

# Analysis of public policies and programmes towards water security in post-apartheid South Africa

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## Abstract

Many countries in the world, including South Africa, are water-stressed with increasing pressure on their water resources due to population growth, climate change, and inadequate funding. Post-independence in 1994, many policies and programmes were introduced by the government with the aim of promoting water management. While these policies and strategies achieved much in terms of water provision to communities and households, they failed to establish a water-conscious country with sufficient knowledge and expertise in water management. In addition, these policies and programmes are outdated, compartmentalised, complex, and lack robust water governance with resilient stakeholder partnerships that advance the more explicit second phase of the National Development Plan (NDP) to achieve water security under the threat of climate change. Using data collection tools inspired by the traditional method of participatory research, this paper analyses the structural and systematic factors hindering the implementation of comprehensive policies to achieve water security in South Africa. There is, therefore, an urgent need for South Africa to establish an independent water regulator to ensure coordination between different government departments, including the National Treasury, to strengthen weak governance capacity and to make it independent to attract private equity into the sector and to recover fiscal deficits in the water sector.

**Keywords:** Climate change; Policies; Regulations; South Africa; Water management; Water security

## Highlights

- The paper deals with water security in South Africa post-1994.
- The country inherited a backlog of unfair water distribution due to the racial injustices of the past.
- Post independence in 1994, the new government of South Africa introduced numerous policies and programmes to address the challenges in the water sector, while much have been achieved in terms of fair water distribution of water.
- The policies and programmes have, however, failed to address other issues and constraints in the sector.

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doi: 10.2166/wp.2021.017

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## 1. Background

Water scarcity is one of the greatest global challenges of the 21st century (Abu-Zeid & Shiklomanov, 2003). Around the world, businesses, governments, and policymakers are working together to move beyond the business-as-usual approaches to water management to increase water supply and improve the quality of current water resources but, importantly, to reduce withdrawals by reshaping the underlying economic activities in agriculture, manufacturing, and energy production (Boccaletti *et al.*, 2010). It is estimated that the global water demand is on track to outpace supply by 40% within the next two decades, and the potential effects of climate change, drought, deforestation, and pollution are increasing the risks even higher (Rosegrant *et al.*, 2009; United Nation World Water Development Report (UNWWDR), 2015). The World Economic and Social Survey (WESS) (2017) indicated that unsustainable and uncoordinated water policies among countries and regions, high water demand across the globe, fragmented administration to address water challenges nationally and internationally, wrong perceptions, and the negative attitude of people towards water resources are all significant threats to the sustainability of water resources. Many countries in the world are facing increased water shortages in the 2020s and beyond. They include parts of India, China, much of the Middle East, Mexico, the United States, Poland, Russia, and a clear majority of African countries (Falkenmark, 1990). Falkenmark (1990) and Abu-Zeid & Shiklomanov (2003) further disclosed that by 2025, 1.1 billion Africans, about 75% of countries on the continent including South Africa, are projected to be living in severe water stress countries with enormous economic, social, environmental, and political consequences.

Post-independence in 1994, the government of South Africa initiated and adopted various water policies and programmes aimed at creating sustainable water development to improve both the quality and quantity of water supply to its citizens, especially the previously disadvantaged black population. According to Coning & Shrwil (2004), the water policy was modified to include the following: ‘Water Service Act, (White Paper) 1994 to address the backlogs in the country’s water service the institutions and mechanisms needed to remedy the accumulations. The Republic of South Africa Constitution (Act 108 of 1996) established as the human right dimension with prominence to access to adequate and sustainable water supply and services. The Bill of Right; Water Service Act (WSA) of 1997 (Act 108 of 1997) further established and empowered people with the right of access to basic water supply and sanitation.’ The Act provided a regulatory framework and establishment of water service institutions such as water boards and water service providers (StatsSA, 2017). This Act created a comprehensive legislative framework for the provision of water supply and sanitation services to support life and personal hygiene and to recognise the need to operate in a manner that is consistent with the broader goals of water resource management (Meissner *et al.*, 2013). Correspondingly, the Act encouraged cooperative governance with an emphasis on capacity building at all levels. It spelled out the roles and powers of the Department of Water and Sanitation in the event of non-performance by provincial departments and local governments. The National Water Policy of 1997 (DWAf, 1997) redefined ownership and allocation of water. The Water Policy of 1997 stipulated that all water resources irrespective of where it occurs in the hydrological cycle are public water and that the national government will act as a public trustee (Tewari, 2009). The National Water Act (NWA) of 1998 (Act 36 of 1998) was founded on two pillars: sustainability and equity (Soyapi, 2017). To achieve these objectives, the policy framework established the National Water Resource Strategy (NWRS) with the sole aim of managing water resources. The NWRS provides the national implementation framework and divides the country into 19 water management areas (WMAs). The National Water and Sanitation Programme,

an international partnership programme, was designed to enhance access to safe and affordable water supply and sanitation for the poor in South Africa (DWS, 2018).

While these policies ensured that the number of households with access to clean water increased significantly from 67% in 1993 to 85% in 2015, the DWAF data for 2017 and StatsSA (2015) revealed that 6.3 million households in South Africa did not have access to reliable water services and 14.1 million people were still using sanitation facilities that were below the Reconstruction Development Programme (RDP) standard (StatsSA, 2017). Furthermore, the population of the country increased from 56.02 in 2016 to 58.78 million in 2019, which was a 5% increase that was more than double the 2% water reserves that were theoretically available (Benoit, 2019). Based on these statistics, it is unquestionable that water demand had increased in proportion to the population growth without a corresponding increase in supply, hence, the water deficit across the country with its associated social and economic challenges. Besides, it is estimated that more than 35% of the national water infrastructure is completely broken down and is beyond any repair, more than 40% of the country's water is used for flushing toilets, and one-third of the available water resources are lost due to leaking pipes, ageing and broken infrastructure, vandalism, and contamination (South Africa Academy of Engineering (SAAE), 2019). Providing water services to the neglected population has become almost impossible due to funding shortfalls and a failure by municipalities and other users to pay for their suppliers (Ramcharan-Kotze & Lubbe, 2019).

Apart from the above problems, the implementation of the policies and programmes formulated to address water challenges is fragmented and uncoordinated and lacks effective supervision. These constraints are as a result of the appointment of professionally unqualified personnel to senior management positions and rampant corruption in the water sector (Mwendera, 2003; van der Zaag & Savenije, 2014). The NWA, a key policy strategy, enacted to address equity and sustainability, fails to acknowledge the traditional water management structures, the chiefs, and community organisations. However, the Traditional Leadership and Governance Framework Act (Act No. 41 of 2003) makes provision for traditional leadership in promoting sustainable water resource management and requires national and provincial governments to provide for their involvement through legislation and other means (Kahinda & Boroto, 2009). Government institutions and other stakeholders have managed water policies and programmes in isolation and compartmentalised them, while interventions and development at the river sources have taken place without adequate consideration of its impacts on the downstream. Water quality issues have often been disconnected from problems of quantity; groundwater pollution has seriously affected the hydrological linkage between groundwater and surface water, land–water interactions have been overlooked, ecosystems have been impaired, and social equity often disregarded (Kahinda & Boroto, 2009). Between 1999 and 2015, the extent to which the main rivers in South Africa identified as having poor ecological conditions increased by 500%, with many rivers reaching a point beyond recovery. The levels of tributaries with poor ecological conditions have increased by 229% within the same period (Viljeon & van der Walt, 2018). According to van Deventer *et al.* (2018), South Africa had lost over 50% of its wetlands, and of the remaining 3.2 million ha, 48% are critically endangered with one-third already in a poor condition. Presently, many studies conducted on water policies and strategies in South Africa focus primarily on the monitoring and evaluation of strategies towards water management. In most of these studies, there are gaps in addressing the flaws in the current policies and programmes in managing water resources in South Africa. In the light of these challenges, this study explored the systematic and structural challenges facing the current policies and strategies designed to achieve water security in South Africa.

## 2. Climate change impacts on water supply in South Africa and globally

Changes in the relative heating of the earth have, in turn, produced changes in its climate (Driouech 2020). Evidence from different models and observational studies suggests that the global temperature has increased, and warming is expected to increase by 2 °C by 2030 (Ajayi & Ilori, 2020). Climate models are regarded as the most important tools that give projections for future climate variables under different concentration pathways (Ajayi & Ilori, 2020). The models vary in their spatial resolution, and, thus, in the number of dimensions they simulate and the spatial detail they include (Pretoriou, 2001). There is unequivocal evidence that human activities are affecting the earth's environment, including the climate, on a global scale. Increasingly, strong evidence suggests that the functioning of the climate is changing in response to human activities (Pretoriou, 2001; Ajayi & Ilori, 2020; Ilori & Ajayi, 2020). According to Ajayi & Ilori (2020), climate change has impacted two major resources globally: food production and water supply. The negative impacts on these two foremost sectors have led to grave problems on a global scale in the 21st century. The main impact of climate change on the water resources of the entire planet is the disruption of the hydrological cycle (Boudiaf *et al.*, 2020; Almazroui *et al.*, 2021). A rise in temperature leads to an increase in the water vapour content in the atmosphere, resulting in changes in the regime and intensity of precipitation, an increase in evaporation from the earth's surface, a decrease in snow cover, and a melting of glaciers (Yuryev, 2019; Ajayi & Ilori, 2020). The impact of climate change on water resources, in turn, affects all major sectors of the economy. Changes in global water resources have consequences for several economic and social sectors. Water scarcity and drought have a severe impact on agriculture, forestry, the energy sector, and the provision of drinking water (Zwane, 2019). Drought and water scarcity compounded by climate change have led to a competition for water resources and have forced many residents out of their home countries (Boudiaf *et al.*, 2020). It is estimated that a temperature increase of 1 °C in a country with an agrarian economy correlates with an increase in emigration of 5% (Yuryev, 2019). According to Singh *et al.* (2014) and Ajayi & Ilori (2020), the countries of the Horn of Africa, such as Somalia, Ethiopia, Eritrea, Kenya, Sudan and South Sudan, and some Southern African countries, including South Africa and Zimbabwe, are the most vulnerable due to prolonged periods of drought. Urama & Ozor (2010) disclosed that climate change is expected to exacerbate the critical water stress conditions in most parts of the African countries before 2025 due to increases in water demand and in population. Based on projected models, the population to be affected is estimated to be 250–500 million and 750 to over one billion people by the 2020s and 2050s, respectively (Watkiss *et al.*, 2019).

Climate change is projected to alter the current hydrological resources in South Africa and increase pressure on the adaptability of future water resources (Mukheibir & Spark, 2003). During the last 25 years, most of the provinces in the country have experienced extensive drought, and the last two decades (1986–1988, 1990–1992, and 2014–2015) have witnessed severe droughts attributed to the El Nino phenomenon (Ndlovu & Demlie, 2020). Water scarcity is a challenge in many parts of the country. Poor distribution of water resources, pollution, coupled with infrastructure backlog, have led to direct hardship for many people in the country, particularly the poor, since these have affected food production as well. According to Averchenkova *et al.* (2019), the integration of climate change into South Africa's water policies such as Water Framework Directives has not yet taken place. Furthermore, these directives themselves do not include specific provisions to address climate change impacts (Maphela & Cloete, 2019). However, Averchenkova *et al.* (2019) disclosed that the recently developed White Paper sets out South Africa's climate change response strategy to achieve the National Climate

Change Response Objective in a manner consistent with the outlined principles and approaches that are structured around the following strategic priorities: risk reduction and management; mitigation actions with significant outcomes; sectoral responses; policy and regulatory alignment; informed decision-making and planning; integrated planning; technology research, development, and innovation; facilitated behaviour change; behaviour change through choice; and resource mobilisation.

### 3. Legal framework of water management in South Africa

Water management in South Africa covers the three spheres of government: national, provincial, and local. They are constitutionally mandated to observe and apply the principle of cooperative governance and intergovernmental relations while developing and implementing policies and performing their functions (Simo, 2014). The South African Constitution 108 of 1996 acknowledges that each sphere of government has its distinctive character but stresses that these spheres are interdependent and inter-related in their task of managing water resources. The relationship of cooperative government binds all spheres of government together and underscores the principle of participative decision-making in water governance (Haigh *et al.*, 2010). The national and the local spheres are the significant role-players together with the citizens, who constitute an imperative component of governance, particularly at the local level (Simo, 2014). An integrated development plan is established to smooth cooperative governance across the three spheres of government. For the effective and efficient provision of water, the local governments' integrated development plans must be aligned to the Water Service Development at the National Department of Water and Sanitation (Fuo, 2013). The provincial governments play a significant role in coordinating alignment between the integrated development plans and water services development plans. They manage water policies in relation to developmental planning and environmental management (Petzer *et al.*, 2000).

The national water policies and legislations are transformational masterpieces that not only resolve the complications of the past but also assist in building a better future (Karodia & Weston, 2002). This is explicitly stated in the resolution of the NWA of 1998, which is to ensure that the country's water resources are protected, used, developed, conserved, managed, and controlled in ways that take into consideration factors such as, among other things, meeting the basic human needs of the present and future generations, promoting equitable access to water, redressing past discrimination, facilitating social and economic development, and protecting aquatic elements and their associated ecosystems. In addition, the National Environmental Management Act (NEMA) 107 of 1998 and the Water Service Act (WSA; Act 108 of 1997) are linked to the sixth objective of the Sustainable Development Goal 6 (Clean Water and Sanitation), which is the cornerstone of social and economic development as well as alleviating poverty and enhancing sustainable livelihood.

#### 3.1. Constitution of the Republic of South Africa Act 1996 (Act 108 of 1996)

The Constitution of the Republic of South Africa (No. 108 of 1996) creates provisions for water legislations. The Bill of Rights in the Constitution guarantees fundamental human rights to all people of South Africa. Among other things, it affords everyone the right to live in an environment that is not harmful to health and well-being and to have access to sufficient water, extending these benefits to future generations. The Constitution sets out the objectives of local government, including to provide



water services sustainably and to promote a safe and healthy environment. The local government legislation gives effect to this constitutional imperative, and it provides for municipalities to promote a safe and healthy environment in their localities and cooperate with other spheres of government for the realisation of the fundamental rights contained in sections 24, 25, 26, 27, and 29 of the Constitution (Green Paper on Local Government, 1997). The Constitution emphasises that the national government is the custodian of groundwater and surface water resources and that the local government has the responsibility of providing municipal water supply and sanitation services (Republic of South African Government, 1996).

### 3.2. NEMA 107 of 1998

The NEMA, 107 of 1998, is a national environmental management framework legislation that defines the environment as the surroundings in which humans exist and includes land, water, and atmosphere. In addition, it includes the interrelationships, combinations, properties, and conditions of all organisms that exist within the surroundings. This extensive definition of the environment ties into the concept of integrated environmental management, which the NEMA promotes (Day, 2015). Section 24 of the NEMA provides that: everyone has the right to have the environment protected for the benefit of the present and future generations. Similar to the WSA and the NWA, the NEMA prescribes national norms and standards for environmental governance to achieve social, environmental, and economic sustainability. Similarly, the NEMA promotes a ‘polluter pays’ principle for the rehabilitation of the environment (DWS, 2018). Pollution in the context of the NEMA is any emission from an activity related to the provision of services that can hurt human health or the well-being of the ecosystem in the present or the future. The NEMA, 107 of 1998, provides that any government department whose activity affects the environment must exercise these functions in accordance with the NEMA principles or Environmental Implementation Plan which is instituted by the Minister of Environmental Affairs and Tourism and the Environmental Co-ordination Committee (Section 16) with emphasis on sustainable development. ‘Sustainable development’ is defined in section (1) of the NEMA 107 of 1998 as ‘the integration of social, economic and environmental factors into planning implementation and decision-making to ensure that development serves present and future generation’. Boshoff (2010) also defined sustainable development as the right to development that must be fulfilled to equitably meet the developmental and environmental needs of the present and future generations. To achieve sustainable development and a higher quality of life for the people, it is critical to reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies (Boshoff, 2010).

### 3.3. WSA 108 of 1997

The WSA 108 of 1997 is the fundamental governing framework for water services institutions, which are primarily municipalities, giving effect to the Bill of Rights by providing for access to essential water supply and sanitation services necessary to secure sufficient water and an environment not harmful to human health or well-being. The Act deals explicitly with water services or potable water and sanitation services provided by municipalities to households and other municipal water users. It embraces guidelines and regulations regarding what and how municipalities ought to supply water and sanitation services. The Act outlines the municipal roles of guaranteeing water services provision and sets out

strategies for the WSA as well as Water Service Providers (WSP). The functions and responsibilities of both WSA and WSP in terms of water resource management are not openly specified but can be inferred from their diverse roles in the provision of water services.

### 3.4. *NWA 36 of 1998*

The NWA gives effect to the post-1994 water law reforms and is a significant piece of legislation to establish the principles of efficiency, equity, and sustainability within the water sector (Mogomotsi, 2017). The reforms introduced by the NWA require equitable allocation of water to all water users, and it places importance on managing the effects of water use on land, especially the water environment and resources. The NWA identifies 11 types of water use, which may have a detrimental effect on water resources. Water uses in sections 21(f), 21(g), 21(f), and 62 relate to the management of Wastewater Treatment Works. In other words, The NWA 36 of 1998 strived to transform how water was controlled and managed, from a system of rights based on land ownership (the riparian system) to a system designed to allocate water equitably in the public interest. The progressive reallocation of water to sectors of society that were previously excluded from access to water can help to bridge the divide between the first and the second economies, while maintaining existing beneficial water uses and encouraging greater efficiencies needed in our dry country. With the promulgation of the NWA in 1998, groundwater lost its previous status of private water and became public water. This has enormous implications for all users and essential benefits for municipalities as public users. It is now possible for municipalities to exploit groundwater resources even where these can only, or best, be accessed on private land.

### 3.5. *NWRS of 2004(1) and 2013(2)*

The NWRS of 2004(1) is a crucial document and a legal instrument for implementing or operationalising the NWA (Act 36 of 1998). The first edition of the NWRS defined the fundamentals of integrated water resource management and presented a clear perspective of the water situation in South Africa and the critical interventions required. It is a binding document on all authorities and institutions implementing the Act. It is a crucial document that provides the framework for the protection, use, development, conservation, management, and control of water resources for the country as a whole. It also provides the framework within which water is managed at the provincial, regional, or catchment levels in the defined WMAs. Furthermore, this policy document provides relevant information about how water resources will be managed and the institutions to be established. It also provides quantitative information about the present and future availability of, and requirements for, water in each of the 19 WMAs. The key components and drivers of the NWRS of 2004 are its progressive decentralisation of the responsibility and authority of water resource management to catchment management agencies and, at a local level, to the water user associations. These institutions, representative of water users and other stakeholders, facilitate active participation in the management of water resources in their areas. The NWRS provides the Department of Water and Sanitation to make a shift from its current multiple roles as an operator, developer, and regulator to become the sector leader, policymaker, regulator, and monitor. In addition, the NWRS of 2004 provides a platform for essential collaboration and cooperation among all departments in all spheres of government involved in economic development.

The NWRS 2013(2) has been developed within a changing environment and acknowledges that monitoring and collecting relevant data will not only provide accurate assessments of the status of

water resources and the magnitude of water problems but also vastly improve planning and policy formulation processes. The national water legislation (section 68 of the WSA) requires the minister concerned to maintain a national information system to record and provide data on the development, implementation, and monitoring of national policy. This monitoring should not be done only for the sake of addressing national concerns, but should be in response to the obligations committed within international river basins. Approximately 60% of the streamflow in rivers is shared through trans-boundary water systems. The policy on this sharing stresses that Integrated Water Resources Management (IWRM) should be implemented in a manner that conforms to international water protocols and treaties, while being compliant with the legislation governing water resource management in South Africa. The regulation policy is to ensure standards values and principles are set and maintained and that there is compliance with the regulatory provisions is a strategic focus of the policy. The attainments of all country and sector goals must be sustained within an environment that protects the integrity of the NWA and all other legislations that have an impact on water resource management. Additionally, this policy underscores that the realisation of the goals and objectives will require robust institutional support, a knowledgeable and capable workforce, coupled with indispensable financial resources to implement interventions. An investment strategy, with financial capital backing, needs to be devised to implement all vital programmes under the NWRs efficiently. This can be achieved only if the government, developmental organisations, the private sector, and other funders collaborate to provide the necessary funding to support water resource management in South Africa.

#### **4. The flaws in the policies and strategies towards achieving water security in South Africa**

South Africa's water legislations have been hailed by the international water community as one of the progressive pieces of global legislation and a significant step forward towards achieving the goals of IWRM and making it into a law (Bond, 2011; Schreiner, 2013). The country's water policies and strategies have been widely quoted and referred to in many countries across the globe. For instance, some sections of the policies were included in China's and Zambia's new water policies and have been used as a yardstick for drafting many water legislations (Karodia & Weston, 2002; Mackay, 2003). However, these accomplishments are not without challenges, as within South Africa itself, the access to clean water for all has been hampered and the overall water quality is on the decline, despite the various policies and legislations seeking to transform the policy of water allocation to redress the historical and racial discrimination on access to water for all (Mwendera, 2003; Mukheibir, 2007; Bayliss, 2016). Various researchers in the scientific literature have argued that very little has been achieved since the NWA was promulgated in 1998. This is particularly true in the agricultural sector, where 95% of the water reserves remain in the hands of white commercial farmers (Claassen, 2013; StatsSA, 2017). Existing lawful use was initially intended as a transitional arrangement. However, even after nearly 24 years since the NWA was promulgated, the agriculture sector remains the most water-stressed sector in the country, with the highest volume of water being used and consumed (Viljeon & van der Walt, 2018). While the restitution of agricultural land has been slower than intended, the reallocation of water has not always kept pace with the transfer of such land. In some instances, the previous owners traded away their existing lawful water-use rights, so that water allocation was not transferred to land reform beneficiaries (Chikozho *et al.*, 2020). Furthermore, the Department of Economic and Social Affairs (ECOSOC) (2008) argues that there are other considerable challenges and impediments



to the attainment of water sustainability as set out by the Millennium Development Goals (MDGs), the New Partnership for African Development (NEPAD), and above all by the underlying obligations set out in the Constitution of South Africa of equitable supply of water. Water demand in South Africa is increasing at an exponential rate, and, therefore, supply-side management will have to improve enormously to meet even the basic requirements of the previously disadvantaged black population in the new South Africa. Water quality is deteriorating in many ways and will continue to decline as more pressure is exerted on the scarce supply. Rivers and dams are running dry as impoundment, evaporation, and extraction are increasing and as the buffering capacities of catchment areas are reducing due to rapid urbanisation and degradation (Mander *et al.*, 2005).

Just like the NEMA, the discourse and thinking on ecological modernism that underpins the national water policies, particularly the calls for sufficiency and sustainability, are ambiguous and undefined in terms of public interest and the facilitation of social and economic development (Long, 2017). Thus, for Bond (2011), the national water policies and the legislation of the protection, use, development, conservation, management, and control of water resources have failed to meet the country's vast unmet human needs, and are, therefore, questionable. Furthermore, the policies are characterised by uncertainty; there is a lack of clarity on the principles of meeting the basic water needs of the people as stated in the 1997 and 1998 National Water Policies and the Constitution and also on meeting the cost requirements to provide the services (Karodia & Weston, 2002). One of the fundamental constraints mentioned by many scholars and researchers blocking the formulation of effective water policies in post-independence South Africa is that water is severely under-priced, leading to a failure in achieving cost recovery (Donnenfeld *et al.*, 2018). Based on this analysis, with regard to the 'Free Basic Water policy', it is estimated that a capital funding of around R33 billion per annum for the next 10 years must be arranged through a combination of improved revenue generation and a significant reduction of costs to sustain and improve water supply in South Africa (Viljeon & van der Walt, 2018). To support this argument, Karodia & Weston's (2002) report highlights that South Africa's annual operating expenditure in the water and sanitation sector is currently in the order of R124 billion per annum, with about R109 billion per annum needed by municipal services. The total available operational funding in the sector is about R136 billion per annum, comprising a water services revenue of R84 billion and additional operating subsidies of R52 billion from the equitable share. However, these funds are not ring-fenced and are, thus, not necessarily available for the operation of water and sanitation services (National Treasury, 2015). The demand for funding in the water sector will continue to grow, both in terms of capital expenditure and in terms of funding for operation and maintenance and refurbishments. In order to achieve financial sustainability, the costs need to decrease and revenue needs to increase as a first principle. The sector needs to consider what it can do with the currently available funding (Karodia & Weston, 2002).

## 5. Methodology

The study examined South Africa's water management strategies and their relationship with the water security agenda. It specifically focused on the country's water challenges, where particular attention was paid to the policies and programmes designed to drive water security post-independence. Both qualitative and quantitative methods were used to collect information from government institutions and private organisations (either as individuals or as groups) in the formal and informal sectors within the water

industry in four provinces (Gauteng, Western Cape, Eastern Cape, and Free State) in South Africa. These provinces were selected due to persistent challenges in accessing water and the fast-growing population in the provinces. Semi-structured questionnaires were administered face to face to individuals, officials, and/or groups who are directly involved in the formulation and implementation of policies. Non-governmental organisations (NGOs) and households who are directly or indirectly impacted by these policies were also engaged in the interviews and questionnaires. The structured questionnaire data were complemented by focus groups and informal discussions with key players in the water sector as well as secondary data sources, which largely involved a literature review. In all, 85 respondents' completely answered questionnaires were used for statistical purposes. Two focus group discussions were conducted to collect additional data on water governance challenges in the provinces. Some institutions related to the water sector, such as the Department of Agriculture and Forestry and the Department of Monitoring and Evaluation, and some experts on South Africa's water sector were also interviewed to acquire first-hand information on factors hindering water policy implementation. Questions and discussions primarily focused on the appraisal of policies and strategies enacted post-independence, capacity, and financial challenges at local levels and stakeholder involvement in water governance. The discussions also touched on the strengths and weaknesses of the current policies and management structures. The data from the surveys were tabulated and the interviews were transcribed verbatim. Responses from questionnaires were analysed using descriptive statistics. Emerging themes were identified and analysed.

## 6. Results

### 6.1. The perspective of current policies and programmes among respondents

The fundamental issue driving this study is to examine the level of satisfaction among respondents on the current water policies and programmes designed to achieve water security in South Africa. Therefore, the respondents were asked to indicate whether the current policies and programmes are appropriate to achieve water security for the country. Figure 1 reflects the perspectives of the respondents in the field survey.

The study results revealed that among those who responded to the study, a majority (51%) believed that the country does not have the right policies and strategies to achieve water security for all, against 49% of those who held opposing views. As shown in Table 1, different explanations were given by the

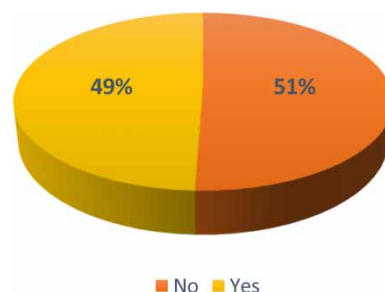


Fig. 1. Perspectives of respondents on the current water policies. *Source:* Field survey September 2019.

Table 1. Justification for the rating  $\sum(fx/n)$ .

Policies and strategies assessment	Very weak/poor	Weak	Fairly good	Good	Very good	Outstanding	Total number of respondents (108)	Majority of views on each indicator
Appropriate policies and strategies	5	46	30	18	3	–	102	Weak
Water accessibility	15	25	20	30	10	5	105	Good
Fragmentation of policies	20	28	25	20	7	–	100	Weak
Effective integration and coordination	25	42	28	5	3	–	103	Weak
Institutional capacity and resources	28	35	23	15	5	–	106	Very weak
Functional institutions and research	23	18	45	17	7	–	110	Good
Correlation between supply and demand	37	28	20	12	6	–	103	Very weak
Strategies on pollution control and climate change	25	48	19	8	5	–	105	Weak
Stakeholder's participation	36	27	25	10	4	–	102	Very weak
Public awareness and education	28	35	20	18	2	1	104	Weak
Investment and innovation	29	23	35	10	5	–	102	Fairly Good

$\sum$  is the grand total;  $f$  is the frequency;  $x$  is the number of participants with a specific perspective; and  $n$  is the total of participants.

Source: Field survey September 2019.

participants to justify their perspectives on the current policies and strategies. In-depth interviews with some respondents revealed that South Africa is overvalued as having world-class water policies and strategies. Concepts, such as circular economy, water–energy–food nexus, and fourth industrial revolution, are well embedded into policies. The policy framework stressed a coordinated management of water, land, and other related resources in order to maximise economic and social welfare in an equitable manner without compromising the sustainability ecosystems. Nevertheless, the ability to translate these into tangible impacts of water security is severely lacking. From the focus group discussions, it was established that some of the policies and strategies, such as the WSA of 1997, NWA of 1998, and some portions of the NWRS of both 2004 and 2013, are outdated, contradictory, fragmented, uncoordinated, and difficult to implement. For instance, some of the participants stated that the current policies and strategies lack adequate coordinated strategies and action among the stakeholders and also clear-cut strategies and goals, while the models of operation are complex, difficult to understand, and tough to implement. Open discussions with some respondents and the literature of Seppala (2002) established that all policies and strategies enacted post-independence in 1994 lack a clear direction of funding and financing of water projects. It was disclosed that a majority of the population are unwilling to pay for water services, while funding sources are very limited. Views from some participants further revealed that the process of policy formulation and participatory implementation of the policies are far more important than the contents of the policy document itself. Nevertheless, the involvement of all stakeholders, especially ordinary people, in the implementation processes is completely lacking in

the sector. From the focus group discussions, it was observed that the implementation mechanisms of these policies are weak at all levels of governance. For instance, it was pointed out that, generally, the national implementation strategies do not correspond to the operational activities at the local levels. Vast scholarly literature revealed that nearly all of the policies and strategies are enacted with the help of donors sponsored by international consultants, and, therefore, the policies are more a product of the donor countries or countries at the international level rather than local or indigenous expertise, and are often difficult to implement at the local level by taking into account the local context. As shown in Table 1, only ‘water accessibility and functional institutions’ were rated as ‘good’ out of the 11 assessment standards, while ‘investment and innovation’ was assessed as ‘fairly good’. None of the participants ranked any of the indicators as outstanding.

## 6.2. Capacity and institutional constraints to policies’ implementation

The respondents provided a number of responses (Figure 2) to the question on capacity and institutional constraints to the implementation of policies and strategies designed to drive the water security agenda in South Africa. As indicated (Figure 2), a majority of the participants agreed that the implementation of water policies and programmes is hindered significantly by both human capital and infrastructure challenges. Judging from the figure, it is obvious that infrastructure challenges were mentioned as the most significant constraint to water policy implementation. Out of the 85 respondents surveyed, 55 of them, representing 65%, mentioned infrastructure decay, poor governance and maintenance, and a lack of data on infrastructure development as some of the fundamental contributors to these predicaments. A lack of human capacity and financial capital was mentioned by a significant number of respondents (60%). From the focus group discussions, it was observed that a lack of skills in the managerial and operational autonomy of service providers is a significant hindrance to policy implementation. For instance, it was highlighted during the engagement that the water sector lacks people with professional skills and expertise, though the department is overstaffed. It was suggested that institutional transformation has not actually addressed the challenges of human resource issues effectively.

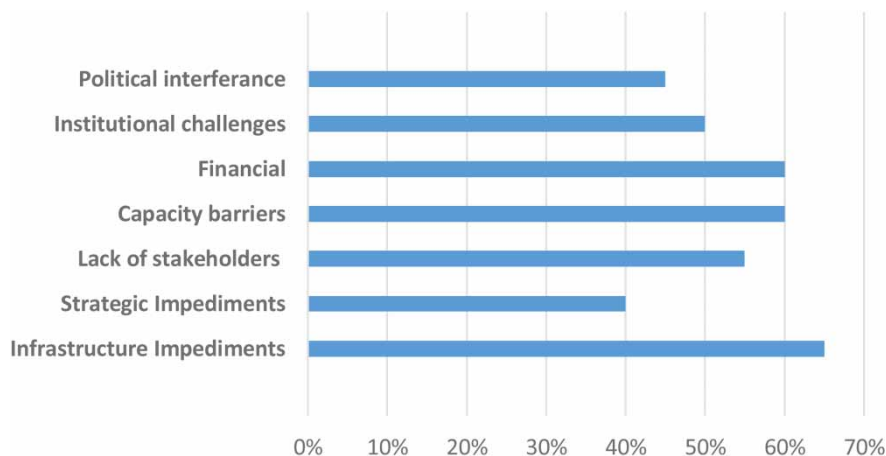


Fig. 2. Capacity and institutional challenges to water management. *Source:* Field survey September 2019.

The role of private sector involvement has not been addressed effectively, and the department seems to think that the principle of public–private partnership (PPP) will become automatically operational in an institutional or policy vacuum. Some of the participants suggested that the government does not seem to stress privatisation and PPP as a remedy for water service production. Financial constraint was also mentioned by a significant number of participants, and a majority of the participants alluded to the lack of funding and appropriate financing models, the reluctance to pay for water services, and the high operational costs in the sector as major obstacles to policy implementation. The lack of stakeholder engagement was identified by 50% as a barrier to policy implementation. From the discussions, it was revealed that in a majority of cases, policy formulation and implementation are not informed by grassroots realities. There are gaps between what is pertaining to communities and what the policies seeks to address. Consultants or top politicians determine the policies without consulting with grassroots communities. The implementation strategies strongly embrace the traditional command and control methods and only marginally integrate the collaborative, open-forum decentralised approaches. Institutional strategic constraints and political meddling are other major impediments identified as hindrances to policy implementation in the country. [Figure 2](#) reflects the views of participants in the field survey.

## 7. Discussion

As shown in [Table 1](#), different justifications were given based on the standpoint of respondents. The views expressed among the proponents of the current policies and programmes and the literature of [Park et al. \(2019\)](#) point to the fact that, before 1994, an estimated 59% and, thus, 38 million of the population had access to basic water suppliers. This has now increased to 86%, translating to 55 million of the population now having access to at least a basic water supplier. Besides, the findings disclosed that the policies and strategies integrated a mechanism to reduce water pollution, eradicate health hazards associated with water, and protect the ecosystems by introducing technologies for affordable sanitation and industrial and domestic wastewater treatment, thus mitigating the effects of groundwater contamination and establishing a national-level monitoring system and an effective legal framework. Furthermore, a majority of the proponents of these policies and strategies mentioned that the programmes and regulations had adapted protection and prevention mechanisms to promote sustainable water use and to address water challenges in the country. For instance, within the study, it was established that the second edition of the NWRS 2 of 2013 clearly outlines South Africa's water security and contains steps that need to be taken to address its water woes, e.g. by adopting different reconciliation strategies, a different type of water demand and conservation management, as well as the gradual introduction of wastewater (grey) re-use, while at the same time exploring the possibility of desalination for coastal cities.

Nevertheless, the findings, as shown in [Table 1](#), reveal that a majority of the respondents (51%) believed that South Africa does not have appropriate policies and strategies to achieve water security. These groups of respondents' assertions stem from the fact that the policies and strategies do not go far enough to tackle the challenges posed by municipalities, which are significant polluters of water resources in South Africa. Furthermore, it was discovered that policies such as the NWA, NWRS, and NW&SMP lacked the substance, direction, momentum, and impetus in addressing the real challenges pertaining to water in South Africa. The policy documents touch upon only surface issues or



problem areas, which are widely known and acknowledged, but are silent on the more critical problems and on how to go about confronting these problems. Furthermore, they do not provide any new insights or suggest new approaches, which is in contrast to the earlier (1990) water policies. These observations confirmed the views of Mackay (2003) that, while South Africa has some of the world's best water legislations and policies, such as the NWA of 1998 and NWRS 2 of 2013, it is critical to understand that these policies and strategies are still profoundly linked with the pre-2000 policy position of the DWAF. These regulations were formulated in line with some of the most pressing water-related challenges at a particular era such as the unequal distribution of water, grey water research, dam storage concerns, and other environmental issues (Maphela & Cloete, 2019). The implementation of the policies through the enactment of associated water regulations is continuing; however, the process seems to be a prolonged one. The new Water Master Plan of 2019 is yet to be approved by the Parliament and is seriously hindered by funding. Restructuring water management and establishing an independent water regulator are still at their preliminary stages of implementation. The ownership of water reserves is still a contentious issue in the new South Africa. The water reserves were transferred to the government through the DWS and the water boards have not been managed and maintained efficiently (Meissner *et al.*, 2013).

Adding to the complexity of water management and governance, the literature of Karodia & Weston (2002), Mackay (2003), and Maphela & Cloete (2019) and the follow-up discussions identified a disconnect between the water governance and management policies and the actions taken on the ground in South Africa. An overwhelming majority, 90% of the respondents interviewed, believed that the failure to implement policies and programmes is aggravated by bureaucratic implementation procedures within and among government departments and ineffective communication with key stakeholders. For instance, a majority of the respondents stated that there are eight different departments within the government institutions that look after different facets of water management such as its use, supply, pollution level, and so on. However, very little or no coordination and interaction occurs among these institutions. Notwithstanding the few interactions between and among water management institutions in South Africa, their roles are very fragmented and this is more pronounced at the provincial and national levels than at the local municipality and district levels (Makaya, 2020). This is because community leaders are not obliged by the NWA to be involved in water resources management (Makaya, 2020).

Regarding water governance and management challenges, a majority of the respondents acknowledged that the state institutions empowered to manage and regulate water in South Africa have ill-equipped resources, lack independence from political interference, and are poorly defined or overlapping authorities. These sentiments find an echo in the scientific literature (Meissner *et al.*, 2019), even though academic publications generally do not pronounce the challenges of specific institutions. Respondents singled out corruption in the appointment of senior managers in most of the provincial and regional DWS and some of the water boards as a significant obstacle to effective water management in South Africa. These water institutions are not proactive in dealing with water challenges, are stuck in the conventional strategies of managing water resources, and are manipulated by politicians. These views confirm the observations of Karodia & Weston (2002) that water management is mainly related to the technical abilities of the water managers; nevertheless, political and personal interests have controlled the daily operations of the industry. For instance, it was disclosed that South Africa loses R7 million, or a quarter of its non-billed water, annually, due to leaking or burst pipes and collapsing infrastructure, which are, in turn, due to poor operational management. At the same time, the country spews over 4 million litres of waste or partially treated sewage into rivers annually. One of the key findings of

this study revealed that the payment for services in the water sector has entered the political realm in most of the provinces in South Africa, and politicians or governments find it extremely difficult to promote the culture of payment of services if it impacts on votes. The findings revealed that these anomalies could be attributed not only to a lack of political will, inadequate funds, and expertise to implement legislation and policies, especially at the municipal level, but mainly to governance issues, as the national government often dictates to the local municipalities how to manage water resources.

## 8. Conclusion

South Africa, like many African countries, specifically those in the eastern and southern parts of the continent, such as Kenya, Tanzania, Ethiopia, Zambia, Mozambique, and Namibia, has renewed or launched its national water policies during the last two decades. Similar to South Africa's water reforms, these policy changes have had a profound effect on people's access to efficient, effective, and equitable water and sanitation services. The underlining principles of water reforms in South Africa post-independence include increasing private provision of water and sanitation services and financing, enhancing the participation of nongovernmental organisations (NGOs) and community-based organizations (CBOs) in water management. While these policies seem good theoretically and have achieved some level of success in terms of water provision to the previously disadvantaged communities, the implementation of these policies and subsequent institutional reforms have generally not been successful. The policies, as pointed out in the study, are fragmented, uncoordinated, and unclear and are silent on the administrative challenges and worsening water quality and the steps needed to tackle these. The implementation of the policies and programmes is hindered by several structural constraints ranging from a lack of capacity and skills, funding, and investment shortfalls to poor revenue collection. Other impediments range from weak inter-sectoral linkages and coordination to a lack of effective public participation by all stakeholders, particularly women and disadvantaged groups. To ensure successful implementation of the policies and strategies, it is imperative to identify the relationships between various institutions involved in water policy formulation at the local, provincial, and national levels. This means identifying the barriers hindering effective coordination and collaboration of crucial stakeholders at the levels of administration, funding, capacity building, and infrastructure planning. Effective policy coordination is therefore required both at intergovernmental institutions with technological interventions, institutional reforms, community participation, water conservation and re-use and legal frameworks which are feasible and provide opportunities to systematic approach to water resources management.

## Conflict of interest

The authors have declared that no competing interests exist.

## Data availability statement

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

## References

- Abu-Zeid, M. & Shiklomanov, I. A. (2003). *Water Resources as a Challenge of the Twenty-First Century*. World Meteorological Organisation, University of Cairo, Cairo.
- Ajayi, V. O. & Ilori, O. (2020). *Projected Drought Events over West Africa Using RCA4 Regional Climate Model*. Department of Meteorological and Climate Science, Federal University of Technology, Akure.
- Almazroui, M., Saeed, F., Saeed, S. & Ismail, M. (2021). *Projected changes in Temperature and precipitation over the United States, Central America, and Caribbean in CMIP6 GCM. Earth Systems and Environment 2020* (5), pp. 6–12.
- Averchenkova, A., Gannon, K. E. & Curran, P. (2019). *Governance of Climate Change Policy: A Case Study of South Africa*. Economics and Political Science, University of Leeds, Leeds.
- Bayliss, K. (2016). *Neoliberalised Water in South Africa*. SOAS, University of London, London.
- Benoit, R. L. (2019). *Failure to Maintain Infrastructure to Blame for Water Shortages*. The South African Water Chamber, Johannesburg.
- Boccaletti, G., Stuchtey, M. & van Olst, M. (2010). *Confronting South Africa's Water Challenge*. McKinsey and Company.
- Bond, P. (2011). *South Africa's 'Rights Culture' of Water Consumption: Breaking Out of Liberal box and Into the Commons?*. University of Western Cape, Cape Town.
- Boshoff, B. C. (2010). *Conceptualizing Sustainability: The Case of Johannesburg and Water*. Environmental Design and Planning, Virginia Polytechnique Institute, Virginia.
- Boudiaf, B., Dabanli, I., Boutaghane, H. & Sen, Z. (2020). Temperature and precipitation risk assessment under climate. *Earth System and Environment 2020*(4), 3–9.
- Chikozho, C., Manaya, R. & Dabata, T. (2020). *Ensuring Access to Water for Food Production by Emerging Farmers in South Africa; What are the Missing Ingredients?*. Institute of South Africa – HSRC, Pretoria.
- Claassen, M. (2013). [Integrated water resource management in South Africa](#). *International Journal of Water Governance* 1(2013), 323–338.
- Coning, C. B. & Shwill, T. (2004). *An Assessment of the Water Policy Process in South Africa*. Water Research Commission, Pretoria.
- Day, K. D. (2015). *Integrated Environmental Management: Where Is South Africa Headed Given Recent Developments Relating to NEMA and Infrastructure Development Act*. Institute of Marine and Environmental Law, University of Cape Town, Cape Town.
- Donnenfeld, Z., Crookes, C. & Hadden, S. (2018). *A Delicate Balance Water Scarcity in South Africa*. Water Research Commission, Pretoria.
- Drriuech, F. (2020). *Assessing future changes of climate extreme events in CORDEX-MENA region using regional climate model ALADIN-Climate. Earth System and Environment 2020* (4), 477–490.
- DWAF (1997). *White paper on a National Water Policy for South Africa*. Department of Water Affairs and Forestry, Pretoria.
- DWS (2018). *National Water and Sanitation Master Plan: Ready for the Future and Ahead of the Curve*. Department of Water and Sanitation, Pretoria.
- ECOSOC (2008). *Achieving Sustainable Development and Promoting Development Cooperation*. United Nations Publication, New York.
- Falkenmark, M. (1990). Global water issues confronting humanity. *International Journal of Water Resource Development* 6(4), 191–200.
- Fuo, O. N. (2013). A critical investigation of the relevance and potential of IDPs as a local governance instrument for pursuing social justice in South Africa. *PER/PELJ* 2013(16), 225–230.
- Haigh, E. H., Fox, H. E. & Davies-Coleman, H. D. (2010). [Framework for local government to implement integrated water resource management linked to water service delivery](#). *Water SA* 36(4), 477–478.
- Ilori, O. W. & Ajayi, V. O. (2020). *Change Detection and Trend Analysis of Future Temperature and Rainfall over West Africa*. Department of Meteorology and Climate Science, Federal University of Technology, Akure.
- Kahinda, J. M. & Boroto, J. R. (2009). *IWRM Survey and Status Report*. Global Water Partnership Southern Africa, South Africa.
- Karodia, H. & Weston, D. R. (2002). *South Africa's new Water Policy and Law*. Department of Water Affairs and Forestry, Pretoria.
- Long, D. (2017). *Reaching for Sustainability: Ecological Modernisation and Environmental Justice in South Africa Energy Policy and Practice*. School Geography, Archaeology and Environmental Studies, University of Witwatersrand, Johannesburg.

- Mackay, H. (2003). *Policies and Practices: Background, Pressure for Change in the Water Sector*. WWF/CSIR, Pretoria.
- Makaya, E. (2020). Water governance challenges in rural South Africa: exploring institutional coordination in drought. *Journal of World Water Council* 22(4), 29–34.
- Mander, N. D., Mander, M. & Sullivan, C. (2005). *Orange River Basin-Baseline Vulnerability Assessment Report*. Research-Gate, South Africa.
- Maphela, B. & Cloete, F. (2019). Johannesburg's implementation of the NWA, 1998 in Soweto, South Africa. *Journal Development Southern Africa* 37(4), 537–540.
- Meissner, R., Funke, N., Nienaber, S. & Ntombela, C. (2013). [The status quo of research on South Africa's water resource management institute](#). *Water SA* 39(5), 32–37.
- Meissner, R., Funke, N., Nortje, K. & Steyn, M. (2019). *Understanding water security at local government level in South Africa*. Palgrave Macmillan, London, UK.
- Mogomotsi, P. K. (2017). *South Africa's Regulatory and Policy Framework: A New Institutional Economic Review*. Okavango Research Institute, University of Botswana, Maun.
- Mukheibir, P. & Spark, D. (2003). *Water Resource Management and Climate Change in South Africa: Vision, During Factors and Sustainable Development Indicators*. Research Centre, University of Cape Town, Cape Town.
- Mukheibir, P. (2007). *Access to water - the impact of climate change in small municipalities*. Energy Research Centre, University of Cape Town, Cape Town.
- Mwendera, E. J. (2003). *Overcoming Constraints to the Implementation of Water Demand Management in Southern Africa*. Faculty of Agriculture, University of Swaziland, Luyengo.
- National Treasury (2015). *Public-sector infrastructure update*. Department of Finance and Treasury, Pretoria.
- Ndlovu, M. S. & Demlie, M. (2020). *Assessment of Meteorological Drought and Wet Conditions Using Drought Indices Across KwaZulu-Natal Province, South Africa*. School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Durban.
- Park, R., McLaren, M., Taumi, R. & Rivett, U. (2019). *Experience and Lessons in Managing Water From Cape Town*. Grantham Institute, London.
- Petzer, E., Oranje, M. & van Huyssteen, E. (2000). *A Policy Paper on Integrated Development Planning*. Department of Provincial and Local Government, Cape Town.
- Pretorius, R. W. (2001). *International protocols regarding global climate change and the impact on water resources*. Centre for International Political Studies, University of Pretoria, Pretoria.
- Ramcharan-Kotze, C. & Lubbe, J. (2019). *Investing in Implementation Model for Water Security and Resilience a Must*. City Press, Pretoria.
- Rosegrant, M. W., Ringler & Zhu. (2009). *Water for Agriculture: Maintaining Food Security under Growing Scarcity*. International Food and Policy Research Institute, Washington.
- SAAE (2019). *Municipal Water Crisis Is Looming, Warns Engineering Body*. BusinessDay.
- Schreiner, B. (2013). Viewpoint – why has the South African national water act (NWA) been so difficult to implement? *Water Alternatives* 6(2), 239–245.
- Seppala, O. T. (2002). *Effective water and sanitation policy reform implementation: need for systemic approach and stakeholder participation*. *Water Policy* 4 (4), pp. 367–369.
- Simo, T. S. (2014). *Cooperative Governance in South Africa: A Case Study of Intergovernmental Relations in Provision of Housing*. University of KwaZulu Natal, Durban.
- Singh, V. P., Chowdhary, H., Mishra, A. & Khedun, C. P. (2014). Climate change and its impact on water resources. *Handbook of Environmental Engineering* 15(2014), 8–12.
- Soyapi, C. B. (2017). Water security and the right to water in Southern Africa: an overview. *PER/PELJ* 2017(20), 2–6.
- StatsSA (2017). *Household Access to Services Stabilised*. Department of Statistics, Pretoria.
- StatsSA (2015). *Households access to water provision and sanitation*. Department of Statistics, Pretoria.
- Tewari, D. D. (2009). [A detailed analysis of evolution of water rights in South Africa: an account of the three and half centuries from 1652 to present](#). *Water SA* 35(5), 694–706.
- UNWWDR (2015). *Water for a Sustainable World*. UNESCO, Paris.
- Urama, C. K. & Ozor, N. (2010). *Impact of Climate Change on Water Resources in Africa: the Role of Adaptation*. African Technology Policy Studies Network, Nigeria.

- van der Zaag, P. & Savenije, H. G. (2014). *Principles of Integrated Water Resource Management*. UNESCO – Institute for Water Education, Delft.
- van Deventer, H., Smith-Adao, L., Petersen, C., Mbona, N., Skowno, A. & Nel, J. L. (2018). Review of available data for a South African inventory of inland aquatic ecosystem (SAIIAE). *Water SA* 44(2), 185–196.
- Viljeon, G. & van der Walt, K. (2018). *South Africa's Water Crisis – An Interdisciplinary Approach*. National Water and Sanitation Master Plan. Water and Sanitation, Pretoria.
- Watkiss, P., Downing, T., Handley, C. & Butterfield, R. (2019). *The Impact and Cost of Climate Change*. European Commission, Stockholm.
- WESS (2017). *World Economic and Social Survey 2017: Reflecting on 70 Years of Policy Analysis*. UN, Geneva.
- Yuryev, A. (2019). *Impact of Climate Change on Water Resources*. Quard Alliance, China.
- Zwane, E. M. (2019). Impact of climate on primary agriculture, water sources and food security. *Jamba* 11(1), 6–12.

Received 14 January 2021; accepted in revised form 3 March 2021. Available online 25 March 2021