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ORIGINAL ARTICLE

A systematic literature review of sustainable water management in South Africa

Jack Olley[1] · **Marin Cvitanovic**[1] · **Tilak Ginige**[1] · **Laura Bunt-MacRury**[2]

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Abstract
Addressing global challenges of inequitable and unsustainable natural resource management is imperative. South African water management serves as a critical case study allowing for the deep exploration of the intricate complexities surrounding these issues. South Africa's apartheid era witnessed inequitable water distribution and, despite the efforts made through the post-apartheid National Water Act of 1998 to prioritise equity and sustainability, challenges still persist in its implementation. This review aims to bridge knowledge gaps in sustainable water management in South Africa, focusing on environmental justice and sustainable development within the framework of the three pillars of sustainability. Through a systematic literature review of 57 scientific papers published in the Web of Science database between 1995 and 2021 this study aims to provide a comprehensive examination of the complex dynamics shaping water management in South Africa. Major themes, challenges, and solutions in sustainable water management are identified, emphasising the importance of stakeholder interactions, insufficient collaboration, and a lack of capacity building. The study also explores water policy implementation, environmental impacts of business, particularly in agriculture and mining, and the management of freshwater sources and their overexploitation. Economically, the mining industry's role and associated challenges such as acid mine drainage and water use competition are assessed. The Water-Energy-Food Nexus's influence on water management, water pricing efficiency, user willingness to pay, and the potential of decentralised systems and corporate social responsibility are also explored. With South Africa facing urgent challenges of water scarcity and resource management, integrated approaches that consider environmental, social, and economic dimensions, alongside robust multi-stakeholder collaboration, are essential. This review offers valuable insights for policymakers, water managers, and researchers working toward a sustainable water future in South Africa.

Keywords Sustainable development · South Africa · Environmental justice · Water management · Water policy · Multiple stakeholders

Introduction

There is an increasingly critical need for a global change in the way that natural resources are managed, to ensure their long-term future (Rosser and Mainka 2002). The over-exploitation of natural resources is a pervasive issue with significant ramifications for the environment, resulting in the loss and fragmentation of habitats, the degradation of the climate, and the extinction of species on a global scale. Because of the challenge of balancing the fragile state of the environment and the need for economic growth, sustainable development moved to the forefront of environmental research (Gore 2015). It was the Brundtland report in 1987 which set a clear definition of sustainability *"to meet the needs of the present without compromising the ability of future generations to meet their own needs"*. This report set the foundation for sustainability and remains the most widely used definition. Much of the international community embraced this concept as the new paradigm for development (Alvarado-Herrera et al. 2017). The Brundtland report was successful in increasing awareness amongst key policy makers to incorporate sustainability in policies around the world

✉ Jack Olley
jolley@bournemouth.ac.uk

[1] Department of Life and Environmental Science, Faculty of Science and Technology, Bournemouth University, Poole, Dorset, UK

[2] School of Political and Social Science, University of Glasgow, Glasgow, UK

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(Mbanze et al. 2020; Boulakhbar et al. 2020; Majid 2020; Belfiori and Rabassa 2021). Sachs and Warner (1995) point out that sustainable development presents the promise to find compromise and balance between sustainability which has an environmental focus and development which has an economic focus. Emas (2015) notes that the Brundtland definition of sustainability is vague and therefore susceptible for misinterpretation. However the Brundtland definition of sustainability does clearly define the foundations of sustainable development as securing the long-term stability of the economy and the environment (Emas 2015). Thus, the Brundtland report should be viewed as the most basic definition, of which greater scientific detail should be built upon it.

The concept of sustainability is challenging to implement into policy and practice due to its inherent complexity, which stems from the need to balance environmental, economic, and social dimensions. This multifaceted nature requires policymakers to consider long-term impacts, diverse stakeholder interests, and the interconnectedness of global systems. For instance, achieving environmental sustainability often necessitates economic sacrifices or social adjustments that may not be immediately palatable or feasible (Hopwood et al. 2005). Additionally, the uncertainty and variability of ecological and social systems further complicate the development of effective and adaptable policies (Kates et al. 2005). This complexity makes it difficult to formulate clear, actionable guidelines and to secure the necessary political and public support for sustainable initiatives.

Another critically important concept that also has its own associated issues is environmental justice.The origins of the environmental justice movement can be traced back to the unfair distribution of resources in the United States during the 1970s and 1980s, when environmental pressure groups were established to combat environmental injustices whereby particular groups received an unfair and disproportionate share of negative environmental consequences (Mohai et al. 2009). Waste facilities were frequently located in predominantly low-income, African-American neighbourhoods, leading to negative impacts on large community groups (Cutter 1995). Due to the racial and socioeconomic factors that influenced the siting of waste facilities, these communities experienced disproportionate environmental health risks (Smith et al. 2002). Environmental injustices refer to the disproportionate impact of environmental burdens on certain segments of society. Environmental justice is a growing and evolving movement, particularly outside of the United States where it originated (Paddock 2016).

Implementing environmental justice into policy and practice is particularly challenging due to its conceptual complexity, which involves addressing the equitable distribution of environmental benefits and burdens among all social groups. This requires a thorough understanding of socio-economic disparities, historical injustices, and the varying capacities of different communities to respond to environmental issues. Policies must be tailored to account for the diverse and often marginalised voices of affected communities, which can be difficult to integrate into traditional policymaking frameworks (Agyeman et al. 2002). Moreover, the intersectionality of race, class, and other social determinants adds layers of complexity, making it necessary to navigate a historical web of social, political, and economic factors that often work in opposition to achieving environmental justice (Schlosberg 2007). This multifaceted nature not only complicates the policy design but also poses significant challenges in implementation and community engagement.

The transition in South Africa (SA) from an unsustainable and inequitable water management system to one that aims for sustainability and equity is a valuable case study for examining the challenges and potential solutions for achieving sustainable development and environmental justice goals (Le Maitre et al. 2009). The apartheid era in SA resulted in a legacy of unequal water distribution, with white farmers disproportionately benefiting from unjust water management and exacerbating socio-economic disparities (Jegede and Shikwambane 2021). Following the end of apartheid in 1994, the newly elected government sought to address these disparities and incorporated principles of equity and sustainability into the constitution (van Koppen and Schreiner 2014). These principles served as the foundation for the National Water Act of 1998 (Republic of South Africa 1998), the country's primary water policy. However, challenges remain in the effective implementation of this policy as the nation struggles with the bureaucratic burden of implementing such a monumental policy redress (MacKay et al. 2003).

This study constitutes, to our knowledge, the first study of this kind to attempt to deliver a detailed account of the historical development and current state of sustainable water management in SA. Given the interdisciplinary nature of water, which has implications that extend across various domains, it is imperative to investigate all relevant factors comprehensively. The research objective of this study is to understand the degree to which water management in SA is sustainable. The study identifies the primary obstacles confronting the nation's water management. To develop a thorough understanding of the intricacies of the issue and engage the diverse range of stakeholders involved, a comprehensive and inclusive analysis is essential. This literature review has integrated a range of viewpoints and narratives, organised into the three pillars of sustainability, social, environmental and economic (Purvis et al. 2019).

The social section of this study investigates the function of various stakeholders and public participation in water resource management. It emphasises the necessity of inclusive decision-making processes that involve various stakeholders, including local communities, government agencies, and nongovernmental organisations. Moreover, it highlights the significance of water policy and management approaches that promote social equity and gender equality, with a focus on addressing the unique water challenges faced by marginalised groups. However, despite the National Water Act 1998 receiving great acclaim amongst scholars, its implementation has been unsuccessful (van Koppen and Schreiner 2014). Furthermore, the study stresses the need for robust monitoring systems to ensure accountability and transparency in water management practices.

The environmental section of this study assesses the environmental factors related to rivers, agricultural practices, mining activities, and ecosystem services in a critical manner. Regarding agriculture, it is noted that it is the primary industrial user of water in SA, and over time, farmers have become more efficient in their irrigation practices by adopting technological advancements and changing crop patterns. However, the overexploitation of groundwater remains a threat to water security, and it is recommended that monitoring of this exploitation be increased (Nhamo et al. 2020). Additionally, sustainable agriculture practices are crucial for maintaining both water quality and quantity, as highlighted by Chami and Moujabber (2016). Moreover, the study highlights the importance of managing water resources associated with mining activities, and emphasises the need to preserve ecosystem services that depend on healthy aquatic ecosystems.

This economic section of this study the economic consequences of mining operations on water resources and stresses the need for sustainable practices and heightened accountability in the industry (Naidoo 2015). The study delves into the concept of the Water Energy Food nexus, examining the interdependencies and compromises between these vital resources. Additionally, it discusses the potential of decentralised water management systems and the significance of water pricing mechanisms to encourage optimal resource utilisation. The study also scrutinises the role of corporations in upholding social responsibility in water management and their ability to make a genuine difference, emphasising the need for sustainable business practices.

Methods

A systematic literature review was conducted, with the purpose of identifying, synthesising, and evaluating data to address the research question (Mallett et al. 2012). This section describes the steps carried out for the identification and evaluation of literature related to sustainable water management in South Africa.

Data collection

The review followed the protocol for data collection and analysis developed based on Nightingale (2009). It considered the scientific database Web of Science (WoS) due to the multidisciplinary nature and prestige (Salisbury 2009). The literature search entered into Web Of Science was: "Sustain*" AND "Water management" AND "South Africa" up to March 2021. The initial search yielded 122 paper published between 1995 and 2021.

An inclusion criterion was developed to exclude papers that would not yield knowledge pertinent to the research question. The title and abstract were read for every article and book that arose to assess if it met the inclusion criteria (Table 1). If it was still unclear as to whether the article met the inclusion criteria, then the article or book was read in full.

Table 1 Inclusion criteria

Filter	Criteria
1—Geography	Only sources relating to South Africa were selected
2—Date	Only sources from 1950 onwards are to be selected
3—Language	Only sources written in the English language were included
4—Information	Sources must contain information which relate to at least one of: The extent of water scarcity in South Africa The management causes of water scarcity in South Africa The approaches set out to manage water sources in South Africa The challenges of managing water sources in South Africa Potential solutions for managing water sources in South Africa The types of stakeholders involved in water management in South Africa and their uses, needs and demands

Excluded papers included those that were not related to the research question, those that were not available for full-text reading and duplicate papers.

Data extraction

The final number of papers after accounting for the inclusion criteria was 57. The data obtained from the selected articles such as titles, authors, year and key themes were gathered in a master document on excel. The filtered literature was read in full and notes were made and organised in a master document. Notes were organised by relevant topics. Examples include but were not limited to: Policy, Participation, Climate, Water-Energy-Food Nexus, Rainwater harvesting.

The papers meeting the inclusion criteria were categorised according to the three pillars of sustainability: environmental, social, and economic (Purvis et al. 2019). Each paper's content was evaluated for their relevance to these pillars, identifying whether key themes within each pillar were addressed. Papers were categorised as environmental if they mentioned droughts, floods, climate change, ecosystems, ecosystem services or biodiversity and related themes. Papers were categorised into social if they mentioned health, multiple stakeholders, governance, participation, resource management, planning or communities or related themes. Papers were categorised into economic if they mentioned business, corporate social responsibility and financial costs and related themes. Each paper falls in to one category only. There were papers that had aspects of more than one of the three pillars of sustainability, in this case they were grouped into a category with multiple pillars of sustainability, those groups were "environment, social and economic", "environment and social", "environment and economic" and "economic and social".

Some papers focussed on specific locations within SA, using these areas as case studies in evaluating sustainable water management practices (see Table 3 and Fig. 2). These locations were mapped to provide a geographical analysis in this systematic review. Conversely, other studies evaluated sustainable water management more broadly, without relying on data from specific locations.

Results

Out of 57 analysed papers, the highest number (22 or 38.6%) focused solely on the social pillar of sustainability. It was followed by papers focusing solely on the environmental pillar of sustainability (19 or 33.3%), with the remainder focusing solely on the economic pillar (8 or 14%) or their combinations (Table 2).

Before 2007, only four papers on the topic were published in Web of Science. The year with the highest number of papers was 2018, demonstrating a relatively recent increase in research into this topic (Fig. 1).

In total, 31 papers focussed generally on SA without any specific locations used in the analysis. Of the 26 papers which focussed on a specific location (Fig. 2), there were several categories of location that varied in scale, population and water use involved (Table 3).

The social pillar

Out of 57 papers in the analysis, 22 focused mainly on the social pillar of sustainability, predominanly focusing on policy analysis. The South African government have set in their policy that water should be distributed equitably, redistributing water that was unfairly distributed during the apartheid era. This section evaluates the discourse amongst scholars surrounding stakeholder collaboration and participation, water policy, management approaches and monitoring.

Multiple stakeholders

Water management in SA involves a complex network of multiple stakeholders, each with unique demands, uses, and requirements for water resources (Askham and van der Poll 2017; Schoeman and Khorommbi 2007; Malisa et al. 2019). The recognition of the interdisciplinary aspect of water management by the SA government is evident in the integration of IWRM principles into policy (Schoeman and Khorommbi 2007).

Williams et al. (2018) conclude that the fair representation of all stakeholder types has proven to increase the effectiveness of water management and policy. Furthermore, experience suggests that goal setting can foster collaboration and teamwork (Askham and van der Poll 2017). However,

Table 2 Number of papers for each category

Theme	Only Environment	Only Social	Only Economic	Environment, Social & Economic	Environment & Social	Environment & Economic	Social & Economic
Number of articles	19	22	8	1	6	1	0

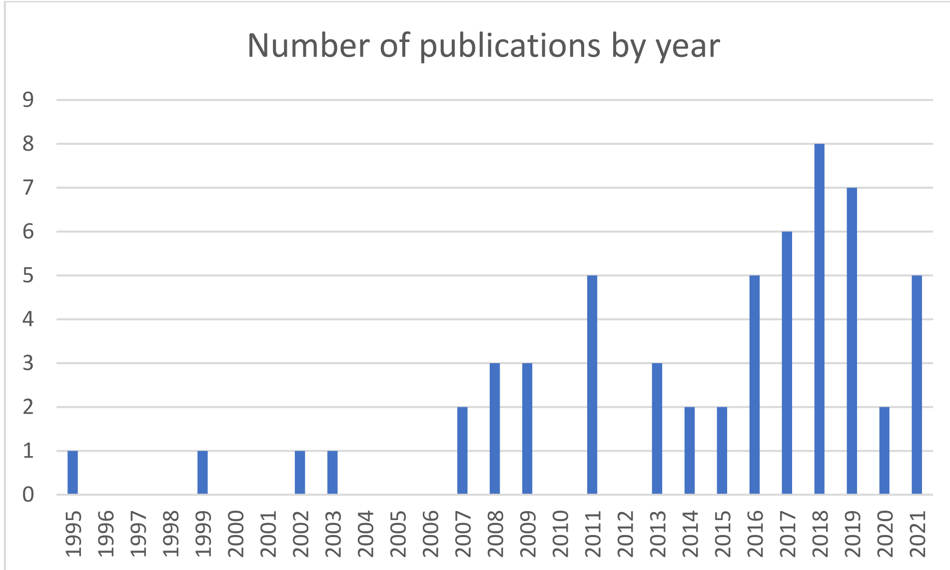

Fig. 1 Number of articles included per year published

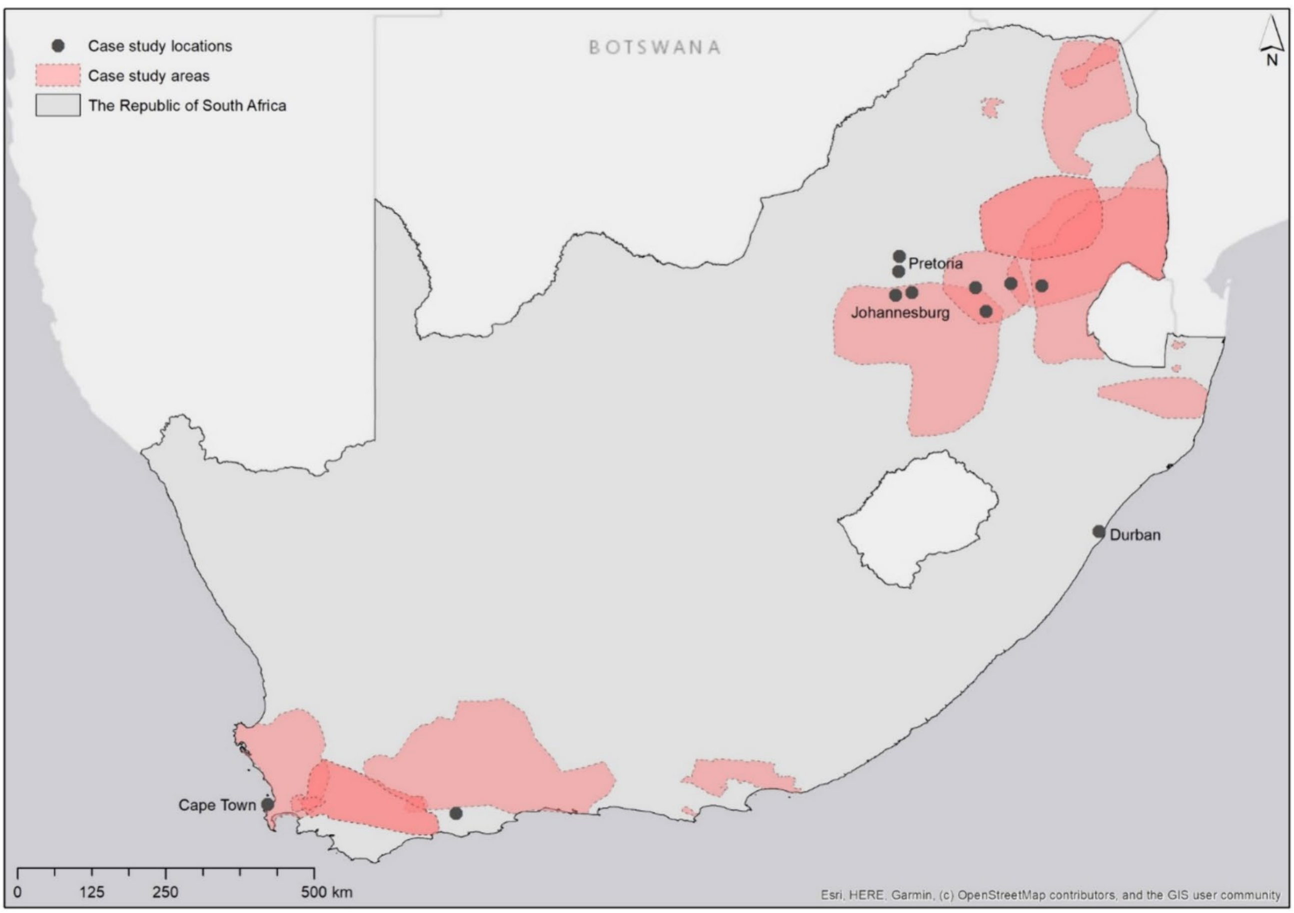

Fig. 2 Map of study areas, made by authors

there is insufficient collaboration of stakeholders involved in water management in SA, whereby stakeholders discuss equitable and sustainable water management plans and to

Table 3 Number of papers by each location category

Category:	Description:	Number of papers:
Urban	Focussed on a densely populated area	9
Rural	Focussed on a sparsely populated area	2
Farmland	Focussed on an agricultural site	7
Mine	Focussed on a mining site	4
River catchment	Focussed on a specific river catchment	4

listen to and acknowledge the needs and demands of other users (Knüppe 2011).

The literature identified a disconnect between stakeholders. Particularly, local communities do not feel like they are being supported by the government and that they are not working in the best interest of the public, often feeling as though they are given a "second rate" service (Malisa et al. 2019). Knüppe (2011) hypothesises that facilitating greater co-operation between stakeholders would build understanding between stakeholders and contribute to problem solving, basing this hypothesis on the experience that high levels of participation and co-operating amongst stakeholders influences the likelihood of successful resource management.

Schoeman and Khorommbi (2007) suggests that past stakeholder-engagement approaches have been ineffective in identifying the real, practical issues that stakeholders face, especially local communities, and developing and implementing solutions to address these issues. The problems identified are often perceived problems that other stakeholders assume communities face and so the solutions implemented don't work towards addressing real world issues (Schoeman and Khorommbi 2007).

The literature suggests that local communities are frequently the stakeholder type that are most burdened by present water management (Schoeman and Khorommbi 2007). They are also the most underrepresented in decision-making processes (Williams et al. 2018). Schoeman and Khorommbi (2007) hypothesise that capacity building is critical in enabling greater representation of local communities in decision-making. Research suggests that the stakeholder groups that use the largest shares of water, who are wealthier, more educated and have greater resources tend to dominate decision-making processes relating to water management in SA (Schoeman and Khorommbi 2007). In this case, large-scale users of water are able to dominate decision-making to favour their own agenda, regardless of whether this activity negatively impacts other stakeholder types. Furthermore, when small scale users are represented in decision-making they are largely dominated by men and thus, women tend to be under-represented (Schoeman and Khorommbi 2007). This means that the decision-making processes are not informed with potentially valuable knowledge that women involved in water management may have (Figueiredo and Perkins 2013).

To address this bias in decision-making, Schoeman and Khorommbi (2007) discuss a devolved management approach, where no stakeholder leads the decision-making process. However, water management requires strong leadership to ensure fair and productive decision-making (Knüppe 2011). Consequently, questions remain regarding the most efficient and equitable approaches for guiding stakeholder collaboration (Knüppe 2011). Pahl-Wostl (2019) notes the difficulty of transitioning from an approach where the government operates in an authoritative manner, towards a network governance, with a "co-decision making" approach. Additionally, the literature identifies that management approaches tend to be formed in a generic "blanket management" style, which are naive to the intricate nuances that influence case specific issues (Schoeman and Khorommbi 2007).

Catchment Management Agencies (CMAs) were developed in SA for the purpose of water management in an integrated and collaborative manner (Knüppe 2011). CMAs can be established by proposals from communities; however, the national government still largely maintain authoritative power in decision-making. For example, the government has discretionary power, allowing them to decide on water rights (Pahl-Wostl 2019). Though CMAs resemble an advancement in progress towards cooperative water management, only 2 of 19 proposed CMAs were in operation as of 2019, working as an example of a lack of progress in sustainable and equitable water management in SA (Pahl-Wostl 2019). Ramulifho et al. (2019) give a concise summary of the overall challenges in achieving cooperative water management in SA. They highlight five major challenges, "(i) A lack of CMAs, (ii) a lack of the understanding of environmental flow benefits, referring to the quality and quantity of freshwater river sources, (iii) financial restraints and limited resources, (iv) a lack of institutional and human capacity, (v) conflicts of interest".

Local communities and public participation

The urban poor of SA experience challenges such as low-income levels, high density of household living, a lack of access to water and sanitation, poor health, a lack of access to emergency services and are often situated in environmentally vulnerable locations, thus making these communities the most at risk to climate change (Williams et al. 2018). Despite this vulnerability and its urgent need to be addressed, a disconnect exists between local communities and their government, impeding their involvement in managing water resources crucial for their quality of life.

In general, the benefits of public participation are largely underutilised and indigenous knowledge is not being integrated into water management approaches in a manner which yields significant value (Williams et al. 2018).

In response, research highlights the importance of addressing the issue of environmental issue in SA by implementing approaches that work to build the capacity of local communities to adapt to climate change and a lack of water availability (Williams et al. 2018). There are hurdles in place that make public participation challenging, e.g. communities may lack the fundamental literacy skills and technical knowledge that would support decision-making (Schoeman and Khorommbi 2007). Similarly to Williams et al. (2018), Schoeman and Khorommbi (2007) advocate for mechanisms that support and educate local communities to develop the skills and knowledge needed to increase their resilience against climate change and enable them to participate in decision-making processes. A significant issue is that benchmarking targets may overlook local communities, leading to a situation where water services for the area may be deemed efficient regarding drinking water requirements, even if a large proportion of the community do not have access to these services. Therefore, future planning must ensure the equitable distribution of benefits (Carden and Armitage 2013).

While it is clear that supporting local communities in their adaptation to climate change must be a priority, the literature highlights evidence of a disconnect between the government and local communities. In their case study, Williams et al. (2018) highlight the community's lack of trust in the local municipality, stemming from a perception of unequal treatment among stakeholders. This distrust is exacerbated by a clear lack of communication between the local community and the municipality, which has manifested in violent protests within informal settlements.. However, there are cases of strong community-led projects, led by innovative members of local communities, particularly in response to flooding (Williams et al. 2018). In addition, Schoeman and Khorommbi (2007) highlight that though communities may receive decent opportunities for participation at local-levels, it is important not to ignore the importance of communities participating in decision making at an intermediate level, at a catchment level.

According to research, the most effective solution to a lack of trust amongst communities is the inclusion of communities in decision-making and policy planning processes (Williams et al. 2018). Moving forwards, it is critical that all stakeholders understand the importance of constructive water management, to encourage sustainable water use and to identify and implement less damaging activities (Schoeman and Khorommbi 2007). Schoeman and Khorommbi (2007) propose the implementation of a catchment mentor, who is a member of a local community and who receives training to improve the knowledge of water management in the community. This creates a role where the person is able to be more adaptive against climate change in their community and is also able to educate fellow community members about water conservation practices and encourage them to engage in decision-making opportunities, creating a potential pathway of communication between communities, government and other stakeholders. Water managers face a difficult balancing act between how they manage water to benefit the service provisions of local communities, as well as allocation to the industrial sector which is critical for job creation and economic growth in the area (Cole et al. 2018). However, there is a strong need for more reliable data to information decision making (Cole et al. 2018).

In South African communities, women are often responsible for the management of water sources for their household. Because of the particular social roles they play within their communities, women possess valuable knowledge for water management relating to ecology, socioeconomics, and politics (Figueiredo and Perkins 2013). Women understand critical community dynamics and social technologies, making them influential in their communities. However, in SA, women tend to be the most excluded group from participation in decision making processes. This exclusion means that organisations miss out on valuable knowledge derived from women's lived experiences. SA needs to introduce community based environmental education that provides equitable water management education to both women and men (Figueiredo and Perkins 2013). Figueiredo and Perkins (2013) found that by improving an individual’s socioeconomic status and access to resources, their adaptive capacity to climate change also improved.

In several cases within this literature review, education worked as a powerful tool within local communities to build adaptive capacity and to facilitate participation in decision-making and interaction with other stakeholders (Williams et al. 2018; Figueredo and Perkins 2013; Schoeman and Khorommbi 2007). However, there is a lack of implementation of this initiative at a local governance level (Williams et al. 2018).

Water policy and water rights

SA's first main water policy, the Water Act 1956, primarily valued water supply for economic purposes. It treated water as a commodity and implemented measures to meet demand (van Koppen and Schreiner 2014). One of the most successful water management measures during the apartheid era was the construction of dams to improve supply and at that time SA was an international leader in dam construction (Maphela 2009). After the end of the apartheid in 1994, the newly elected democratic government began drafting new policies (Knüppe 2011). The constitution put sustainability and equitability at the forefront (Visser and Verhoog 2007). Focus was shifted to protecting aquatic environments rather than relying on their capacity to recover (Roux et al. 1999). The lead policy for water management in SA is the National Water Act 1998 (Republic of South Africa 1998).

As part of the ambition to achieve equitability, the NWA 1998 was developed to encourage participation from previously disadvantaged communities, to engage in public forums to discuss ideas and develop approaches that work towards equitability for all stakeholders and to achieve sustainable water management. The NWA 1998 is widely regarded as one of the most progressive and scientific pieces of national policy. Collaboration with environmentalists meant that a recognition for the need to protect the ecosystem services was incorporated into the NWA 1998 (Knüppe 2011).

The previous 1956 Water Act focussed on water rights based on land ownership, resulting in an inequitable and undemocratic distribution of water. Water allocation was centred around land ownership, based on the riparian rights principle (Van Koppen and Schreiner 2014; Hattingh and Claassen 2008). To attempt to address the inequal provision of water rights, the NWA 1998 allocated water rights through the development of compulsory licensing, which required all present and potential users of water to apply for a license (Movik 2011). To address the limitation in license allocation methodology, the Water Allocation Reform was launched in 2003 to align water law with constitutional values of equality and sustainability (Visser and Verhoog 2007; Movik 2011). This policy was developed in consultation with a variety of experts across multiple disciplines, comprising of lawyers, environmentalists, government officials and NGOs, demonstrating collaboration amongst multiple stakeholders (Fisher-Jeffes et al. 2017). The final draft became official policy in 2006 (Movik 2011). The NWA 1998 law abolished the riparian principle, the geographical location of the water source and the ownership of that land would no longer be a factor in water allocation (Visser and Verhoog 2007). However, Askham and Van der Poll (2017) reported that of the nine mining companies researched, all nine had difficulties in applying for a water license. While policy changes shift greater attention towards equitable allocation of water, there is danger in poorly defined water rights. Secure water rights should give smallholder farmers greater encouragement for efficient water management (Fanadzo and Ncube 2018).

The incredible depth of detail and scientific planning within the NWA 1998 left a great burden of work needing to be done for the Department of Water Affairs to implement (Visser and Verhoog 2007). Roux et al. (1999) credit the NWA 1998 for establishing a reserve that prioritises water for basic human needs and the protection of the aquatic environment. However, they note that this approach requires effective and reliable monitoring to ensure the appropriate quantity of water is designated to the reserve and properly maintained. This added to the monumental task facing the national government, which must find the capacity and resources to address this issue, which the literature reports to be very low (Pahl-Wostl 2019).

Water management approaches

Reuse Grey water recycling is considered a valuable approach for enhancing water-use efficiency and water security, by reusing water for non-potable uses such as lawn irrigation and toilet flushing. South African municipalities have been drawn to grey water recycling as a relatively cost-effective approach in comparison to more significant, centralised water management approaches (Wanjiru and Xia 2018). However, greater measurement of the benefits of domestic grey water recycling and rainwater harvesting systems to end-users are required. Uptake in grey water recycling would ease the burden on sewerage services in SA, additionally, water conservation for alternative users would reduce the demand of potable water (Wanjiru and Xia 2018). Despite clear benefits, the high initial costs of implementing grey water recycling has tended to act as a deterrent to its investment within SA. Wanjiru and Xia (2018) highlight a need for appropriate regulations, policies, incentives and public education to encourage the uptake of grey water recycling.

The economic benefits of direct potable reuse (DPR) compared to indirect potable reuse are attributed to the absence of environmental buffers and the reduced costs associated with conveyance and mixing of the purified water with other potable sources (Lahnsteiner et al. 2018). However, ensuring a sufficient supply of usable water through reuse is a critical factor for the success of water reuse initiatives (Mamane et al. 2021; Swana et al. 2020). The literature suggests that DPR initiatives suggest that treated domestic and municipal used water can be utilised securely and financially for potable reuse (Lahnsteiner et al. 2018).

Rainwater harvesting Rainwater harvesting (RWH) has been in use in SA for a long time, but it has never made a significant contribution to the urban water supply. A study by Ndeketeya and Dundu (2019) shows that only 0.1% of the city of Johannesburg population utilises RWH. It primarily involves individual setups, often with small buckets (50–5000 L), and has been mainly limited to individual efforts. Various factors hinder RWH implementation, including financial viability, reliability, quality, and maintenance concerns. Household income is a significant factor contributing to the low adoption of RWH infrastructure in SA. For example, a 5,000 L water tank costing US$346 is compared to the average household income, with 16.8% of households in Johannesburg having no income and 50% of South Africans earning below US$391.29 per month (Ndeketeya and Dundu 2019).

Furthermore, RWH requires a sloped roof so that rainwater runs into the harvesting tanks. Many urban households have flat roofs, making installation difficult, and some don't own their property, limiting their ability to install RWH infrastructure. Seasonal rainfall patterns in SA mean larger tanks are needed to ensure sufficient water during dry months, increasing costs and space requirements. (Ndeketeya and Dundu 2019). Research in SA is increasingly exploring the feasibility of implementing rainwater harvesting (RWH) for agricultural irrigation. RWH coupled with water transfer systems could supplement water loss, to give further resilience and reduce reliance on boreholes. However, further research is needed to ascertain the possibility of success (Velasco-Muñoz et al. 2019).

Integrated water management Interest in integrated water resource management (IWRM) has grown in SA (van Koppen and Schreiner 2014). IWRM is designed to facilitate public participation and is a point for information exchange amongst stakeholders.It functions as a mechanism to ensure that stakeholders that are directly impacted by water management have a voice in water management. It aims to create a comprehensive understanding of local water resource use and stakeholder needs (Du Plesis 2014; Havenga and Cooke 2003). IWRM is incorporated in the national water act, by recognition of the relationship between socio-economic development and integrated water management to achieve poverty eradication (Schoeman and Khorommbi 2007). However, IWRM has faced criticism as for the neglect of infrastructure (van Koppen and Schreiner 2014). The DWA adopted developmental water management in 2013 in attempt to overcome some of the issues. While IWRM has potential benefits through its holistic approach, its past failures were partly due to a lack of interdisciplinary collaboration across departments (van Koppen and Schreiner 2014).

The National Water Resource Strategy 2 (NWRS2) was a fresh attempt at water resource management by the SA government (Chami and Moujabber 2016). After 20 years of difficulty in implementing IWRM principles, NWRS2 was developed to provide more guidance in interpretation (van Koppen and Schreiner 2014). NWRS2 adopts a "developmental" approach, emphasising water's crucial role in equitable economic and social development. It aims to invest in water infrastructure for rural communities, creating socio-economic opportunities (van Koppen and Schreiner 2014). NWRS2 also seeks to streamline bureaucratic processes for faster action. This approach simplifies previous policies and offers hope for achieving long-standing equitable goals (van Koppen and Schreiner 2014). Helness et al (2017) add that successful IWRM requires tailored efforts to suit local environmental and socioeconomic conditions, accounting for different stakeholder perspectives. Furthermore, to ensure the success of IWRM in SA, authorities must be held accountable (Herrfahrdt-Pähle 2013). Successful IWRM relies on decentralising water management and promoting cooperative water governance. There is a need for stakeholders to collaborate and utilise conflict resolution strategies to avoid inequitable outcomes (Nyam et al. 2021). IWRM implementation in SA has also been impeded by a lack of government capacity since 1994, such as many well qualified white engineers and hydrologists leaving the DWA, being replaced by black employees who had less experience and qualifications, to meet transformation goals (van Koppen and Schreiner 2014).

Monitoring While initiatives aimed at monitoring and benchmarking water management in SA are important, it is essential to acknowledge that the National Water Services Regulation Strategy, developed by the Department of Water Affairs, has significant flaws that need to be addressed (Carden and Armitage 2013). Despite providing a means to identify underperforming areas, the plans overlook statistics that consider water service provision to poor communities. This approach means that the performance indicators may suggest efficient water supply levels, but the system overall is not sustainable if the needs of vulnerable communities are not met. Moreover, while the SDGs have provided a helpful framework for water management, decision-makers must use relevant indicators to highlight areas requiring attention (Cole et al. 2018). The implementation of SDG 6, which emphasises access to safe and sufficient water, is critical in addressing the challenges in the water sector. However, it is important to recognise that the SDGs do not necessarily consider the unique context of SA, and it is necessary to identify relevant indicators that can effectively measure progress towards sustainable water management. Therefore, it is crucial to take a critical look at existing strategies, recognise their limitations, and make efforts to address them, to achieve truly sustainable water management in SA (Cole et al. 2018).

Water quality management in SA relies on reliable data and effective tools (Hattingh and Claassen 2008). Water footprint assessments (WFA) are valuable for sustainable freshwater allocation in SA (Pahlow et al. 2015; Munro et al. 2016). Calculating average water use per product enables informed decision making for farmers, to decide which crops require less irrigation (Munro et al. 2016). However, despite its potential, WFA adoption in SA has been slow (Munro et al. 2016). WFA is criticised for not considering all relevant data, such as local influences and only environmental impacts, disregarding social impacts (Munro et al. 2016). Lack of public interest may stem from varying statistics (Le Roux et al. 2018). Therefore, to achieve sustainable water resources, WFA requires more investment, resources and training to generate more reliable local data to insure its greater use and value in SA.

The environmental pillar

Climate change and societal demand are affecting the availability of water in SA, which is exacerbated by the population increase (Chami and Moujabber 2016; Carden and Armitage 2013). Dryland areas, which are important for biodiversity, are particularly vulnerable to the impacts of water scarcity due to climate change (Stringer et al. 2021). Climate change has led to increased rainfall in the east of the country, such as the Klein Karoo region, often resulting in intense and less regular rainfall events that can cause flooding (Stringer et al. 2021). The consequences of climate change are also evident in decreasing water levels in rivers (Kapangaziwiri et al. 2011), putting further pressure on SA's water resources. Out of 57 papers in the review, 19 have focused primarily on the environmental aspect of water and water use in SA. The topics covered included decreased streamflow in rivers and increased flooding, with the main uses being in agriculture and mining. Several papers focused on ecosystem services provision and water quality.

Rivers & flooding

SA's growing population and water scarcity are putting pressure on its river systems to provide water for drinking, farming, and industry (Ramulifho et al. 2019). According to Pahlow et al. (2015), the major river basins of SA experience blue-water scarcity for extended periods of the year. This is expected to continue as the demand for water is projected to increase by 23–150% by 2025, which will further deplete SA river systems (Le Maitre et al. 2009). In addition, there is a trend of reduced stream flow in rivers across the country (Kapangaziwiri et al. 2011). Human activity primarily causes low stream flow, harming aquatic biodiversity. Understanding groundwater-surface water interactions is crucial to pinpoint the causes (Kapangaziwiri et al. 2011). Ramulifho et al. (2019) conclude that improving stream flow benefits stakeholders by enhancing economic and social well-being. However, progress towards sustainable streamflow in SA is impeded by a lack of understanding of benefits amongst stakeholders, financial restrictions, a lack of capacity and conflicting interests.

CMAs have been tasked with data collection, analysis, and strategy implementation by the DWA, but Ramulifho et al. (2019) suggest the need for an independent body to evaluate CMA performance and ensure sustainable practices. CMAs should adopt sustainable catchment management strategies and engage with stakeholders to support conflict resolution when dealing with land-use trade-offs, additionally, implementing more efficient irrigation systems, removing alien plant species, and planning irrigation patterns have been seen to contribute to increased streamflow (Le Maitre et al. 2009; Stringer et al. 2021). The national government is actively combating invasive species through the "Working for Water" program, engaging local communities to remove invasive plants and restore ecosystem services. The effort restored ecosystem services worth approximately US $8 billion, including more fresh water, timber products, woody fuels, and grazing opportunities. (Zikhali-Nyoni 2021).

SA's rivers are experiencing reduced streamflow due to the impacts of climate change (Kapangaziwiri et al. 2011), but the effects of urbanisation and climate change are also contributing to increasingly intense and severe flood risks in the region (Williams et al. 2018). This risk is particularly high in informal settlements, because of the high density of housing, with most roofs composed of metal sheeting and with little vegetation to contribute to the uptake of water (Fitchett 2017). Such areas are almost completely impervious; water is directed to pedestrian lanes where litter is collected and blocks water flow, with communal toilets and standpipes also contributing to flooding. To address this issue, Fitchett (2017) conducted a preliminary study on sustainable drainage systems (SuDs) in the informal settlement of Diepslott. The approach involved creating permeable channels that divert water into an attenuation pond, mimicking natural water management processes that had been disrupted by urbanisation. The results were promising, with a reduction in pollutants such as nitrates and phosphorus. The project also involved significant community engagement.

While practical management by communities is important, Williams et al. (2018) argue that local governments must also implement policies and strategies to mitigate the impacts of climate change. One approach is to promote the socio-economic benefits of ecosystem services, which could encourage local governments to take action to improve local ecosystems.

Agriculture and groundwater

According to Pahlow et al. (2015), crop production is responsible for 75% of the water footprint of all production in SA, and the five crops of maize, fodder, sugarcane, wheat, and sunflower alone make up 83% of the total footprint of all crop production. Since surface-water sources in SA are nearly fully utilised (Chami and Moujabber 2016), and there is little availability for more dams to be built to increase supply, agricultural practices have adapted to the changing availability of water. Over time, crop patterns have been modified, and irrigation management has become more efficient. Farmers have increasingly adopted water-saving technologies, such as centre pivot systems instead of furrow irrigation, and low-pressure systems in place of high-pressure ones (Masiyandima et al. 2002), to conserve water and enhance sustainability. In addition, given the semi-arid and windy climate, soil degradation is a major concern. To increase drought tolerance in agriculture, Chami and Moujabber (2016) recommend improving soil moisture holding capacity, reducing soil erosion and salinity, and increasing biodiversity.

Numerous studies have emphasised the growing significance of groundwater utilisation in various sectors, primarily agriculture and household consumption (Knüppe and Meissner 2016). In SA, groundwater is recognised as a precious asset that serves essential purposes such as drinking water, sanitation, industrial support, poverty alleviation, and ecosystem preservation (Knüppe 2011). Although groundwater use may not constitute a substantial portion of overall water consumption, it plays a crucial role in local-scale irrigation across SA (Masiyandima et al. 2002).

Research by Nhamo et al. (2020) in the Venda-Gazankulu area of Limpopo Province examined the utilisation of groundwater for irrigated agriculture, showing that effective management of groundwater resources could lead to improved crop yields and increased resilience in arid regions facing water scarcity. At the time of the study, groundwater accounted for 13% of SA's freshwater resource usage, with 59% allocated to irrigation, 13% to mining, and 6% to livestock. It was also revealed that groundwater played a crucial role in domestic water supply, with 280 urban areas relying wholly or significantly on it.

However, despite growing awareness regarding the importance of sustainable groundwater utilisation, Masiyandima et al. (2002) identified persistent over-exploitation of these resources due to the absence of alternative water sources. This poses a significant concern since a decline in water availability can have a substantial impact on farmers' incomes, prompting them to continue overusing groundwater. The study suggests that the existing "3% rule" which allows only 30 hectares of irrigation per 1000 hectares to mitigate water level reduction in the Dendron aquifer, is inadequate. More explicit abstraction regulations are necessary to address this issue effectively.

As a result, urgent action is needed to establish a monitoring and feedback system that helps farmers identify how much land they can irrigate without over-exploiting groundwater sources, promoting sustainable groundwater use in the long run. This was suggested by Masiyandima et al. (2002), and it remains relevant today. Nhamo et al. (2020) add that the extent and availability of groundwater sources remain uncertain in SA and that using groundwater to improve the water supply will fail if done so without a thorough understanding of its present use, indicating a need for more regular and accurate monitoring. Quantifying groundwater availability to measure the amount that can be used for irrigation can create availability for groundwater to support other ecosystems that will in turn provide further goods and services (Nhamo et al. 2020). Chami and Moujabber (2016) propose a sustainable research framework that focuses on strategic crop research, intensified research in agricultural practices and methods to increase the efficiency of water use in agriculture. However, achieving further monitoring requires investment in technology and skilled personnel to implement this (Nhamo et al. 2020). An understanding of the dynamic of groundwater and its interactions with the surface and an identification of the main causes of low flow are critical for the development of sustainable water management strategies (Kapangaziwiri et al. 2011).

Mining wastewater is emerging as a potential irrigation solution to combat drought in SA's farmland. While the use of mining wastewater raises concerns about its long-term impacts on groundwater quality and quantity, Vermeulen and Usher (2015) suggest that it could contribute to increased water availability. Their study found that irrigation with mining wastewater led to considerable attenuation capacities in the soil, with much of the salts being stored in the soil during irrigation.

Mining & water quality

The mining industry is the second largest user of water in SA, after agriculture (Askham and Van der Poll 2017) with gold and coal mining being of huge importance to the South African economy (Vermeulen and Usher 2015). Mining companies in SA have started to prioritise sustainability and develop sustainable initiatives (Liphadzi and Vermaak 2017). However, mining operations in the country pose significant environmental, socioeconomic, financial, and political risks (Naidoo 2015). Acid mine drainage (AMD) is highly acidic and saline, and adversely impacts the environment by way of heavy-metal uptake, the degradation of soil quality and harm to aquatic species (Hobbs et al. 2008; Naidoo 2015). Contaminated water from AMD reaches river systems and affects water uses which are critical for socioeconomic development. Living in close to proximity mining waste increasing the likelihood of individuals suffering from poor health. According to the same study, acidic mine water has been known to cause flooding, and contribute to ground deformation and breakdown of structures such as concrete buildings.

It is crucial that mining companies operating in SA monitor and report their water consumption in addition to their environmental and social impacts responsibly, including AMD (Askham and Van der Poll 2017). While mining companies have historically developed innovative approaches for water security, such as backfilling boreholes that were dug for mining to create man-made aquifers (Botha and Maleka 2011). There remains a need for increased investment in the monitoring of water quality across SA (Hattingh and Claassen 2008). This need is identified in policy but lacks in implementation. Successful water quality monitoring is dependent on an understanding of the principles of water quality monitoring by key stakeholders, access to the relevant resources and tools.

The importance of water quality is recognised in South African water policy, yet water quality is often overlooked in favour of managing water quantity. There is a lack of understanding and knowledge in managing water quality effectively. Hand in with policy implementation, monitoring of water quality is also lacking. This has raised concern, as the chemical and physical characteristics of water are critical to ecological integrity (Hattingh and Claassen 2008), and Pahlow et al. (2015) found that the major river basins of SA are characterised by unsustainable levels of pollution such as nitrogen and phosphorus. Both water quality and quantity affect the provision of ecosystem services in SA (Hattingh and Claassen 2008).

Ecosystems and ecosystem services

Historical water management practices during the apartheid era favoured specific sectors of society and the economy, such as the construction of dams to support agriculture (Bohensky 2008). This, in turn, negatively impacted ecological resilience and ultimately degraded ecosystems and the services they provided. Large dams favoured the agricultural sector, utilising water for provisioning ecosystem services for food production, but at the expense of supporting ecosystem services provided by native aquatic biodiversity, and by diverting water away from local communities that use the environment for cultural ecosystem services. The reduction of river levels due to abstraction for irrigation, had another adverse impact in the form of increased population of blackflies, which are a significant pest to livestock. This resulted in alterations to aquatic biodiversity, ultimately reducing the productivity of the farm (Bohensky 2008).Williams et al. 2018 found that environmental capital was significantly improved as a result of raising community awareness of the benefits that ecosystem services can provide and how they can be protected, to improve local governance of ecosystems.

To ensure the long-term sustainability of these valuable ecosystem services, the quantity and quality of water required to maintain ecosystem function must be protected, without competition from alternative water uses (Visser and Verhoog 2007). South African policy recognises the value of ecosystem services and encourages their protection and conservation overexploitation (Roux et al. 1999). The conflict in SA over the most valuable ecosystem services provided by aquatic ecosystems pose a challenge for water managers to balance both ecological and societal needs. This challenge is compounded by the increasing population and water demand, which make it more critical to find a solution (Bohensky 2008).While efforts to address ecosystem resilience in SA have emerged, they have been mostly superficial and require continued management and monitoring (Bohensky 2008). Recognising the range of ecosystem services associated with aquatic environments is crucial to restoring and maintaining ecosystem resilience. Restoration efforts that restore environmental flows to their natural state can lead to increased biodiversity and valuable ecosystem services (Ramulifho et al. 2019).

The economic pillar

The results of this literature review show that out of 57 papers in this literature review, eight focus primarily on the economic factors of water management in SA. Themes include the economic influence of mining, the relationship between water, energy and food, the potential of decentralised systems, the economic and social influences and water pricing and the potential of corporate social responsibility.

Economic influence of mining

The coal mining industry plays a crucial role in the South African economy, with gold and coal being the two largest contributors in the mining sector. Coal sales account for 16% of exports, making it a significant source of revenue for the country. However, as the mining industry continues to grow, it puts increasing demands on water resources, leading to conflicts with other stakeholders. Hobbs et al. (2008) found that the coal mining industry in SA had an annual water use increase of 3.5%, which has significant implications for water availability and use in the country.

In addition to its impact on water resources, coal mining is crucial for power generation in SA. For example, in 2003, the Witbank coalfield alone accounted for 48% of the country's power generation. However, coal mining has significant negative environmental impacts, such as acid mine drainage, which has significant economic implications. Hobbs et al. (2008) found that from 1993 to 2003, the South African government spent R120 million on investigating and cleaning up the effects of acid mine drainage. Therefore, while the coal mining industry is critical for the South African economy, it is essential to consider the trade-offs it presents, such as increased water demands, conflicts with other stakeholders, and negative environmental impacts. Future policies and regulations should aim to balance economic development with sustainable use of natural resources and environmental protection to ensure the long-term prosperity of SA (Novhe et al. 2016).

Water energy food *nexus*

The Water Energy Food (WEF) Nexus framework has gained recognition in SA as an effective tool for the holistic management of the interconnectivity between water, energy, and food systems (Ding et al. 2019; Magidi et al. 2021). Although it is still in the framework stage and it has not been fully implemented in practice, Seeliger et al. (2018) demonstrated the potential value of the WEF Nexus. By using a farm budget model, they evaluated the benefits of switching from an electrically powered irrigation pump to a gravity-fed pump, which is an energy-saving approach. The study found that this approach improved water availability and farm profitability, demonstrating that a shift in perspective from water scarcity to the relationships between water, energy, and food can improve all aspects of the WEF Nexus. However, effective implementation of the WEF Nexus requires a holistic management approach, and further research is necessary to fully understand the interconnectivity between these systems and how they can be managed sustainably.

Water pricing

Despite concerns about its economic and social impacts, water pricing has proven effective in enhancing water efficiency (Akinyemi et al. 2018). In 2018, only 35% of South African households were paying for water, but research indicates that pricing can incentivise efficient water use, especially among farmers (Chipfupa and Wale 2019). Speelman et al. (2009) agree and find that wealthier smallholder irrigators are more willing to pay for water than those with lower incomes. Poorer irrigators were unable to absorb the increased costs of water, which resulted in decreased profitability and decreased access to water. It underscores the importance of considering the social and economic context when implementing water pricing policies, particularly their impact on vulnerable smallholder farmers.

In the case of smallholder farmers, it was envisioned that there would be a gradual progression of the payment for charges. Charges would be subsidised over a 5-year period, whereby the subsidy gradually reduces. However, payment for irrigation within smallholder farms varies regionally, many of the smallholder farmers did not yet pay for irrigation up to the point of the paper by Speelman et al. (2009).

While the use of pricing may encourage more efficient water use, it also has negative economic consequences, particularly for businesses such as agriculture. The increased costs of water usage resulting from pricing can have ripple effects on other aspects of these businesses, leading to decreased profitability and potentially fewer employment opportunities (Walter et al. 2011). Additionally, water pricing may disproportionately impact marginalised communities that may not be able to afford increased costs for water access (Speelman et al. 2009; Warmsley 1995). The reliance on market-driven pricing to manage water resources can also lead to conflicts between various stakeholders who may have different needs and interests (Akinyemi et al. 2018).

Decentralised systems

Wanjiru and Xia (2018) explore the potential of decentralised water systems as a cost-effective alternative to centralised systems in SA. Specifically, they examine the cost savings associated with grey water recycling and rainwater harvesting systems, indicating that a decentralised system can lead to substantial savings in water, energy, and operational costs by promoting more efficient use of resources.

Despite the potential benefits of decentralised systems, there are significant start-up costs associated with their implementation, which may deter the government from investing in them. Furthermore, the successful implementation of such systems requires public education and awareness to build capacity for managing decentralised systems. The need for relevant regulations and policies to facilitate implementation is also crucial. Thus, the likelihood of decentralised systems becoming a widely adopted alternative in SA is currently uncertain (Wanjiru and Xia 2018).

Corporations and social responsibility

Corporate social responsibility (CSR) entails corporations disclosing information related to social factors, aiming to instil values such as honesty and reliability in SA (Sánchez-Hernández et al. 2017). The study by Sánchez-Hernández and colleagues (2017) focused on 22 companies, emphasising the importance of large companies' commitment to sustainability initiatives. Moreover, CSR advocates for companies to create value for all stakeholders by engaging in fair trade, minimising environmental harm, and fostering socio-economic development opportunities for their employees.

Mining is a crucial employment sector in SA with socio-economic development potential. However, acid mine drainage (AMD) has lasting negative health effects on local communities. Furthermore, mine closures can leave communities financially vulnerable as employment opportunities disappear, and the impact of AMD may also reduce safe water (Naidoo 2015). Mining companies in SA must take more responsibility for AMD and its cleanup.

Discussion

In the discussion section, the emergent themes from the results are critically discussed, with a focus on the challenges surrounding sustainable water management in SA. Each subsection of this work is divided into three parts. The first part highlights the main findings within the literature, relating to that subsection. The second part focuses on the significance of those findings to the scientific framework. Finally, the third part focuses on identifying knowledge gaps and areas of future research that are required.

Among the three pillars of sustainability, the social aspect drew the most papers, 22 (Table 2), likely due to SA's post-apartheid transition, making it a compelling case study to assess progress of policy redress, as the SA government were tasked with redistributing water infrastructure that had previously favoured white farmers and excluded the majority of the population, to achieve environmental justice (Tempelhoff 2017). Of the papers focusing on specific areas, 9 out of 26 addressed urban settings, while only 2 covered rural areas (Fig. 2). These urban studies were concentrated in the Northeast, particularly the Gauteng province, driven by higher population density, increased water scarcity impact, and greater institutional capacity with better access to resources in comparison to rural areas, meaning there is a need for sustainable water management in SA to increase (Black et al. 2000; van Maarseveen 2021). Research on sustainable water management in SA peaked from 2017 to 2019 (Fig. 1). This surge was likely triggered by escalating water scarcity concerns (Liu et al. 2017) and was notably amplified by the 2018 Cape Town water crisis whereby the city of Cape Town came alarmingly close to zero water and instigated tremendous water management changes to increase availability (Rodina 2019).

Social pillar of sustainability

Multiple stakeholders

Successful sustainable resource management depends on partnership amongst diverse stakeholders who bring varied knowledge and values (Bieluch et al. 2017). Fair representation is pivotal for successful stakeholder collaboration (Williams et al. 2018). The case study by Malisa et al. (2019) underscores trust issues between low-income communities and water service authorities, necessitating new relationships and trust-building strategies. This work showcases SA as a case study for how policies have initiated cooperation among stakeholders (Knüppe 2011). Addressing disparities in water access requires understanding the root causes of trust issues and ensuring equitable access for marginalised communities. However, challenges concerning leadership and impartiality in stakeholder cooperation limit progress (Miska and Mendenhall 2018).

Understanding stakeholder relations and how they can be facilitated is critical for sustainable development (Leal Filho and Brandli 2016). The findings emphasise the need for further research to delve into the effectiveness and impact of Catchment Management Agencies (CMAs) as a means to facilitate multiple stakeholder cooperation, particularly in integrating indigenous knowledge and diverse perspectives for inclusive water resource management (Knüppe 2011; Havenga and Cooke 2003). Additionally, there is a pressing need to identify and address the factors hindering effective stakeholder collaboration in SA, and to critically examine the most effective approaches for facilitating multiple stakeholder engagement.

Future research should assess the effectiveness and impact of CMAs and other co-operative approaches in achieving inclusive water resource management (Havenga and Cooke 2003) and identify the primary causes for the lack of implementation. It should explore and validate the most efficient approaches for fostering meaningful engagement and developing trust among multiple stakeholders in the context of sustainable water management (Malisa et al. 2019). Magombeyi et al. (2008) implemented a novel approach of a game tool, to instigate co-operation amongst stakeholders. Such work could improve the awareness of valuable aspects for successful water management, such as transparency amongst stakeholders, acceptance of operating rules and the provision of education. There is yet to be a comprehensive study that gathers the opinions of stakeholders regarding collaborative water management that incapsulates the wide range of factors influencing water management.

Local communities

There are clear disconnects between local communities and other stakeholder groups, hindering opportunities for participation in decision-making opportunities. Local communities believe that they are purposely mistreated, and they lack trust in the government (Williams et al. 2018). Consequentially, invaluable local knowledge is not utilised as much as it could be to effectively support water management in SA. The significant challenges in facilitating participation for local communities are a lack of technological knowledge and the literacy skills necessary for water management. As such, there is a need to build capacity and educate individuals to enable fair representation (Schoeman and Khorommbi 2007). Furthermore, while there are some efforts for participation at community level, there is a significant lack of opportunity at a catchment management level.

Community-led projects have seen some success in capacity building. Inclusion activities have helped bridge connections and restore trust between local communities and other stakeholders (Williams et al. 2018). There is a need to re-evaluate the indicators used to monitor the standards of living for local communities and to re-evaluate the mechanisms used to facilitate public participation. Water managers face a difficult balancing act between managing water to benefit the service provisions of local communities and allocating it to the industrial sector, which is critical for job creation and economic growth in the area (Cole et al. 2018). However, there is a strong need for more reliable data to inform decision making (Cole et al. 2018).

Research suggests that local communities should be given more responsibility in natural resource management, but they tend to lack a sense of ownership of projects (Chirenje et al. 2013). Therefore, more research should focus on the work of Schoeman and Khorommbi (2007), which advocates for mechanisms that support and educate local communities. These mechanisms aim to develop skills and knowledge that will increase their resilience against climate change and enable them to competently manage water resources. Additionally, there was a noted lack of studies that gather the perspectives of individuals in local communities on how water scarcity impacts their lifestyle, their opportunities for participation in decision-making and how they collaborate with other stakeholders.

Policy

Developments in SA's water management policy include a notable shift from treating water as a purely economic commodity, as observed in the 1956 Water Act, to a more sustainable and equitable approach embodied in the 1998 National Water Act (NWA) (van Koppen and Schreiner 2014). The NWA 1998 emphasises public participation, environmental protection, collaboration with environmentalists, and recognition of ecosystem services (Movik 2011), marking a positive step toward integrating environmental concerns and social equity into water management practices. However, inadequate government capacity in SA hinders the achievement of NWA objectives, necessitating further analysis and research into factors affecting capacity and potential enhancement strategies (Pahl-wostl 2019).

Our findings highlight the significance of policy shift towards sustainability and equity in water management. The South African water policy case study showcases how good policy does not always translate into practice, and goes towards understanding the factors that limit its implementation. These factors include, but are not limited to: government capacity, funding, and the overly scientific nature of the policy (van Koppen and Schreiner 2014).

Future research should focus on understanding how different stakeholders comprehend and interpret the NWA 1998, as well as the challenges they face in compliance. Additionally, it is essential to capture and articulate the opinions of water managers regarding water policy in SA. Addressing these gaps can contribute to refining and improving water management policies, ultimately supporting sustainable and equitable water resource management in SA. Furthermore, research into funding mechanisms for the Department of Water and Sanitation, political will, and strategies for policy implementation and monitoring is warranted.

Inequalities in water access

Climate change disproportionately impacts low-income local communities with high population densities and limited resources, particularly in environmentally vulnerable areas (Williams et al. 2018). Women, often responsible for household water management in South African communities, face heightened vulnerability due to their marginalised status (Figueiredo and Perkins 2013).

Our findings underscore the need to address social inequalities in the context of climate change impacts, especially concerning water access and management (Figueiredo and Perkins 2013). They emphasise the importance of gender-sensitive approaches in climate adaptation strategies (Pearse 2017). The research highlights that women play a crucial role in community climate change adaptation efforts, particularly in South African communities, where they are often responsible for managing water sources within their households (Figueiredo and Perkins 2013).

Future research should explore effective local governance mechanisms for enhancing the adaptive capacity of marginalised communities to climate change impacts. Specifically, there is a need for in-depth investigations into strategies to encourage women's participation in decision-making processes and to ensure equitable access to water management education (Terry 2009). Additionally, the development and evaluation of training programs aimed at building local communities' water management skills and resilience to climate change should be a priority (Schoeman and Khorommbi 2007). These research endeavours can inform policies and interventions that promote social equity and climate resilience in South African communities. Research should investigate whether women have an interest in decision making and whether they have these opportunities available to them.

Environmental pillar of sustainability

Groundwater and pollution

In SA, groundwater plays a vital role in irrigation (Masiyandima et al. 2002), but it is susceptible to over-exploitation (Bai et al. 2022). Greater monitoring of groundwater resources is needed to understand exploitation patterns (Nhamo et al. 2020). Many farmers tap into groundwater without considering sustainability and efficiency, highlighting the need for education and more efficient irrigation techniques (Nhamo et al. 2020).

This work reinforces the significance of groundwater in SA. Due to the distribution of water infrastructure, especially in rural locations and for irrigation purposes, groundwater sources are often tapped into as a last resort (Knüppe 2011). Water availability can be improved in agriculture by modifying crop patterns and adopting water-saving technologies (Masiyandima et al. 2002). Persistent over-exploitation of groundwater due to the absence of alternative water sources is a concern. Sustainable groundwater use requires more explicit regulations and monitoring systems to prevent depletion (Masiyandima et al. 2002).

Future research should focus on identifying and implementing effective mechanisms for supporting small-scale farmers in groundwater conservation and how to incentivise water conservation to avoid overexploitation. Additionally, there is a need to investigate the potential of new technologies, such as climatic sensors, in improving water efficiency in agriculture (Pérez-Blanco et al. 2020). Research efforts should also explore innovative approaches like utilising mining wastewater for crop irrigation (Vermeulen and Usher 2015). Furthermore, understanding how knowledge can be effectively disseminated and applied by water managers and farmers is crucial, and this could be facilitated through the implementation of frameworks and technology investment (Nhamo et al. 2020). Research should also explore successful collaborative approaches, such as those found by Meseret (2014), to learn from and support farmers in sustainable groundwater use.

Rivers

South African water infrastructure faces increasing pressure due to population growth (Ramulifho et al. 2019). Water loss is exacerbated by climate change and evaporation (Williams et al. 2018), worsened with more frequent climatic events such as droughts and flooding (Kapangaziwiri et al. 2011). SA is in a unique position in comparison to most nations whereby its major cities were constructed based on proximitiy to mineral resources rather than water sources (Harrison and Zack 2012), thereby necessitating large water transfer systems to connect cities to river systems (Jacobs and Nienaber 2011). Because of this complicated water management, regular monitoring of river systems is especially important to understand the factors influencing water quality and quantity (Ramulifho et al. 2019). Various factors impact water availability, such as pollution from sources such as acid mine drainage and household waste, which can lower water quality and reduce the amount of available water (Hattingh and Claassen 2008). Additionally, invasive species compete for water resources, thereby affecting streamflow (Stringer et al. 2021).

These findings emphasise the complexity and multifaceted nature of water management challenges in SA. Understanding and addressing the diverse factors influencing streamflow and water quality are critical for effective scientific frameworks in water resource management (Hattingh and Claassen 2008; Kapangaziwiri et al. 2011). SA's experience with erratic rainfall patterns and prolonged droughts due to climate change mirrors a global trend affecting various regions (Konapala et al. 2020). The historical legacy of apartheid, impacting water resource distribution and access, resonates with international discussions on social and environmental justice (Mohai et al. 2009).

Future research should prioritise investigating the constraints on investing in water infrastructure maintenance to mitigate water loss and enhance system efficiency. It is essential to investigate the reasons for poor infrastructure maintenance, including potential shortages of skilled personnel and training programs, as well as examining political will. Additionally, research should assess the performance of catchment management agencies and identify opportunities for enhancing their role in protecting water quantity. Research should also prioritise water quality monitoring and understanding its implications, particularly in addressing issues like acid mine drainage and its socio-economic impacts on informal settlements. Overall, further research and investment are required to address the intricate challenges facing South African water management.

Economic pillar of sustainability

Mining and water resource challenges

Coal mining is a vital sector in SA's economy, contributing significantly to revenue (Hobbs et al. 2008). However, its growth strains water resources, leading to conflicts with other stakeholders and causing negative environmental impacts like acid mine drainage (du Venage 2020). Coal mining plays a crucial role in power generation, but it contributes to load shedding issues in SA.

Our findings highlight the pressing need to address water-related challenges in the coal mining industry to ensure environmental sustainability and mitigate conflicts with stakeholders. Additionally, the role of coal mining in power generation and its impact on load shedding underlines the importance of a reliable and sustainable energy sector, illustrating the interrelated nature of water, energy and food (Seeliger et al. 2018).

Future research should explore innovative approaches within the mining sector to reduce pollution and wastewater. Additionally, corporate social responsibility is gaining interest; however more concrete proof of its genuine impact on local communities is needed, especially within the mining communities. Future research is required to identify the most effect methods for ensuring that mining companies are responsible for the mitigation of AMD during after mine closure.

Water pricing and economic consequences

Water pricing is used to control water usage and encourage efficient use (Walter et al. 2011). However, it can have negative economic implications, particularly for businesses like agriculture (Berbel and Gómez-Limón 2000). Proper rate structures are essential to account for varying factors influencing water availability, and water pricing should serve as an incentive for informed water usage (Dinar 1998).

There is a need to establish a balance between water pricing as a mechanism to control usage and its potential economic impacts, particularly in sectors like agriculture. Effective rate structures and incentives are crucial components of water management policies. Our literature analysis has shown that stakeholders are willing to pay for reliable water sources, however, this varies depending on the wealth of the individuals involved (Akinyemi et al. 2018).

Future research should investigate the effectiveness of different water pricing models in SA, considering their economic and environmental impacts. Additionally, assessing the influence of rate structures and incentives on water usage patterns is important. Research should also explore innovative approaches to minimise the economic burden of water pricing, especially for sectors like agriculture.

Water and energy

SA places considerable reliance on coal for energy production, although it possesses considerable potential for renewable energy sources (Makgetla and Patel 2021). The shift towards renewable energy may be impeded by obstacles such as the nationalised energy sector, as well as the substantial financial investments required. The prospect of privatisation as an alternative may face opposition due to SA's historical experiences with privitasation in other sectors (Smith 2009; Young 1991). It is important to recognise that Water, Energy, and Food have an interconnected relationship. This is exemplified by SA's current struggle with power outages, which have a detrimental impact on irrigation systems as there is limited energy available to power pumps (Wiese and van der Westhuizen 2024).

Water management involves expertise from multiple disciplines, that each influence each other (Seeliger et al. 2018). This reinforces the "silo" approach to governance, whereby each discipline is managed by a different department, potentially limiting successful management (Scott and Gong 2021). The implications of this silo approach to governance are far-reaching and can lead to inefficiencies, lack of coordination, and suboptimal decision-making (Scott and Gong 2021).

Future research should investigate strategies and policies to facilitate the shift towards renewable energy sources in SA. Novel approaches that implement the values of the WEF nexus, which emphasise conservation of energy, water, and food, could benefit the rural areas that lack a consistent energy supply (Seeliger et al. 2018). Moreover, it is crucial to explore the public perception of privitisation in the energy sector and its feasibility in South Africa's specific context. Future research should also examine the potential for integrated resource management, rather than a fragmented approach.

Conclusion

Unique challenges stemming from historical legacies, climate variability, and rapid population growth have exacerbated the water crisis in SA. The available water resources are often mismanaged due to inadequate infrastructure and poor governance, hindering effective water distribution and access. Although SA boasts commendable water policies, the implementation process has encountered numerous obstacles, leaving room for improvement in translating policy intentions into practice. The key inhibitors are government capacity, funding and the scientific complexity of policy. The legacy of apartheid continue to negatively impact equitable water resource management, and politics will play a pivotal role in determining the success of sustainable water management initiatives. A lack of implementation across the board, of many water management approaches such as CMAs, RWH, IWRM and monitoring suggest a lack of political will and direction.

SA's water policy has garnered recognition in the scientific community for its emphasis on sustainability and equity. However, the disparity between policy intent and on-ground implementation remains a pressing issue. To overcome this policy-implementation gap, efforts must be focused on strengthening governance structures, enhancing coordination among relevant authorities, and fostering a culture of accountability. Despite having a robust legal framework centred around sustainability and equity, the full realisation of these principles in water management has yet to be achieved. Integrating the environmental, social, and economic pillars of sustainability is crucial to overcome the multifaceted challenges of water scarcity and pollution. A holistic approach that considers the interconnectedness of these pillars is imperative for successful water resource management.

Water management is an inherently interdisciplinary field, involving various stakeholders with diverse interests and priorities. While some stakeholders benefit disproportionately from existing water management practices, achieving a fair and inclusive system that considers the needs of all is vital. Collaborative efforts between communities, government agencies, NGOs, scientists, and industry players are essential to develop comprehensive and practical solutions that address the water crisis from multiple perspectives.

This review acknowledges the improving opportunities for public participation in water management decision-making processes in SA. Inclusive and participatory approaches empower and foster collaboration between local communities and stakeholders, enabling them to contribute with their insights and concerns in shaping sustainable water policies and projects. By involving diverse perspectives, the nation can foster a sense of ownership and collective responsibility towards water resources.

As SA strives to overcome the formidable challenges posed by water scarcity, equitable distribution, and sustainable management, a collaborative and integrated approach is paramount. Challenges are exacerbated by climate change and population growth. The lessons and insights garnered from this literature review offer valuable guidance for policymakers, water managers, and researchers to devise strategies that ensure the effective implementation of sustainable water management practices.

Data availability This is a systematic literature review and uses secondary data only. These data sources are pre-existing and can be seen in the references.

Declarations

Conflict of interest On behalf of all authors, the lead author, Jack Olley, states that there there is no conflict of interest.

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