. Several desalinisation plants are operational in Kwa-Zulu Natal, Eastern and Western Cape. The Department of Water & Sanitation (DWS) determines the use and needs of towns and villages through All Towns Reconciliation Strategies programme. It focusses on existing water resources and supply schemes, consider both current and expected future water requirements, along with the potential water resources available to meet these requirements. The overall aim is to ensure that towns and village clusters always have a positive water balance up to 2035.

Water security at the settlement to household level can be achieved by a variety of means. Unfortunately, all the metrics that we track relate to water held in storage. This is usually surface water impoundments and groundwater stored in aquifers. The latter is poorly monitored because of

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underinvestment in monitoring schemes coupled with its distributed nature needs assessment at the very local level.

Water security is not only rooted in the physical availability of freshwater resources relative to water demand, but also on economic and social (e.g. sound water planning and management approaches, institutional capacity to provide water services, sustainable economic policies). Advanced tools and methods are available for the assessment of water scarcity. Since the assessment of water security at a domestic scale has not been adequately undertaken in developing countries such as South Africa, it is essential to develop an appropriate framework for the assessment of water security at a domestic scale and apply it for towns and cities within South Africa. The aim of this brief is to explore the development of a water security assessment framework. The framework comprises five dimensions: water supply, sanitation, hygiene, water management and governance and environment and ecosystems and nineteen indicators and thirty variables. Analytical hierarchy process (AHP) and equal weighting methods were suggested to compute an index by giving different and equal weighting factors for variables, indicators and dimensions, respectively.

Introduction

Water security is the "availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies" (Grey and Sadoff, 2007). Meeting water needs is a significant challenge exacerbated by physical and economic scarcity. Physical water scarcity causes and challenges are well documented, but issues associated with economic water scarcity are less so. Economic water scarcity results from a lack of water infrastructure investments or poor management of water resources where infrastructure is in place.

Water insecurity can be expressed at various scales depending on the intended use. In a hydrological sense, we can look at it at various catchment scales (tertiary, secondary, primary and quinary). In an administrative sense, we can look at it at from National to Provincial to community and finally at the household scale. Agricultural scale can be disaggregated into, depending on whether it is rainfed or irrigated, catchment and field scale.

Household water security is a function of what happens at the source of water (dam, aquifer, desalinisation plant), how it is being distributed, and how it is being used and experienced at the point of use. Water security dimensions at the source may include the quantity of water, storage capacity (including unavailable storage because of siltation), climate change and weather variability, source access (infrastructure and allocation) and management of the source. Living next to a water supply source is not a guarantee for water security as evidenced be several schemes where pipelines pass communities on its way to those allocated the water. The conveyance systems between the source and point of use depend on access to the source, reliability, affordability, energy costs and infrastructure integrity (water losses) among others. Point of use indicators are water quality, quantity, uses, affordability, and consumption requirements. All this is enveloped in competing drivers and pressures such as climate change,

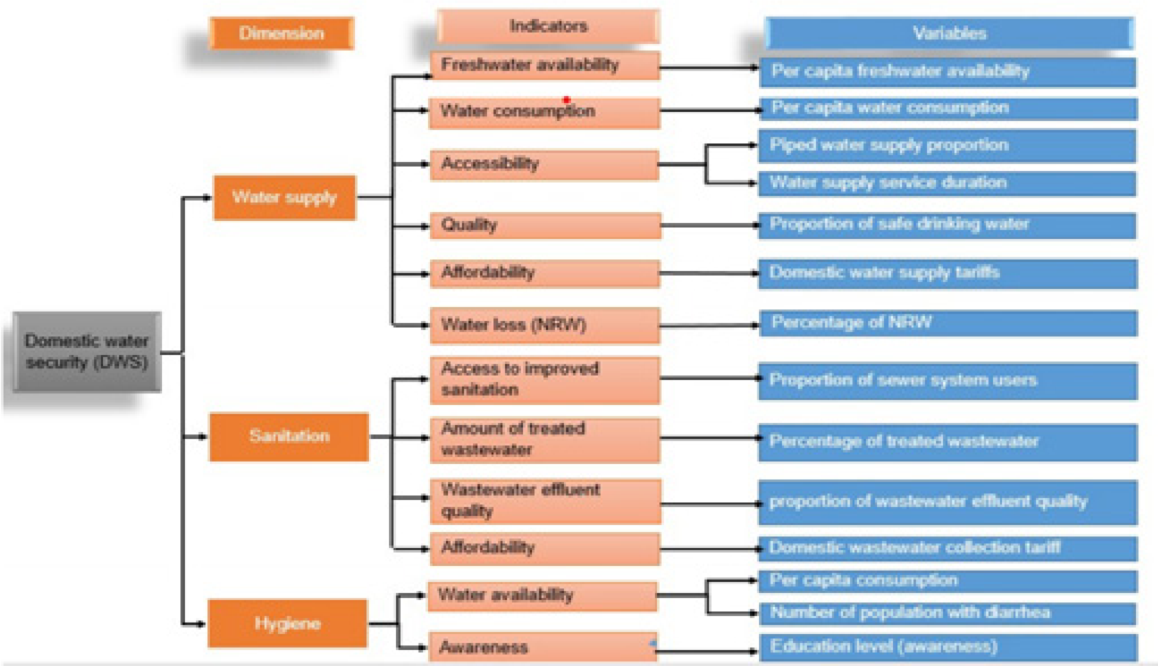

Figure 1: Dimensions of domestic water security as described in SDG 6 (Assefa et al., 2019).

rapid urbanisation, economic expansion, and population growth. Water insecurity also affects food security, health, and sanitation services. Land-use planning, and especially settlement planning, without due regard for infrastructure layout and conveyance energy costs, determines affordability and access. Integrated planning, across sectors and levels of government, is key to ensure household water security.

The 2021 StatsSA Household Survey notes the following – " … access to water actually declined in six provinces between 2002 and 2021. The largest declined was observed in Limpopo (-4,4 percentage points), Mpumalanga (-4,3 percentage points), North West (- 2,2 percentage points) and Free State (-2,0 percentage points). In addition, access to water has been declining in both Eastern Cape and Limpopo since at least 2014. On the positive side, one should, however, consider that many more households were provided with water in 2021 than two decades earlier.".

Many of these surveys and water-related statistics depict what the end-user experience and not the root causes of water insecurity. Access to water sustainably is often lumped into the statistics and rarely reflect the time households do not have a continued supply of water even if they have access to water delivery systems.

Each scale has its own usefulness for planning and allocation purposes. Another layer can be the water requirements and availability related to domestic (household), food, energy, economic and environmental security. As an example, water security further depends on not only water availability but also consumption patterns, access to water sources, water quality, affordability, and water losses (leaks, wastage and incorrect allocation) (Figure 1).

Overview of available water security indices

The concept of water security has been widely recognised as an increasingly important policy challenge. To confront this challenge, appropriate indicators and indices are required to measure the effectiveness of interventions and simulate policy action. In recent years, many conceptual frameworks, methods, and indicators have been developed to assess and determine water security at various levels. The notability and proliferation of water security indices in integrated water resource management (IWRM) are attributed to their simplified, mathematically sound and easily communicated outputs (Brown and Matlock, 2011). Water indices are beneficial as they identify vulnerable areas that require strengthening, suggesting potential leverage points for intervention and monitoring the efficiency and effectiveness of specific interventions (Mason & Calow, 2012). Comparatively, they enable benchmarking performance, cross-learning, and the creation of best-practice standards. A review of existing water security indices can be a helpful reference for researchers interested in harmonizing different methodologies or developing new water security or availability indices. Below is a table illustrating the diverse water security indices available:

Table 1: Summary of water security indices

INDEX	DESCRIPTION	SOURCE
Falkenmark Indicator	Water resources per capita index that assesses the adequacy of a nation's water resources	Falkenmark, 1989; Data: FAO, 2013
Water stress index		Falkenmark, 1989
Social Water Scarcity Index	Ratio of water scarcity/stress index (WSI) to the HDI; considered as a workable proxy for the social adaptive capacity of a society	Appelgren & Klohn, 1999; Data: FAO, 2013; UNDP, 2013a
Water Poverty Index	Combines into a single number a cluster of data directly and indirectly relevant to water stress. Subcomponents of the index include measures of: a. Access to water b. Water quantity, quality and variability c. Water uses (domestic, food, productive purposes) d. Capacity for water management e. Environmental aspects f. Questions of spatial scale	Lawrence, Meigh, & Sullivan, 2002
Enhanced Water Poverty Index (eWPI)	Intended to integrate biophysical, social, economic and environmental issues as well as the existing pressures and policy responses into one single comparable, dynamic indicator	Garriga & Foguet, 2009
Rural Water Livelihoods Index	attempts to assess some of the more fundamental, water-related components which influence rural livelihoods, and which can support rural poverty reduction	Sullivan et al. 2009

INDEX	DESCRIPTION	SOURCE
Index of Drinking Water Adequacy-2	Addresses the gap identified in Rao (2007), that is, the need for indicators of 'quantitatively and qualitatively good access with coverage that is secure.' IDWA components are same as those of WPI such as resources, access, capacity to buy water, use and quality. The index values for these components are averaged to obtain IDWA values by country. Provides the relative position of the different countries in a more comprehensive fashion than do simple access indicators; each component could trigger a message, depending on an economy's particular need	Kallidaikurichi & Rao, 2009
Water Resources Vulnerability Index	tool that communities can use to assess their relative vulnerability-resilience to changes in their water resources from a variety of biophysical and socioeconomic processes	Raskin et al., 1997
Composite Water Vulnerability Index	designed to rank slums on various parameters such as Availability, Accessibility, Reliability, Quality and Burden of Disease.	Paladini, 2012
National Water Security Index	measures water security by quantifying the five KDs in terms of clear and measurable indicators	Asian Water Development Outlook 2020
Water Service Index	Combines a set of measurable indicators of a water service into a single measure	Kayser et al., 2013
urban water security index	The urban water security index describes the progress the countries are making to provide better urban water services and management in order to develop vibrant, liveable cities and towns	**Asia Water Development Outlook 2016,** by Babel et al. (2017)
Household Water Security Index	measures the achievement of a higher standard of services including piped water supply, access to improved sanitation and hygiene. It provides an assessment of the extent to which countries are satisfying their household water and sanitation needs and improving hygiene for public health in all communities	Hailu et al.,2020

Conceptual process in developing a domestic water security index

Amidst the extensive assessment frameworks and definitions of water security, a wide variety of well-established indicators have been applied at a domestic level to provide different perspectives on water security. The two most widely utilised indicators include:

- Stand-alone indexes, which include the water poverty index and water stress index. These indexes were developed to be applied at all scales, including the city scale, but are not narrow and salient enough to capture multiple aspects and dynamics of domestic water security. Thresholds utilised are arbitrary and not rooted in scientific principles

- Composite indicators, such as the Asian Development Bank's Urban Water Security index. This index forms part of Asia's national water security rankings, utilising the averages of all urban areas and is likely to be utilised by decision-makers at the urban level. The development and application of a city-specific water index can be achieved by integrating a city's blueprint framework (CBF) to capture urban water security issues, but it specifically seeks to measure integrated water resource management (IWRM) implementation within different cities and also benchmark cities on their resilience at the economic, social and environmental dimensions.

The proposed framework has been developed according to the needs and special characteristics of domestic water security in South Africa, to evaluate current and future state of water security scientifically soundly, using a standard method for constructing indicators based on the definition of domestic water security. The method for operationalizing domestic water security is based on seven systematic steps, as shown in Figure 2, starting with (1) defining domestic water security; (2) identifying appropriate dimensions; (3) selecting indicators for each dimension; (4) then choosing appropriate variables for each indicator; (5) scoring, weighting and benchmarking variables (6) measuring the index and (7) interpreting the index

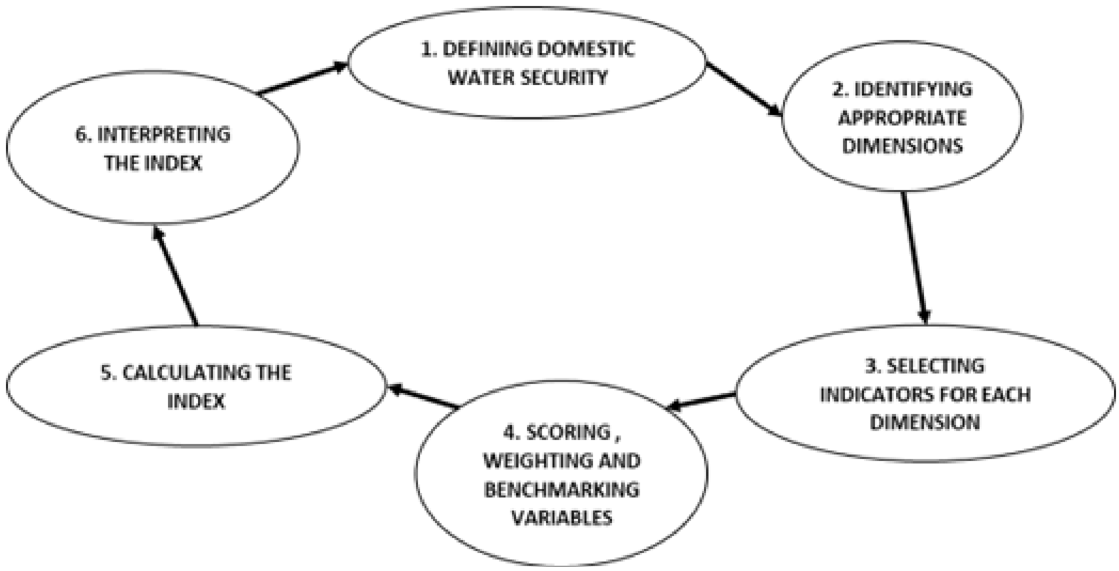

Figure 2: The domestic water security framework cycle.

Proposed method

The dimensions selected will depend on the scale of assessment, locality and the specific aim and objectives of stakeholders and decision-makers. Based on the definition of domestic water security and various literature , domestic water security consists of three main integrated issues as the dimensions of the assessment, which are: Water supply, Sanitation and Hygiene. Two additional dimensions must be added; Water Governance and Management and Environment and Ecosystems.

Selection of indicators for each dimension

Indicators are tools that provide information about something. They are used to express the nature of key dimensions and their selection will depend on the purpose and specific application of the assessment. They also communicate or inform about the process toward a goal, such as water security, but also indicate a trend about a phenomenon and evolution in management performance. The DPSIR framework and SMART criteria are the basic approaches to select and identify indicators and variables. On the applied DPSIR framework, the impact is the problem on domestic water security and the driver is the cause for the pressure or stress created on. The state is the change due to the stress created or changing the domestic water security status and the response represents the possible solution for solving the problem on domestic water security or to achieve domestic water security. Since the dimensions of water security are water supply, sanitation, hygiene, water governance and management and environment and ecosystems, the driving forces for these dimensions in the South African context are, anticipated population growth, low-income levels, institutional factors and governance climate variability. Due to these driving forces, there is a pressure created on local communities, which is high water demand for drinking, sanitation purpose and hygiene, higher demand of sanitation and hygienic services. The state created due to the pressure are: on water supply(the coverage, availability, quality, quantity, accessibility and affordability of water supply), on sanitation (because of the stress created by the driving forces, there is an issue related to coverage of sanitation system, management of sanitation system and affordability of sanitation facilities) and on hygiene (the coverage of hygienic facilities, implementation of hygienic practices and affordability of hygienic services are the state due to driving forces and the pressure created). The impact was the effect of the change in quantity or quality (state) on the community. Below is a table of indicators for each dimension.

Table 2: Indicators for each dimension

DIMENSION	DIMENSION INDICATORS
WATER SUPPLY	■ Availability ■ Accessibility ■ Quality ■ Quantity ■ Affordability ■ Coverage
SANITATION	■ Coverage of sanitation systems ■ Management of sanitation systems ■ Affordability of sanitation systems
HYGIENE	■ Coverage of hygiene facilities ■ Implementation of hygiene facilities ■ Affordability of hygiene facilities
WATER MANAGEMENT AND GOVERNANCE	■ Overall management of water sector ■ Strategic planning ■ Bulk and Reticulation Infrastructure ■ Disaster management regulations
ENVIRONMENT AND ECOSYSTEMS	■ State of surface water ■ State of ground water ■ Effectiveness of storm network and wastewater network

Selection of appropriate variables for each indicator

Variables are used to quantify the indicators and can answer the question "How to measure". They should be acceptable and reliable and are sensitive to changes over space and time . Several variables can be used to quantify an indicator and they should be able to represent site specific characteristics. They can get directly in the required format or need to apply mathematical equation or techniques to make it in the required format. The variables for each indicator were selected based on the SMART (specific, measurable, attainable, relevant and time bound) criteria. Below is a table with potential water security dimensions, indicators, and variables.

Table 3: Developed domestic water security framework

DIMENSION	DIMENSION INDICATORS	VARIABLE (S)
	Availability	Per capita water consumption Water supply continuity Pressure adequacy
	Accessibility	Per Capita Freshwater Availability
WATER SUPPLY	Quality	Quality of piped water supply Water loss in the system
	Quantity	Adequate water for domestic consumption (per capita consumption)
	Affordability	Affordability of drinking water supply
	Coverage	Coverage of piped water supply

DIMENSION	DIMENSION INDICATORS	VARIABLE (S)
WATER GOVERNANCE AND MANAGEMENT	Overall management of water sector	Institutional factor Adaptability factor Staff productivity
	Strategic planning	National water resource action plans
	Disaster management regulations	Disaster management budget/plans
	Bulk and Reticulation Infrastructure	State of infrastructure Reservoir capacity State of reticulation infrastructure Compliance
ENVIRONMENT AND ECOSYSTEM	State of surface water	Natural water quality factor Sewage treatment factor Heavy metals factor
	State of groundwater	Groundwater quality factor Recharge factor
	Effectiveness of storm network and wastewater network	Sewer system blockages
HYGIENE	Coverage of hygiene facilities	Percentage of the population with access to sanitation services
	Implementation of hygiene facilities	Percentage of the population practising hygienic activities
	Affordability of hygiene facilities	Percentage of the population that is able to afford hygiene services
SANITATION	Coverage of sanitation systems	percentage of population with access to improved sanitation facilities
	Management of sanitation systems	The percentage of safely managed sanitation system
	Affordability of sanitation systems	The percentage of people who are able to afford sanitation services

Scaling and benchmarking of water security variables

Developing domestic water security index means expressing it in terms of number or specific value. It is also helpful for the stakeholders to understand the status of the security in an easy and understandable way. Growth and Transformation Plan II, SDG and Asian Water Development Outlook 2013 documents were mostly applied as a benchmark for the assessment of scales of variables. Therefore, to calculate the index, different variables with various measuring units have to be normalized to a common scale with interpretation. In this approach, the value of each variable is classified into a 1 to 5 scale as shown in Table 4.

Table 4: Representation of variable scores in relation to the 1–5 scale adopted

DIMENSIONS	VARIABLES	UNIT	SCALE					SOURCE
			1	2	3	4	5	
WATER SUPPLY	1. Water supply Availability							
	1.1. Per capita water consumption	L/c/d	>25 & <130	[25–40)	[40–60)	[60–80)	[80–130]	Jumber **et al.,** 2020
	1.2. Water supply continuity	hr	[0–8)	[8–16)	[16–20)	[20–24)	24	Jumber **et al.,** 2020
	1.3. Pressure head adequacy	mH2O	[0–5)	[5–14)	[14–21)	[21–28)	[28–40]	Jumber **et al**., 2020
	1.4. Per capita water availability	m3/c/yr	[0–500)	[500–800)	[800–1000)	[1000–1700)	≥1700	Falkenmark **et al**., 1989
	2. Piped water supply coverage	%	[0–50)	[50–60)	[60–80)	[80–100)	100	Jumber **et al.,** 2020
	3. Water quality index	WQI	>100	(75–100]	(50–75]	[20–25]	≤25	Falkenmark **et al**., 1989
	4. Water loss	%	>35	(30–35]	(25–30]	[20–25]	[0–20)	Jumber **et al**., 2020
	5. Affordability	%	≥5	[4–5)	[3–4)	[2–3)	<2	Jumber **et al**., 2020; Hutton, 2016
SANITATION	1. Sanitation coverage	%	[0–60)	[60–70)	[70–80)	[80–90)	[90–100]	Asian Development Bank. Asian Water Development Outlook 2016 ; Bradley and Bartram, 2013
	1.1. Latrine coverage	%	[0–60)	[60–70)	[70–80)	[80–90)	[90–100]	Asian Development Bank. Asian Water Development Outlook 2016 ; Bradley and Bartram, 2013
	1.2. Coverage of grey water soak pit	%	[0–60)	[60–70)	[70–80)	[80–90)	[90–100]	Asian Development Bank. Asian Water Development Outlook 2016 ; Bradley and Bartram, 2013
	2. Management of sanitation	%	[0–60)	[60–70)	[70–80)	[80–90)	[90–100]	Asian Development Bank. Asian Water Development Outlook 2016 ; Bradley and Bartram, 2013
	3. Affordability	%	≥5	[4–5)	[3–4)	[2–3)	<2	Asian Development Bank. Asian Water Development Outlook 2016 ; Bradley and Bartram, 2013
HYGIENE	Coverage hand wash facilities	%	[0–60)	[60–70)	[70–80)	[80–90)	[90–100]	Gain and Wada ,2016; Vörösmarty **et al.,** 2010

DIMENSIONS	VARIABLES	UNIT	SCALE					SOURCE
			1	2	3	4	5	
	Implementation of hygienic practices (Diarrheal prevalence)	No	>760	(500–760]	(200–500]	(100–200]	[0–100]	Gain and Wada ,2016; Vörösmarty **et al.**, 2010
	Affordability	%	≥5	[4–5)	[3–4)	[2–3)	<2	Karadirek, 2017; Gain and Wada ,2016
ENVIRONMENT AND ECOSYSTEM	Natural water quality factor	%	≤60	61–70	71–80	81–90	90–100	Babel **et al.**, 2017
	Sewage treatment factor	%	≤60	61–70	71–80	81–90	90–100	Assefa **et al.**, 2018
	Heavy metals factor	%	≤60	61–70	71–80	81–90	90–100	Assefa **et al.**, 2018
	Groundwater quality factor	%	≤60	61–70	71–80	81–90	90–100	Assefa **et al.**, 2018
	Recharge factor	%	<5	5-15	15-30	30-60	>60	Expert opinion
	Sewer system blockages	%	>300	200-300	100-200	50-100	<50	Danilenko **et al.,** 2014
WATER GOVERNANCE AND MANAGEMENT	Institutional factor	Questionnaire	1	2	3	4	5	Babel **et al.**, 2017
	Adaptability factor	Questionnaire	1	2	3	4	5	Babel **et al.**, 2017
	Staff productivity	%	<5	4-5	3-4	1-2	0-1	Berg and Danilenko, 2011; ESAWAS. Regional Bemchamarking of Water Supply and Sanitation Utilities 2014/15 Report,2016
	National water resource action plans	Lickert scale 1–5	1-1.49	1.50-2.49	2.50-3.49	3.50-4.49	4.50-5.00	Babel **et al.**, 2017
	State of infrastructure	Lickert scale 1–5	1-1.49	1.50-2.49	2.50-3.49	3.50-4.49	4.50-5.00	Babel **et al.**, 2017
	Reservoir capacity	ha-m^3						Expert
	State of reticulation infrastructure	Lickert scale 1–5	1-1.49	1.50-2.49	2.50-3.49	3.50-4.49	4.50-5.00	Babel **et al.**, 2017
	Compliance	Lickert scale 1–5	1-1.49	1.50-2.49	2.50-3.49	3.50-4.49	4.50-5.00	Babel **et al.**, 2017
	Disaster management budget/plans	Lickert scale 1–5	1-1.49	1.50-2.49	2.50-3.49	3.50-4.49	4.50-5.00	Babel **et al.**, 2017

In the index's calculation, Analytical Hierarchy Process (AHP) can be employed to set the weightings of dimensions. AHP is an effective method for decision analysis and calculation of weighting factors based on multiple criteria to solve computing dimensions. Experts from different organizations were requested to prioritize domestic water security dimensions, indicators and variables in questionnaire form, from 1 to 9 scale of preference and analysed by Saaty scale AHP method. For this approach an example extracted from Jumber ***et al.,*** 2020 and Khan ***et al***., 2020, will be utilised. Table 5 shows the result of weights of domestic water security dimensions, indicators, and variables.

Table 5: Example of weight of dimensions, indicators, and variables

Dimensions	Wt. (%)	indicators	Wt. (%)	Variables	Wt.(%)
Water Supply	**62.1**	Availability	**35**	Per capita water consumption	**69**
				Water supply continuity	**74**
				Pressure head adequacy	**51**
		Accessibility	**34**	Per capita water availability	**72**
		Quality	**31.1**	Water quality index	**78**
		Quantity	**32.5**	per capita consumption	**88**
		Affordability	**6.5**	Water and Wastewater Services (WWS) Charges as percentage of average household income	**65.2**
		Coverage	**21.1**	Piped water supply coverage	**84.3**
Sanitation	**23.6**	Coverage of sanitation systems	**56.6**	Sanitation coverage	**75.9**
		Management of sanitation systems	**43.5**	Management of sanitation	**100**
		Affordability of sanitation systems	**66.7**	Affordability of sanitation	**81.8**
Hygiene	**14.3**	Coverage of hygiene facilities	**50.7**	Coverage hand wash facilities	**100**
		Implementation of hygiene facilities	**49.3**	Implementation of hygienic practices (Diarrheal prevalence)	**100**
		Affordability of hygiene facilities	**60.2**	Affordability	**90**
Environment and Ecosystem	**16.7**	State of surface water	**79.4**	Natural quality water factor	**90**
				Heavy metals factor	**80**
				Sewage treatment factor	**60**

		State of ground water	69.3	Ground water quality	100
				Recharge factor	30
		Effectiveness of storm network and wastewater network	47.1	Sewage system blockages	41.4
Water Governance and Management	30.2	Overall management of water sector	31.8	Institutional factor	29.1
				Adaptability factor	24.7
		Strategic planning	28	National water resource action plans	36.3
		Disaster management regulations	34	Disaster management budget/plans	27.5
		Bulk and Reticulation Infrastructure	57	Reservoir capacity	66.1
				State of reticulation infrastructure	54.2
				State of infrastructure	57.5
				Compliance	44.9

Representation and interpretation of the domestic water security index

To develop a water security index and ensure domestic water security, a water security framework needs to be employed, which entails defining dimensions and indicators, and subsequently measuring these indicators using several variables and empirical equations to calculate DWSI for a given area. Although there is a prescribed DWSI equation, there is a multitude of equations associated with the diverse range of variables and indicators.

$$\mathbf{DWSI} = \frac{\sum Ii * wdi}{\sum Wd}$$

Where:
Wvi - weight of variable,
Svi - score of variables,
WIi - weight of indicator,
Wd - weight of dimension
Inevitably, available data on variables and indicators are recorded and measured on different scales and have dissimilar units. A preliminary step for the aggregation of indicators and variables is normalisation. Several normalization techniques exist in the literature and the best choice depends on the indicators and variables under consideration. Benchmarking each variable and indicator on a scale from 1 to 5; 1 represents the lowest level of security, whereas 5 means highly water secure. The benchmarking is carried out based on previous studies. For the variables proposed in this study, the min-max normalization method for standardization using the following equations:

$$\textbf{Variable (Vi)} = \frac{\sum Wvi * SVi}{\sum Wv}$$

$$\textbf{Indicator (Ii)} = \frac{\sum vi * WIi}{\sum WI}$$

Domestic water security index is a numerical representation of the status of water security at household level.

Table 6 : Interpretation and representation of domestic water security index scores.

INDEX	LEVEL OF DOMESTIC WATER SECURITY	INTERPRETATION
(<1.5)	POOR	The district is incapable of meeting the basic water requirements of its citizens. Water is used indiscriminately without proper planning and management, that is a serious point of concern for all dimensions of water security.
(1.5-2.5)	FAIR	The actions required to ensure water security are clear. However, there are still major gaps and serious concerns regarding almost all dimensions of water security.
(2.5-3.5)	GOOD	The district has a satisfactory system and environment for facilitating water security. However, some dimensions of water security are still a cause of concern.
(3.5-4.5)	VERY GOOD	The district is well-placed, with most of the dimensions of water security. Their security against the dimensions may not be at par with the others, but the overall situation is still very goodly satisfactory.
(>4.5)	EXCELLENT	The district is an ideal example of a water-secure society. It shows exemplary levels of security against every dimension of water security.

Availability and reliability of data sources

South Africa's custodians of water resource data include;

- Department of Water and Sanitation (DWS) who maintain a database of the status of water resources and other parameters within the publicly accessible National Integrated Water Information System (NIWIS)
- Department of Agriculture, Land Reform and Rural Development (DALRRD) which hosts the SASDI portal which provides various water-related datasets
- the Aquatic Resource Management for Local Community Development Programme (ALCOM) which created the Southern African Development Community Water Resource Database" (SADC-WRD) and;
- The Water Resources of South Africa publications (WR2012) have provided a valuable source of baseline regional hydrological and water resource information for many years.

Despite the importance of water resource monitoring, many countries in Sub-Saharan Africa, particularly in South Africa, are not effectively and adequately monitoring the quantity and quality of water resources. In a country where water resources are scarce, it is important to understand where and how fresh water is available and where and what demands are placed on it for use. This enables better decision-making around the allocation of water to different users. A vital prerequisite for the accurate assessment of the status of water and the magnitude of water problems, is information which is based on well-organised monitoring programmes and reliable data. Within South Africa, water resource assessment, monitoring and data collection over the last 60 years has become increasingly complex, water related database systems and the management of water resource data is currently fragmented (Figure 3). Part of the reason for this situation has been the absence of clearly defined roles, policies, strategies and responsibilities and a combination of these factors have resulted in significant fragmentations in the institutional structures mandated to manage water resources.

- Universities and Research institutes
  - Thesis database
  - Databases?
- Department of Human Settlements, Water and Sanitation
    - NGA
    - WARMS
    - DWS Hydrology database + weather data
    - DWS NIWIS
  - Water Research Commission
    - Knowledge Hub
  - CMAs
    - Databases?
  - Water Boards
    - Databases?
    - Scada systems
  - Irrigation Boards
    - Databases?
  - TCTA
    - Databases?
- Department of Environment, Forestry and Fisheries
  - SAWS
    - Databases?
  - SANBI
    - Databases
  - National Parks Board
    - Databases
- Department of Mineral Resources
  - Council for Geosciences
    - GIS:
    - Oracle:
- Department of Agriculture, Land Reform and Rural Development
  - ARC
    - Databases?
- Department of Higher Education, Science and Technology
  - CSIR
    - Databases?
  - NRF
    - Publications
- Department of Public Enterprises
  - ESKOM
    - Databases?
  - SAFCOL
    - Databases?
- Department of Cooperative Governance & Traditional Affairs
  - Municipalities
    - Databases?
  - SALGA
    - Databases?
- Private Sector
  - Mining
  - Organised agriculture
  - Manufacturing
  - Trade services
- Citizens
  - Social media
  - App based tools
  - Notes

Figure 3: Some of the sources of water and related data

Conclusion and Recommendations

To improve water security, the focus should be on the appropriate scale as well as collect and review the correct metrics. Water in storage and drought status are not enough to evaluate whether settlements or households are water secure. National, provincial or catchment statistics often hide what is happening at the livelihood level. The difference between installed infrastructure and functional infrastructure is not well known. Access to reliable water supplies at the local level is well known in urban and peri-urban areas, but less so for rural areas.

Sustainable and safe domestic water provisioning should be based on water security principles to the lowest supply unit (unconnected households) and implementation should be encouraged through regulation and institutionalisation of alternative supply sources and technologies. Globally, we already have significant research concentration, know-how and technologies in all these domains – it now requires technical and policy integration. To make this shift, there is a need to review and amend bylaws and regulations as well as using and creating tools to ensure that provisioning is maintainable over a long period. There is an urgent need for a fundamental change in our water supply approaches and options biases to ensure water security at all levels to meet the challenges of the future. This will require new as well as improving existing knowledge and innovations. Strategies should be adaptively changed to navigate the spaces created by uncertainty in existing knowledge.

The Department of Water and Sanitation has a programme called the "All Towns Studies" or reconciliation strategies for various towns and villages. The water supply reconciliation strategy is used to identify measures that are necessary to ensure the current and future water requirements of an area that can be supplied from the available water resources. DWS has completed 713 settlements as part of the reconciliation strategy. The strategies are periodically updated by DWS. The reconciliation reports have baseline data and information and recommendations to improve water security in the identified areas. Areas of high priority should be prioritised for intervention.

Development of a Water Security Index for various scales and contexts should be considered. This will include physical water availability, access to infrastructure, water quality, institutional viability, skills for operation and maintenance and water losses (leaks, poor allocation) or in line with the indicators suggested in Table 2. This will be the most accurate representation of the state of affairs and improve the relevant indicators to ensure domestic water security. This can be in the form of a dashboard that can be integrated into the NIWIS tool - http://www.dwa.gov.za/niwis2/. The dashboard tool will enable:

- Gaps in data and information systems to run the algorithms to calculate the DWSIs and areas for improvement.

- Display of the current state of water security for immediate interventions and evaluation.
- Provide the decision-makers with an almost real-time assessment of the status of proposed interventions and identify specific areas for improvement or intervention.
- Function as the reporting system for the Annual State of Water report.
- Assist with planning and prioritisation of resources.

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