


Status of drinking water supply and water stress levels in the African Great Lakes region: a time-series analysis from 1980 to 2020

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ABSTRACT

Freshwater is the most important resource because it is vital for human health, agriculture, the environment, urbanisation, and sustainable economic growth. This study uses time-series analysis of World Bank data for the period 1980–2020 to analyse status of drinking water supply in the African Great Lakes region. The results show that Kenya has been a water-stressed country since 2010, as it is withdrawing more than 25% of its renewable freshwater resources, while Rwanda is likely to soon become a water-stressed country, while Tanzania, Burundi, and Uganda are far from being water-stressed countries. In the Democratic Republic of the Congo, freshwater resources are used the least, which is attributed to the political instability and conflict cycles in the country. To achieve Sustainable Development Goal 6, clean water and sanitation for all, in the study area by 2030, Tanzania and Uganda will have to quadruple their current efforts, while Rwanda and Kenya will have to increase their current efforts sixfold, and Burundi will have to increase its current efforts eightfold, while the Democratic Republic of the Congo will have to increase its current efforts 30 times, which is almost impossible; these efforts should be reflected in the budgets of the water sector.

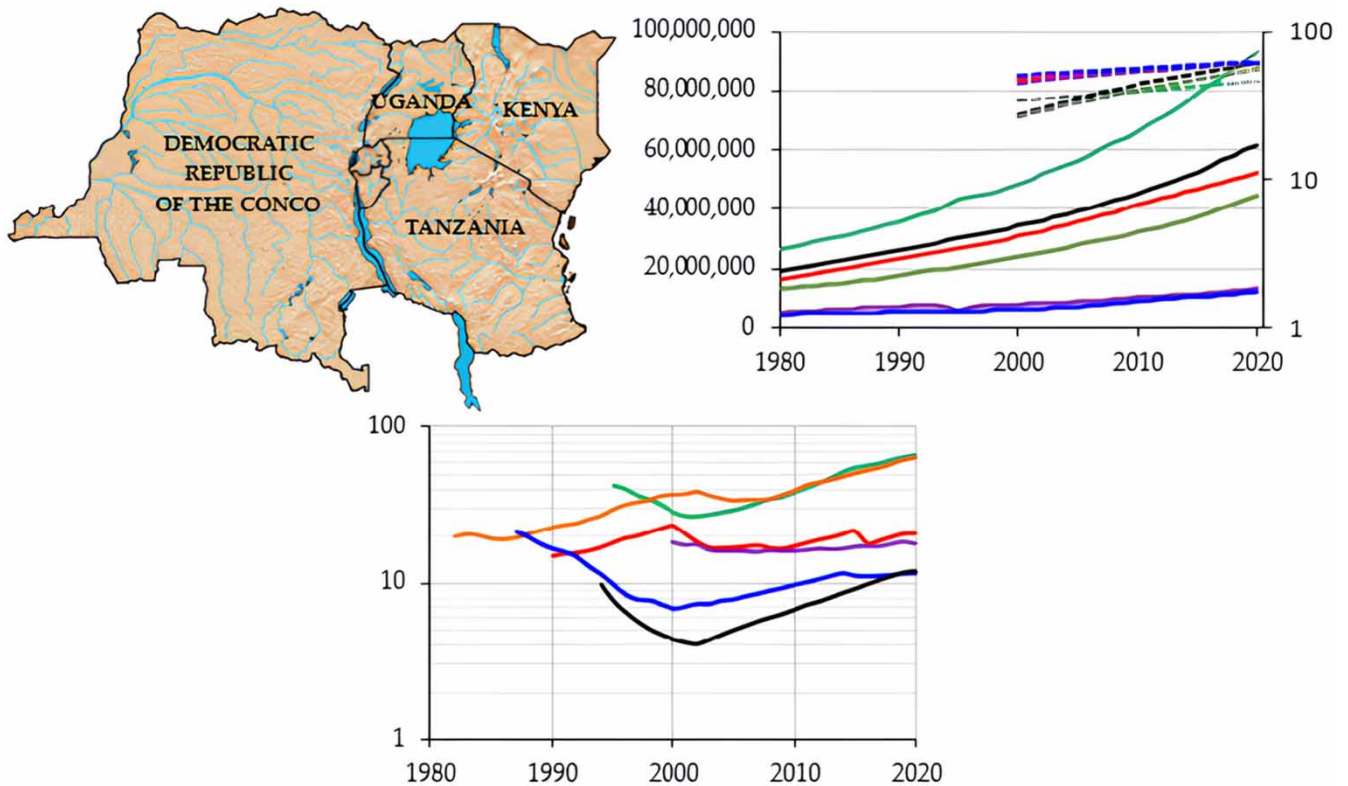
Key words: freshwater withdrawals, Sustainable Development Goal, time-series analysis, water productivity

HIGHLIGHTS

- About half of the region's population has no access to basic drinking water.
- In most countries in the region, freshwater abstraction has stagnated over the past 20 years.
- Insufficient government budgets for the water sector and economic recessions affect drinking water supply.
- The priority should be basic drinking water supply for the rural population, but significant efforts are also needed for the urban population.

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GRAPHICAL ABSTRACT



1. INTRODUCTION

Freshwater resources are important for human life, but they are extremely rare because less than 3% of the water on Earth is freshwater, and the remaining 97% is saltwater. Most of this 3% is inaccessible, as more than 68% of it is found in icecaps and glaciers, and more than 30% is below the surface as groundwater. Only approximately 0.3% of this 3% is in the surface waters of lakes, rivers, and swamps. These resources are unevenly distributed around the world, resulting in approximately one-fifth of the world's population living in water-scarce areas and affecting people's access to safe drinking water, sanitation and hygiene, economic development, and global geopolitics (National Geographic Society 2023; UN DESA 2023). Therefore, freshwater resources must be used and managed efficiently and sustainably.

In the African Great Lakes region, transboundary rivers and lakes support the health and livelihoods of millions of people. Although the region is home to some of the largest and deepest lakes and major rivers in the world, millions of people in the region still live in areas of water stress and water scarcity. This has significant social, environmental, and economic impacts due to several challenges, such as pollution from agricultural and industrial waste, untreated sewage, deforestation, and land degradation in river basins (FAO & UN-Water 2021; Musse 2021; UN-Water 2021; USAID 2021a, b; Lawrence *et al.* 2023). In addition, climate change, population growth, and urbanisation exacerbate freshwater challenges in the area. These challenges threaten water security in the region, which is a critical component of food security, good health and well-being, life on land, and economic growth of communities in general (Falkenmark 1989; FAO & UN-Water 2021; Awandu *et al.* 2023). Huge efforts are therefore needed to achieve water security in the region.

To achieve water security in the region, efforts are being made to achieve Sustainable Development Goal (SDG) 6 as soon as possible; SDG 6 emphasises access to water and sanitation for all. However, SDG target 6.1, which seeks universal and equitable access to safe and affordable drinking water for all by 2030, and SDG target 6.4, which seeks to significantly increase water-use efficiency across all sectors and the sustainable abstraction and supply of freshwater to address water scarcity and significantly reduce the number of people suffering from water scarcity by 2030, will fall far short of their targets based on the current situation (FAO & UN-Water 2021; UN-Water 2021; Ohwo & Ndakara 2022; UN DESA 2023). It is

therefore necessary to analyse trends in the percentage of the population with access to drinking water and efficient water use and to predict the efforts needed to meet the targets by 2030.

The study by [Ohwo & Ndakara \(2022\)](#) provides valuable insights into the state of drinking water supplies in different sub-regions in Africa from 2000 to 2020, but understanding the long historical trends of drinking water supply, water stress levels, and water productivity is important to identify key trends that will help predict future scenarios for achieving SDG targets in the sub-regions. Therefore, this study aims to analyse trends in the percentage of population with access to basic drinking water supplies, freshwater abstraction, water stress levels, and water productivity in the African Great Lakes region in response to population growth from 1980 to 2020 through a time-series analysis. This will help identify influencing factors and uncover challenges that are slowing down efforts to achieve SDG targets 6.1 and 6.4 in the region and suggest ways forward. This study also aimed to determine for each country studied the threshold of current efforts needed to achieve SDG target 6.1 by 2030 in the region, which will add knowledge to the overall predicted efforts to achieve SDG target 6.1 forecasted by [Ohwo & Ndakara \(2022\)](#) in sub-regions in Africa. Understanding the efforts of individual countries will help each country make the right efforts to achieve SDG target 6.1. The findings of this study will help government officials in the region and international stakeholders in the water sector make informed decisions to achieve the SDG 6 targets. The knowledge gained in this study is not only regionally relevant but also contributes to a better understanding of specific global water security issues in other semi-arid regions in Sub-Saharan Africa and elsewhere.

2. MATERIALS AND METHODS

2.1. Study area

2.1.1. Location, population, and climate

The study area includes six countries in the African Great Lakes region: the Democratic Republic of the Congo, Tanzania, Kenya, Uganda, Rwanda, and Burundi ([Figure 1](#)). In 2020, the population in these countries was approximately 276 million, with the Democratic Republic of the Congo, Tanzania, and Kenya accounting for approximately 34, 22, and 19% of the population, respectively, totalling 75% of the study area's population ([World Bank 2023](#)).

The region has a climate characterised by distinct wet and dry seasons, with the wet season characterised by a bimodal rainfall pattern: long rains and short rains, the duration of which varies from place to place within the region. Normally, long rains fall between February and May, while short rains fall between September and December. The highlands are relatively cool, with average temperatures between 15 and 25 °C and abundant rainfall averaging 1,500–2,400 mm/year. The average monthly temperatures in the lowlands range from 25 to 30 °C. The dry season runs from June to August. The vegetation in the southern and eastern highlands consists mainly of grasslands and savannas, i.e., dry grasslands, while forests are the main vegetation type in the lowlands of the Congo-Zaire basin ([Ministry of Foreign Affairs of the Netherlands 2018](#); [Rigaud *et al.* 2021](#)).

2.1.2. Freshwater resources

The African Great Lakes region is home to some of the largest and deepest lakes in the world. The region consists of seven major lake basins and several smaller lakes, rivers, and wetlands (see [Figure 2](#)), whose total volume is approximately 25% of the world's unfrozen freshwater, supporting several ecosystem services to local communities, such as drinking water, fishing resources, and electrical power ([Thiery *et al.* 2015](#); [Chimatiro *et al.* 2021](#); [Ogega *et al.* 2023](#)).

The seven major lakes in the region include Lake Victoria, the second largest freshwater lake in the world in terms of surface area; Lake Tanganyika, the world's second largest in volume; and the second deepest, Lakes Nyansa (Lake Malawi), Lake Turkana, Lake Albert, Lake Kivu, and Lake Edward in order of size; many of these lakes mark the borders between countries. Lake Victoria, Lake Albert, and Lake Edward empty into the White Nile, whereas Lake Tanganyika and Lake Kivu empty into the Congo River system. In addition, groundwater is another freshwater source in the region, providing freshwater for various uses ([Oiro *et al.* 2020](#); [Ligate *et al.* 2021](#); [Bennett *et al.* 2022](#)).

2.2. Data collection, processing, and analysis

The data presented in this study were extracted from the World Bank database ([World Bank 2023](#)). The data collected included population, percentage of population using at least basic drinking water services, freshwater withdrawals, level of water stress, and water productivity. The data span from 1980 to 2020.

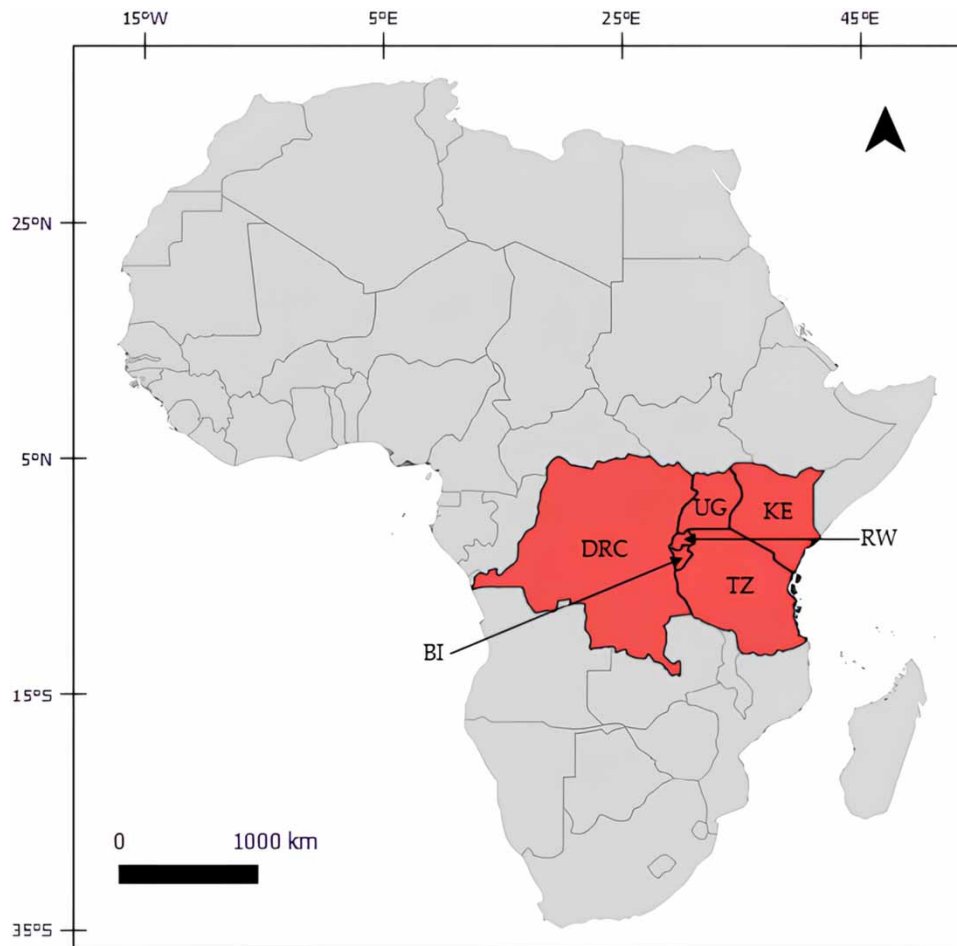


Figure 1 | Map of Africa showing the location of the study area in red, which consists of six countries in the African Great Lakes region: the Democratic Republic of the Congo (DRC), Tanzania (TZ), Kenya (KE), Uganda (UG), Rwanda (RW), and Burundi (BI). *Source:* Authors' own construct.

The data were processed, visualised, and analysed using Microsoft Excel Version 2308 (Build 16731.20170). The time-series analysis of these data sets is applied. Time-series analysis offers significant advantages in understanding temporal dynamics, long-term behaviours, and forecasting. It helps identify patterns, trends, and relationships within data over time, which is crucial for making informed decisions (Ravishankar & Komarasamy 2022; Le 2024; Singh *et al.* 2024). Estimating the thresholds for a country's efforts to meet the SDG 6.1 target by 2030 is based on the simple assumption that the percentage achieved in the next 10 years, i.e., 2020–2030, will be half the percentage achieved in the last 20 years, i.e., 2000–2020; this means that the efforts made to reach the current milestone will not change while achieving the remaining part of the SDG 6.1 target.

3. RESULTS AND DISCUSSION

3.1. Population growth and basic drinking water services

Over the period 1980–2020, there was strong population growth in the Democratic Republic of the Congo, Tanzania, Kenya, and Uganda compared with Burundi and Rwanda (see Figure 3). Over the last 40 years, the region's total population has tripled, from 85 to 276 million in 1980 and 2020, respectively, indicating strong population growth in the region. The Democratic Republic of the Congo hosts 34% of the total population in the study area, while Tanzania, Kenya, and Uganda host 22, 19, and 16%, respectively, while Rwanda and Burundi host 5 and 4%, respectively. Rapid population growth has direct implications for drinking water supplies (Mokoma & Tilahun 2022; Kassay *et al.* 2023; Kironyi *et al.* 2023), and this is reflected in the percentage of the population using at least basic drinking water services. For example, the Democratic Republic of the

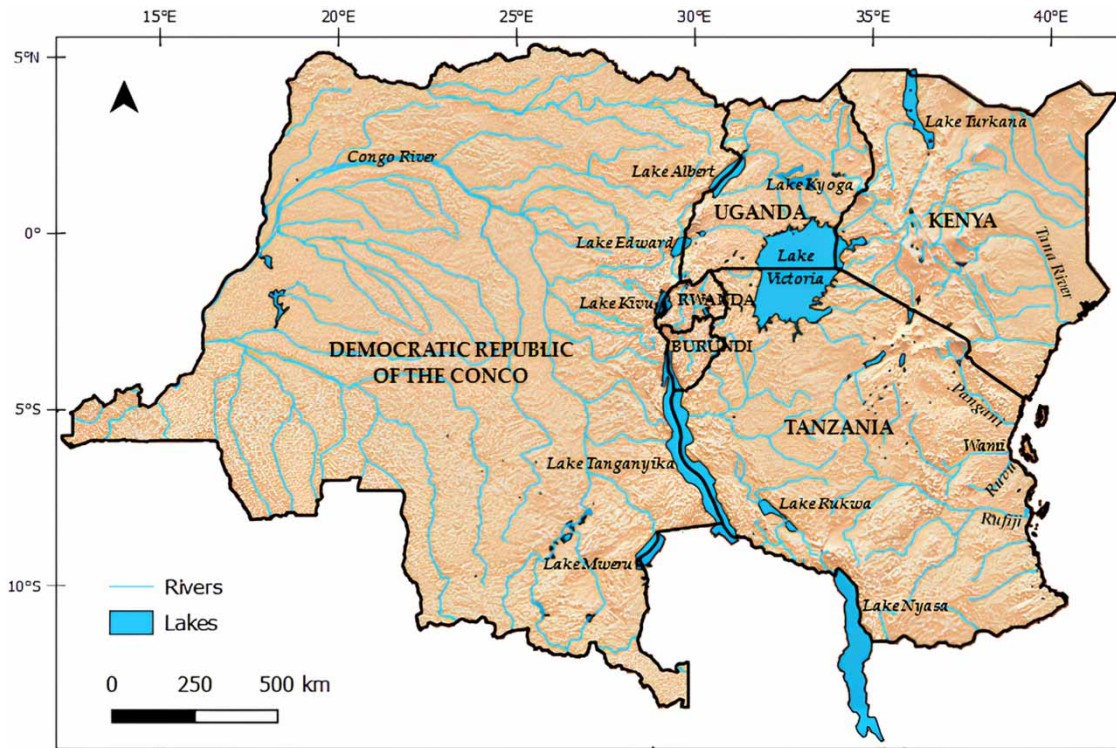


Figure 2 | Map of the study area showing major freshwater bodies: rivers and lakes. *Source:* Authors' own construct.

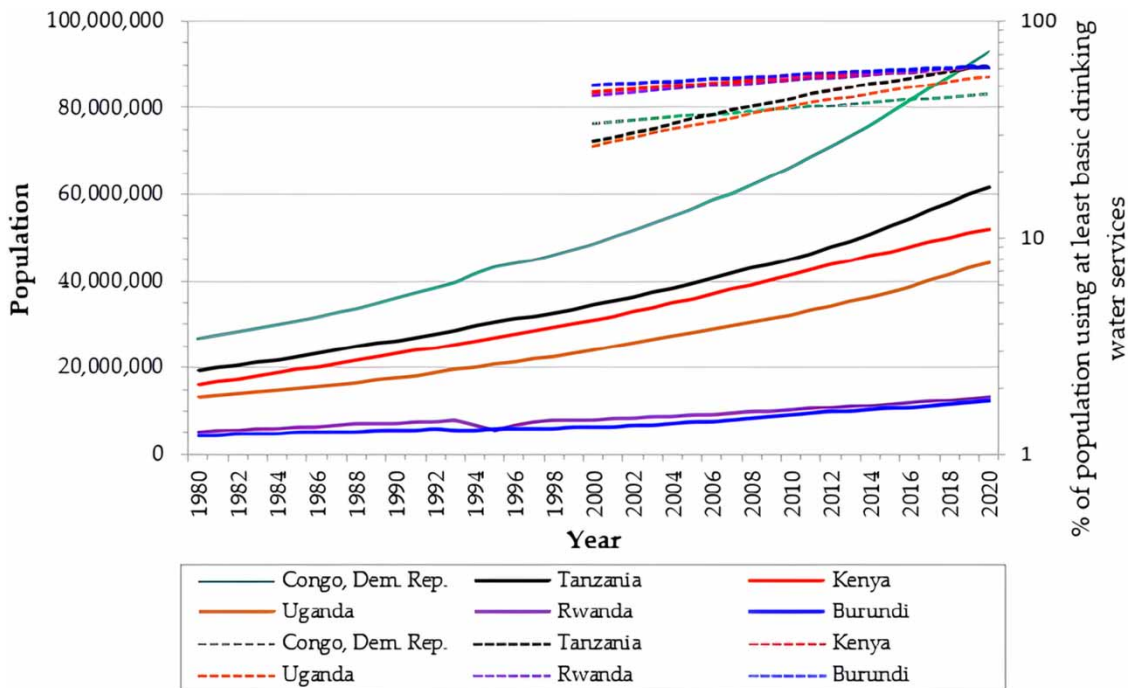


Figure 3 | Population growth trends (full lines) and percentage of the population using at least basic drinking water services (dotted lines) in the Democratic Republic of the Congo, Tanzania, Kenya, Uganda, Rwanda, and Burundi from 1980 to 2020.

Congo currently has the lowest percentage of the population in the study area using at least basic drinking water services, at 46% by 2020, while in Burundi, Kenya, Tanzania, and Rwanda, approximately 60% of the population uses at least basic drinking water services, while in Uganda, the percentage is approximately 55% by 2020. Overall, these results show that, on average, approximately 42% of the population in the study area, i.e., approximately 116 million people in 2020, do not have access to basic drinking water supplies; this is an alarming number, as the large population may have health problems due to a lack of basic drinking water supplies (Gautam & Dahal 2020; Béhanzin *et al.* 2022; OECD/WHO 2022).

Also, results show that people in rural areas suffer the most from the lack of basic drinking water supplies, as approximately 45–58%, with an average of 52% of the rural population in Tanzania, Kenya, Uganda, Rwanda, and Burundi having access to basic drinking water supplies by 2020, while in the Democratic Republic of the Congo, the percentage is approximately 22%, compared with people in urban areas, where approximately 75–90%, with an average of approximately 85% of the urban population having access to basic drinking water supplies by 2020 in the study area (see Figure 4). The low percentage of the rural population with access to basic drinking water supplies can be attributed to the dispersed rural population and the non-functioning nature of many rural water projects due to several factors, including gaps in operation and management (Gomez *et al.* 2019; REAL-Water 2022).

Between 2000 and 2020, Tanzania and Uganda doubled access to basic drinking water supplies for their rural populations, from 21 and 23%, respectively, in 2000 to 45 and 48%, respectively, in 2020 (see Figure 4). However, despite the enormous efforts made by Tanzania and Uganda, these countries still have a slightly lower percentage of their rural population with access to basic drinking water supplies than Burundi, Rwanda, and Kenya, where approximately 52–58%, with an average of 55% of the rural population in these countries having access to basic drinking water supplies by 2020. Burundi, Rwanda, and Kenya increased from 48, 41, and 37%, respectively, in 2000 to 58, 56, and 52%, respectively, in 2020, representing increases of 10, 15, and 15%, respectively. The Democratic Republic of the Congo has the least improvement in basic drinking water supply for the rural population, with an increase from 17 to 22% over the period 2000–2020; the current 22% is the least of all countries in the study, which can be attributed to conflicts and political instability in the country hampering public service delivery (Awandu *et al.* 2023; Ndolo 2023).

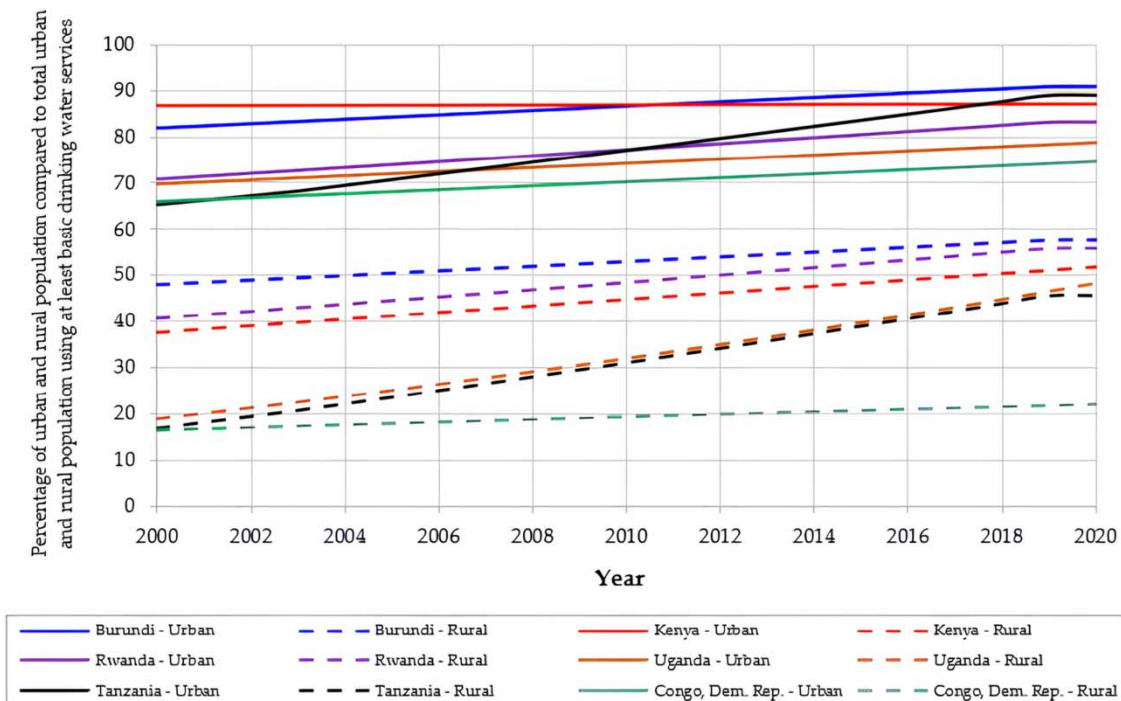


Figure 4 | Percentage of urban and rural population (full lines) compared with total urban and rural population using at least basic drinking water services (dotted lines) in the Democratic Republic of the Congo, Tanzania, Kenya, Uganda, Rwanda, and Burundi from 2000 to 2020.

To fully achieve the target of access to basic drinking water for the rural population in each country by 2030, the sum of the percentages in 2020 and 2030 in Table 1 must be 100%, which is only achieved by Rwanda, while the rest show an average of 97%, which can be considered almost fully achieved. Therefore, SDG target 6.1 for the rural population in the study area should be met by 2030 if Tanzania and Uganda have to quadruple their current efforts, this is in line with Ohwo & Ndakara's (2022) predictions, while Rwanda and Kenya have to increase their current efforts sixfold, and Burundi has to increase its current efforts eight times, while the Democratic Republic of the Congo has to increase its current efforts 30 times, which is almost impossible (see Table 1). This analysis yielded a specific value for each country in the study area compared with Ohwo & Ndakara's (2022) predictions that gave an overall value of at least fourfolds in sub-regions of Africa. This will help each country make the right efforts to achieve SDG target 6.1.

3.2. Freshwater withdrawals, level of water stress, and water productivity

Burundi and Tanzania showed a steady increase in annual freshwater abstractions from the late 1980s and mid-1990s, respectively, until the early 2000s, followed by a steady trend until now (see Figure 5(a)). The same scenario is observed in the Democratic Republic of the Congo and Rwanda, where there is a steady increase in annual freshwater abstractions from 1995 and 2000 to 2005 and 2019, respectively, followed by a steady trend to date. Kenya shows a decreasing trend from 1990 to 2000, an increasing trend from 2000 to 2016, and then, a steady trend to date, while Uganda shows an increasing trend from 1980 to 2008, followed by a steady trend to date. The initial upward trend in each country is attributed to early efforts to provide fresh water to the large population in each country, while the steady trend after the initial upward trend is attributed to the stage when the countries reach their maximum efforts to provide fresh water to the large population. The recent steady trends from 2015 to 2021 can also be attributed to the decline in official development assistance (ODA) to the water sector during that period (UN DESA 2023). Since the large population in the study area does not have access to basic drinking water (refer to Section 3.1), these steady trends in the present may indicate that the countries do not currently have the capacity to increase their freshwater withdrawals to meet the demand of the ever-growing population in the area.

Currently, Tanzania has the highest annual freshwater abstraction in the study area, at 5.2 billion m³ by 2020, followed by Kenya with 4.0 billion m³. The annual freshwater abstraction of Tanzania is approximately eight times greater than that of the Democratic Republic of the Congo, Uganda, and Rwanda (0.68, 0.64, and 0.61 billion m³, respectively) and approximately 20 times greater than that of Burundi (0.28 billion cubic metres). Tanzania's high annual freshwater abstraction is attributed to its large population compared with other countries, with the exception of the Democratic Republic of the Congo, which has the largest population of any country in the study area with the lowest annual freshwater abstraction in the study area. The low annual freshwater abstraction in the Democratic Republic of the Congo is attributed to the low use of available freshwater resources, which is reflected in the lowest water stress level in the study area (see Figure 5(b)), which is 0.2, meaning that only 0.2% of the country's available freshwater resources are used. This low use of freshwater resources can be attributed to political instability and conflict cycles in the country that have led to weak governance and institutions, hindering service delivery to the public (Awandu *et al.* 2023; Ndolo 2023). Currently, Kenya has the highest water stress level in the study area at 33%, followed by Rwanda at 20%, this is consistent with Falkenmark's (1989) predictions that these countries will be water-

Table 1 | Projection of efforts to achieve SDG 6 in the study area by 2030 by considering the percentage of the rural population with access to a basic drinking water supply

Country	% of rural population with access to basic drinking water supply		Increase in % over last 20 years, i.e., from 2000 to 2020	Forecast efforts to provide access to basic drinking water supply to the current % of rural population without access by 2030, i.e., in the next 10 years from 2020
	2000	2020		
Tanzania	21	45	24	$(24/2) \times 4 = 48\%$
Uganda	23	48	25	$(25/2) \times 4 = 50\%$
Burundi	48	58	10	$(10/2) \times 8 = 40\%$
Rwanda	41	56	15	$(15/2) \times 6 = 45\%$
Kenya	37	52	15	$(15/2) \times 6 = 45\%$
Democratic Republic of the Congo	17	22	5	$(5/2) \times 30 = 75\%$

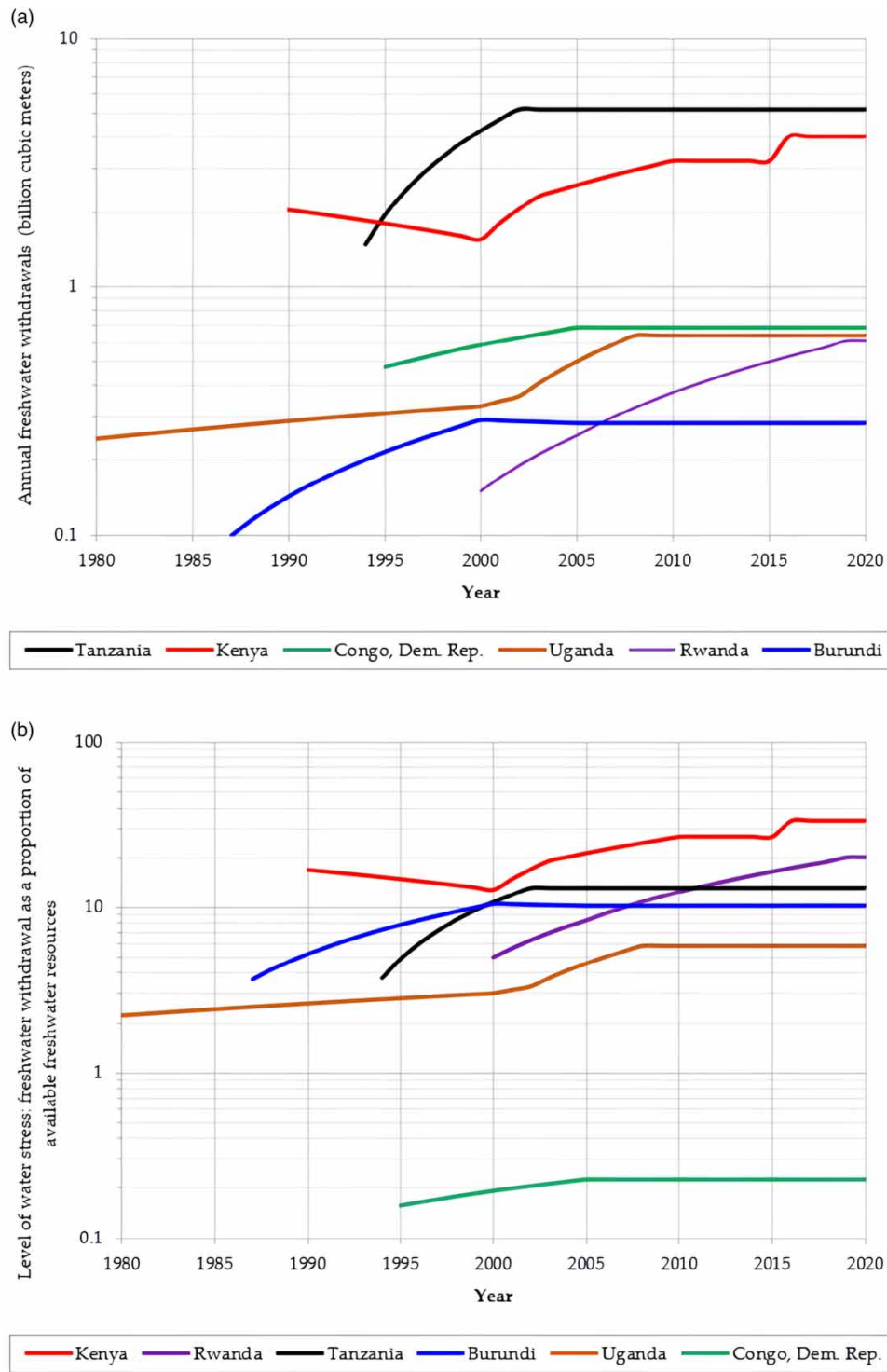


Figure 5 | (a) Annual freshwater withdrawals and (b) level of water stress in the Democratic Republic of the Congo, Tanzania, Kenya, Uganda, Rwanda, and Burundi from 1980 to 2020.

stressed by the period between 2000 and 2025, while the water stress levels in Tanzania, Burundi, and Uganda are approximately 13, 10, and 6%, respectively. Based on the threshold of a 25% water stress level (FAO & UN-Water 2021; UN-Water 2021), Kenya is currently considered a water-stressed country, but approximately 40% of the population does not have access

to basic drinking water; this indicates that based on the country's currently available freshwater resources, water stress will become more severe as the country tries to meet the water demand of its growing population. In addition to water stress caused by drinking water demand, water stress is also exacerbated by irrigation water demand (Musse 2021; Zhang *et al.* 2024). Rwanda, which currently has a water stress level of 20%, is likely to become a water-stressed country soon if it does not develop other freshwater sources, while Tanzania, Burundi, and Uganda are soon far from becoming water-stressed countries. Although Falkenmark's (1989) predictions on water-stressed countries by 2000 and 2025 are consistent to Kenya and Rwanda, the predictions are far from realistic for Burundi and Uganda, which were predicted to be among the water-stressed countries. It is therefore necessary to analyse the status of water-stressed countries from time to time to know their current status.

The Democratic Republic of the Congo, Tanzania, and Burundi showed a steady decline in water productivity from the late 1980s until the early 2000s, after which water productivity increased until the present (see Figure 6). Uganda showed an increasing trend from the early 1980s to the early 2000s, a decreasing trend from the early 2000s to the end of 2000, and then an increasing trend to the present, while Kenya and Rwanda showed stagnant trends from the early 2000s to 2020. The declining trends at the beginning and end of the 2000s can be attributed to the early 2000s recession and the Great Recession. The early 2000s recession occurred mainly in developed countries, but its effects can also be reflected in developing countries, as developing countries rely heavily on funds from developed countries to boost their economic activities. The early 2000s recession affected the European Union and the United States, while the Great Recession from late 2007 to mid-2009 had a global impact on national economies (UK Commission for Employment and Skills 2014; Demyanyk *et al.* 2015; Bianchi 2020; Pinto & Steinbaum 2023). Currently, the Democratic Republic of the Congo and Uganda have the highest water productivity (approximately 65 US\$/m³), followed by Kenya and Rwanda (approximately 20 US\$/m³) and then Tanzania and Burundi (approximately 12 US\$/m³). The water productivity in the Democratic Republic of the Congo and Uganda is approximately three times that of Kenya and Rwanda and approximately five times that of Tanzania and Burundi. This indicates that there is currently higher water-use efficiency in the Democratic Republic of the Congo and Uganda than in the other countries in the study area.

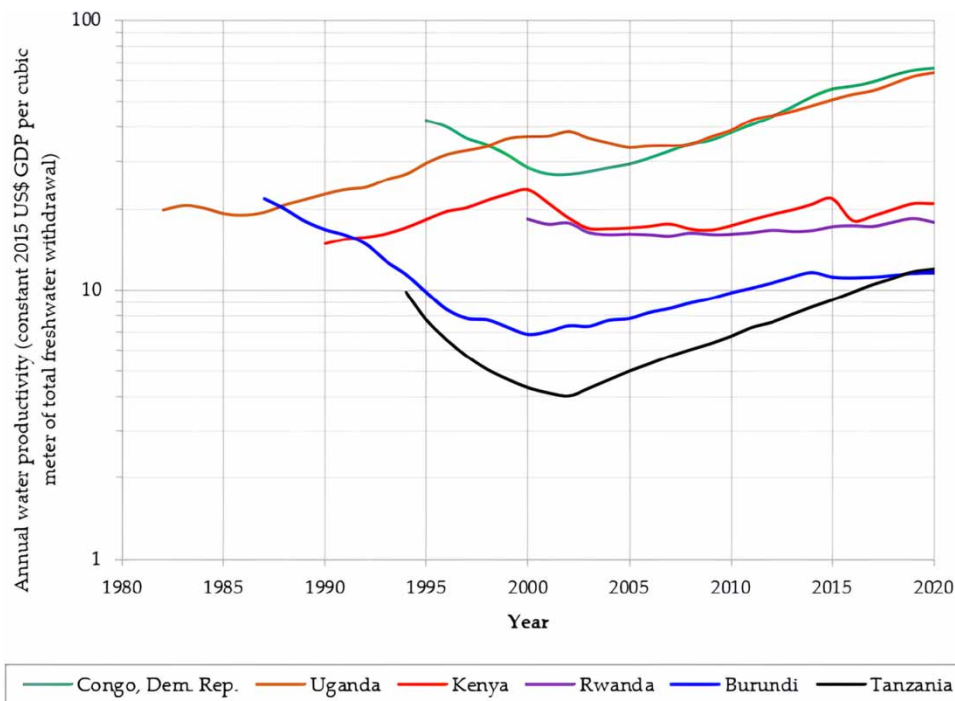


Figure 6 | Annual water productivity in the Democratic Republic of the Congo, Tanzania, Kenya, Uganda, Rwanda, and Burundi from 1980 to 2020.

With ongoing water development projects in the region, such as in the Democratic Republic of the Congo, where a US\$ 400 million water project aims to improve access to basic water and sanitation services in different parts of the country and strengthen the capacity of the public and private sectors to provide water supply and sanitation services (Ndolo 2023), there is expectation for improving people's access to basic water and sanitation services. Recently, Tanzania adopted a US \$ 294 million budget to fund the country's Ministry of Water for the 2021/2022 financial year. Part of the budget was intended to fund various water projects in rural and urban areas, with a high priority in rural areas, to address the country's water shortage, but the budget was deemed inadequate because it focused mainly on water supply, with only 13% of the budget allocated to support sanitation and water resources management activities (Kwezi 2021). In addition to funding constraints, limited technical capacity is a barrier to water resource management in the region (USAID 2021a, b). Thus, to achieve SGD 6 in the study area as soon as possible, the countries in the study area need to guarantee sufficient budgets to finance the exploration, planning, development, utilisation, and management of freshwater resources in the area.

4. CONCLUSIONS AND RECOMMENDATIONS

Currently, an average of approximately 42% of the population in the African Great Lakes region does not have access to basic drinking water; this is an alarming figure, as the large population in the area can suffer health problems due to a lack of basic drinking water supplies. Moreover, since the early 2000s and mid-2000s, i.e., over the past two decades, most countries in the region have shown stagnant trends in their freshwater abstractions, which do not meet the demands of the ever-growing population. As there is a stagnant trend in freshwater abstraction in the region, there is a need for regional policies aimed at encouraging the exploration and extraction of new freshwater resources using innovative methods and integrated management strategies that minimise environmental impacts. Based on the current situation, the focus should be on the provision of basic drinking water supplies for the rural population, but significant efforts are also needed for the urban population. In addition, this study proposes future studies incorporating different drivers of water demand projections in the region to explore different scenarios needed to meet water demand.

ACKNOWLEDGEMENTS

The author thanks the World Bank for making the data public. The author also thanks Ms Isege Zephania Mihayo for helpful instructions on how to access and download data from the World Bank database. Furthermore, the author also thanks the two anonymous reviewers for their thoughtful comments that have improved this manuscript.

FUNDING

No funding was received for conducting this study.

AUTHOR CONTRIBUTIONS

The author contributed to the study conception and design, material preparation, data collection and analysis, writing the first draft of the manuscript, and revising previous versions of the manuscript. The author read and approved the final manuscript.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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First received 3 May 2024; accepted in revised form 15 January 2025. Available online 31 January 2025