Technology Needs Assessment (TNA) for Climate Change Adaptation in Eswatini's Water Sector

STRENGTHENING THE NDA'S TECHNICAL AND INSTITUTIONAL CAPACITY IN ACCESSING GENDER-RESPONSIVE CLIMATE FINANCE

GREEN CLIMATE FUND
JOINT RIVER BASIN AUTHORITIES PROJECT BOARD
SIYINQABA
Global Water Partnership Southern Africa

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Executive Summary

This report prioritises water-related technologies in Eswatini with a focus on enhancing the National Designated Authority's capacity to mobilise gender-responsive climate finance. Climate change in Eswatini is expected to adversely impact the water sector, including increased frequency of droughts and floods, changes in stream flows, rising temperatures, and more. Since this sector is crucial for the country's development aspirations, water-related climate change technologies are essential. Therefore, the report details the water sector in Eswatini. It discusses legal and policy frameworks established to address climate change adaptation in the water sector, the methodology used for prioritising technologies (including stakeholder engagement and multi-criteria analysis) and presents prioritised technologies along with a SWOT analysis. This analysis evaluates the feasibility and potential of the prioritised technologies by examining their strengths, weaknesses, opportunities, and threats in contributing to sustainable development and improved resource management. The prioritised technologies address disaster preparedness, water scarcity, excess water, unknown climate risks, and water pollution. The report underscores the need for effective water-related adaptation technologies, such as improved water storage and management, water-efficient practices, and enhanced water governance.

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Abbreviations and Acronyms

AHP	Analytic Hierarchy Process
CCC	Copenhagen Climate Centre
CRED	Centre for Research on the Epidemiology of Disasters
CMU	Climate Change Unit
CTCN	Climate Technology Centre and Network
DWA	Department of Water Affairs
EEA	Eswatini Environment Authority
ESWADE	Eswatini Water and Agricultural Development Enterprise
EWSC	Eswatini Water Services Corporation
GWPSA	Global Water Partnership Southern Africa
JRBA	Joint River Basin Authority
MRB	Membrane bioreactor
MCA	Multi-Criteria Analysis
MET	Meteorology Department
MNRE	Ministry of Natural Resources and Energy
MoF	Ministry of Finance
MTEA	Ministry of Tourism and Environment Affairs
NDC	Nationally Determined Contribution
NDMA	National Disaster Management Agency
TAP	Technology Action Plan
TNA	Technology Needs Assessment
TPTC	Tripartite Permanent Technical Committee
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations Office for Disaster Risk Reduction
WASH	Water Sanitation and Health

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Introduction

Water is essential for Eswatini's development aspirations, contributing significantly to GDP earnings from agriculture and industry. However, climate change is expected to have several adverse impacts on the water sector, including: changes in precipitation patterns, increased frequency and intensity of incidences of droughts, floods and lightning, changes in the timing and magnitude of river flows, and rising temperatures (Dlamini, 2021; WaterAid, 2021).

One of the major concerns is the potential decrease in water availability due to changes in rainfall patterns. This could lead to reduced water supplies for domestic, agricultural, and industrial use, impacting food security, livelihoods, and economic development in the country. Additionally, the increased frequency and severity of droughts may exacerbate water scarcity issues, particularly in rural areas that heavily rely on rain-fed agriculture (Ministry of Agriculture, 2017). Changes in river flows can also have significant implications for water management and infrastructure. Shifts in the timing and magnitude of river flows may affect hydropower generation, water storage, and irrigation systems, impacting energy production and agricultural productivity (Ministry of Agriculture, 2019). Rising temperatures can also have several negative impacts on the water sector. Accelerated water evaporation rates can lead to increased water loss from rivers, reservoirs and exacerbate water scarcity. Higher temperatures can also affect water quality, as warm temperatures promote the growth of harmful algal blooms and reduce dissolved oxygen levels in water bodies (Eswatini Environment Authority, 2021). This can have an adverse effect on aquatic life and make water less safe for human consumption.

Eswatini has experienced two of its most severe and prolonged droughts in recent history, in 2007 and 2015/2016. These droughts have had a significant impact on the country's water sector and have highlighted the need for adaptation measures to address the challenges of climate change. Evaluations conducted within the nation post the 2015/16 drought revealed that it struggled significantly to cope with one of the lengthiest dry spells in its history. Approximately 410,000 individuals (https://unfccc.int/documents/81631) required various levels of humanitarian aid, including provisions like food, agricultural resources, water and sanitation, healthcare, and nutritional support, as well as assistance for early recovery of livelihoods. The country's rivers and dams reached historic low levels, leading to widespread water rationing across the country.

As an illustration, the availability of water to sustain the requirements of the sugar industry is presently limited due to the over-allocation of all the river systems within the country (Government of Eswatini, 2021a). Water reserves are dwindling as demand continues to rise. Given the existing scale of water consumption, it is imperative for the irrigation sector to enhance its efficiency. Consequently, there is a need to upgrade the existing irrigation systems and practices, alongside promoting greater accountability in water utilization.

These negative impacts of climate change will be exacerbated by baseline conditions of widespread poverty (63% of the population), high unemployment (40%), a high prevalence of HIV (26% of adults), and widespread land degradation as a result of deforestation, alien plant invasions and overstocking of livestock (Simelane et al., 2020).

To address the challenges of climate change, Eswatini needs to adopt effective water-related adaptation technologies. The country conducted a climate change Technology Needs Assessment (TNA) in 2016, which identified several water-related climate technologies that could be used to adapt to the impacts of climate change. These technologies include improving water storage and management infrastructure, promoting water-efficient practices in agriculture and industry, implementing drought-resistant crop varieties, and enhancing water governance and planning processes. Building to this work, the Eswatini Government through the Ministry of Tourism and Environmental Affairs (MTEA) and Ministry of Natural Resources and Energy (MNRE) with funding and technical assistance from the Green Climate Fund (GCF) and Global Water Partnership (GWP), respectively, commissioned a study to reprioritise water related climate technologies and identify some of the existing and potential barriers and gaps hindering the adoption and diffusion of these technologies. By taking these steps, Eswatini can build a more resilient water sector and safeguard its water security in the face of climate change.

Climate change impacts in the water sector

Evidence of the impact of climate change on Eswatini's water sector is mounting. Historical data indicates a notable increase in the average annual temperature, with a rise of about 1.53°C and 1.21°C observed between 1961 and 2020 in the western and eastern part of the country, respectively (Dlamini, 2021). Heatwaves have become more frequent over the past two decades, with an increase in the number of days surpassing 34°C. Rising temperatures have increased evaporation rates, eutrophication; subsequently decreasing stream flows in major river basins, a decline in water quality leading to an increase in waterborne diseases, and a rise in the occurrence of droughts and floods (NDMA, 2017; Tfwala et al., 2020). During the 2015/16 El Niño event, Eswatini experienced a significant decline in water sources and rainfall, with reductions exceeding 50%. This phenomenon has gradually led to the drying of small streams and wetlands, causing alterations in biodiversity and ecosystems (NDMA, 2017).

The negative impacts of climate change on water are likely to cause considerable challenges in the agriculture, WASH and water dependant sectors (FAO, 2023; NDMA, 2017). The Department of Water Affairs (DWA) conducted a climate change vulnerability study for the water sector which established that since 1901 to 2009 the average increase in temperatures across all major river basins (Komati and Usutu) has increased by an average of 1-1.5ºC. This has led to increased evaporation from surface water bodies which subsequently reduces the stream flows. Moreover, prolonged droughts have also reduced stream flows in many major and small rivers. This has reduced water availability for economic activities, especially irrigated agriculture. The recent drought faced by the country in 2015/16 led to over 50% decline in water resources, especially in storage dams.

According to the Government of Eswatini (2021a), rainfall projections indicate that the rainy season is expected to start later and end earlier, with an increase in the intensity and frequency of extreme rainfall events and flash floods, the frequency, intensity, and duration of dry spells, and the incidence of severe droughts. These changes in rainfall patterns could have several negative consequences, including reduced water supplies for domestic, agricultural, and industrial use, crop failures, livestock losses, increased competition for limited water resources, and a higher risk of waterborne diseases.

Objectives

The primary objective of this work was to conduct a reprioritization process for water related climate technologies for Eswatini. Stakeholder consultation and literature review formed the basis of this study. Specific guiding activities for the process were as follows:

- Reviewing the water related climate technologies that were identified in the 2017 Technology Needs Assessment.
- Reviewing water related climate change adaptation options and technologies from the ongoing National Adaptation Planning process.
- Reviewing other relevant sources of technologies for the water sector.
- Facilitating a stakeholder engagement process (two consultative workshops) for re-prioritising water related technologies.
- Identifying existing and potential barriers, risks and gaps that are hindering the acquisition, deployment, and diffusion of prioritised technologies.
- Identifying opportunities for the uptake of water related climate technologies.

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Overview of the water sector in Eswatini

The water sector holds immense value for Eswatini, playing a central role in the country's long-term development objectives and serving as a crucial means of countering the escalating climate-related risks. The water sector plays a crucial role in climate change adaptation by implementing strategies to manage water resources more efficiently, developing resilient infrastructure to withstand extreme weather events, and promoting water conservation and efficient use through relevant technologies. Water resources in Eswatini consist of five main river systems: Lomati, Komati, Mbuluzi, Usuthu, and Ngwavuma Rivers (Figure 1). The country's surface water resources are estimated to be 4.5 km^3/year, with 42% originating from South Africa (Manyatsi & Brown, 2009).

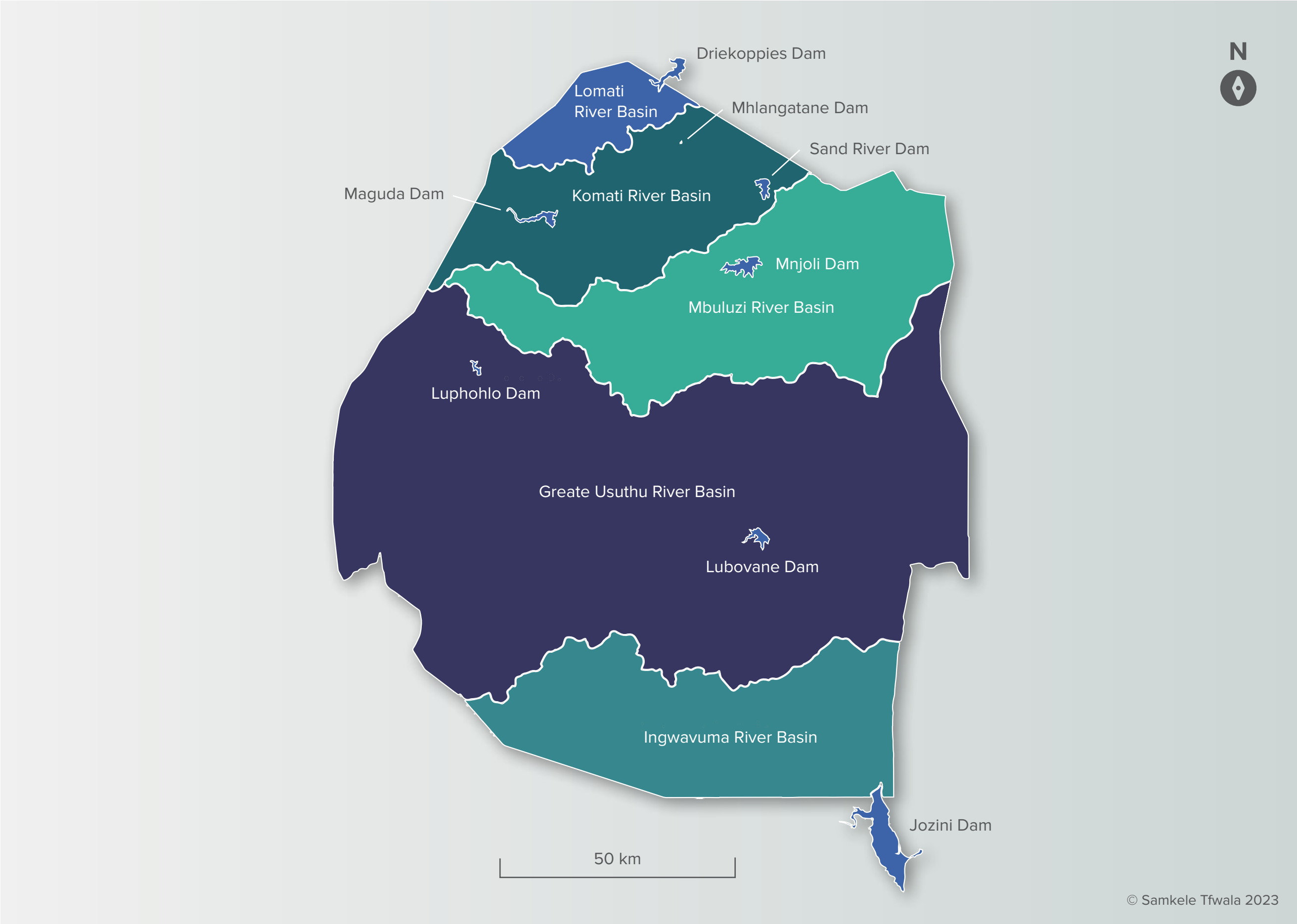

FIGURE 1: Eswatini river systems and selected dams.

Eswatini has also 10 major dams which are important for hydropower, water supply and irrigation. These are Maguga, Mnjoli, Sand River, Luphohlo, Hendrick Van Eck, Nyetane, Sivunga, Hawane, Lavumisa and Lubovane (Table 1 and Figure 1).

Groundwater resources are also available in the country and are primarily utilized for domestic purposes and to a lesser extent for water supply to some industrial activities. As one moves from west to east of the country, the quality of groundwater degrades due to geological factors and reduced rainfall, leading to diminished aquifer recharge. This groundwater also serves as the foundation for river base flow during arid periods. There are, however, no recent studies that have evaluated the potential of groundwater resources in the country. Nonetheless, the Government of Eswatini (2020) has proposed an updated evaluation of the water potential. According to an assessment conducted by FAO (2005), the country's groundwater resource potential, mainly concentrated in the Highveld and Middleveld regions, was estimated to be 0.66 km^3 per year.

A large portion of the country's water supply primarily depends on transboundary rivers (with 42% originating from South Africa). Of the five (5) river basins, only two river basins (Mbuluzi and Ngwavuma) originate from Eswatini (Figure 1). The Komati River basin spans an area of approximately 47,000 km^2 and is shared among Eswatini (6%), Mozambique (31%), and South Africa (63%) (Matondo & Msibi, 2006). Both the Komati and Lomati rivers are sub-basins of the Incomati River basin. Originating from the eastern part of South Africa at an elevation of 2000 m above mean sea level, the Komati River flows through the northern part of Eswatini and eventually discharges into the Indian Ocean in the southern part of Mozambique at an elevation of 150 m above mean sea level. The Mbuluzi basin is a shared resource between Mozambique and Eswatini, encompassing a total catchment area of approximately 5,400 km^2. Within this catchment, Mozambique accounts for 40% with 2,160 km^2, Eswatini covers 58% with 3,130 km^2, and South Africa contributes 2% with 110 km^2 (MNRE, 2016). Situated in the southern region of the country, the Ngwavuma river basin experiences intermittent dry periods, with

TABLE 1: The major dams of Eswatini (Government of Eswatini, 2015).

	Name	Capacity (m^3)	Use	Surface area (1000 m^2)	Date established	River system
1	**Maguga**	332,000,000	Hydropower and irrigation	10,420	2001	Komati
2	**Mnjoli**	153,000,000	Irrigation	14,800	1980	Mbuluzi
3	**Sand river**	50,330,000	Irrigation	698	1965	Komati
4	**Luphohlo**	24,000,000	Hydropower	120	1984	Usuthu
5	**Hendrick Van Eck**	9,865,000	Irrigation	145	1969	Usuthu
7	**Nyetane**	6,780,000	Irrigation	137	Upgraded 1992	Usuthu
6	**Sivunga**	5,920,000	Irrigation	120	1972	Usuthu
8	**Hawane**	2,750,000	Irrigation	70	1984	Mbuluzi
9	**Lavumisa**	345,000	Irrigation	27	1996	Pongola
10	**Lubovane**	155,000	Irrigation	13.9	2009	Usuthu

brief periods of recovery occurring during the rainy season. The Great Usuthu River basin (which is the largest basin in the country) covers an area of around 12,000 km^2, encompassing approximately two-thirds (66%) of the country and providing support for an estimated 75% of the national population.

Water usage from these transboundary river systems is regulated through agreements between Eswatini, South Africa, and Mozambique. One such example is the establishment of the Komati Basin Water Authority (KOBWA) in 1992, which is a bi-national entity formed under the 'Treaty on the Development and Utilisation of the Water Resources of the Komati River Basin between the Kingdom of Eswatini and the Republic of South Africa.' Similarly, the Tripartite Permanent Technical Committee (TPTC) was created in 1983 as a cooperative agreement between South Africa, Mozambique, and Eswatini.

Simulated streamflow for 2021 to 2060 (Matondo, 2012) moreover showed that projected runoff change is negative in Usuthu, Mbuluzi and Ngwavuma basins. In addition, based on the vulnerability assessment conducted in 2016 (Government of Eswatini, 2016b) for the water sector, it is projected that the streamflow of rivers will experience a 40% decrease by 2050 as a result of climate change. Most of the water usage in the country, exceeding 95%, is allocated to commercial irrigated agriculture, with a particular focus on the irrigation (Figure 2) of sugar cane (Eswatini Environment Authority, 2021). A summary of the water demands from the main economic sectors for selected river basins is presented in Figure 2 below. The basins with the highest water requirements, as indicated in the figure, are Usuthu, Mbuluzi, and Komati. These basins are primarily characterized by a significant reliance on irrigation.

Predictions of water demand in the country are projected to increase (Eswatini Environment Authority, 2021). In the Komati River basin for example, the irrigation sector's water demand was 171 Mm^3 in 1997, which increased to 245 Mm^3 in 2015 and is projected to reach 285 Mm^3 by 2025. For the Mbuluzi River basin, irrigation demand was 229 Mm^3 in 2005, increased to 261 Mm^3 in 2015, and is projected to reach 292 Mm^3 by 2025. In the Usuthu River basin, irrigation demand was 310 Mm^3 in 2005, increased to 525 Mm^3 in 2015, and is projected to remain relatively stable at 527 Mm^3 by 2025. Given the escalating demand and the influence of climate change, addressing this situation necessitates the implementation of inventive and efficient adaptation technologies to guarantee the sustainable utilization of water resources.

Sector/Basin	Year	Aforestation	Irrigation	Livestock & Wildlife	Urban and rural water supply	Water transfer
Komati	1997	24	171	2	3	8
	2015	24	245	2	11	8
	2025	24	285	2	16	8
Lomati	1997	22	4	5	1	0
	2015	22	5	5	4	0
	2025	22	6	1	6	0
Mbuluzi	2005	1	229	1	13	0
	2015	1	261	2	17	0
	2025	2	292	2	23	0
Ngwavuma	2005	4	42	2	2	0
	2015	4	42	2	2	0
	2025	4	43	2	2	0
Usuthu	2005	103	310	8	52	0
	2015	103	525	8	56	0
	2025	103	527	8	59	0

FIGURE 2: Water demands (in (Mm³/yr)) in selected basins of Eswatini (MNRE, 2016).

Legal and policy frameworks

Eswatini has developed several national and sector policies and regulatory frameworks to help address climate change adaptation in the water sector. Some of the main documents and their descriptions are provided below in Table 2.

TABLE 2: Legal framework for the water sector and documents showing alignment with national priorities.

Document	Brief description
POLICIES AND ACTS	
National Water Policy (2018)	The primary objective of the National Water Policy (NWP) is to enhance the efficient and sustainable utilization of water resources. This goal is achieved by reinforcing the institutional structure, developing water resources, managing these resources effectively, improving the management of water-related information, providing water supply and sanitation services, establishing sound legal and regulatory frameworks, promoting capacity building, research, and training, as well as fostering awareness and stakeholder engagement, with a particular emphasis on gender inclusivity. This policy also seeks to intensify the monitoring of water usage, especially in response to the growing number of users and the potential conflicts that may arise as a result.
Water Resources Master Plan (2016)	This master plan is an update of the 2011 Integrated Water Resources Master Plan. It offers strategic direction to decision-makers and water users, advising them on the optimal approach to develop and oversee the country's water resources. It operates within the framework of existing policies and legislation, providing guidance on effective implementation.
Irrigation Policy (2015)	The policy aims to maximize the contribution of irrigated agriculture in Eswatini to economic growth and poverty reduction. It focuses on optimizing water productivity in the agricultural sector, establishing transparent regulations and accountable institutions for irrigation, and promoting investment opportunities for emerging farmers. The policy also emphasizes the adoption and practice of water-harvesting techniques and technologies to enhance productivity.
Climate Change Policy (2016)	The climate change policy emphasizes the crucial need for proactive measures in the face of climate change's various impacts, including droughts and floods. One aspect of this policy is the establishment of early warning systems and emergency preparedness plans to effectively respond to these challenges. Furthermore, the policy promotes and prioritises the implementation of an Integrated Water Resources Management (IWRM) Strategy. This strategy not only encompasses the integrated development of river basins but also focuses on the protection of vital water catchment areas. By adopting this comprehensive approach, the policy aims to ensure the sustainable and efficient use of water resources while preserving the health of essential ecosystems. Another significant aspect of the policy is the encouragement of rain harvesting technologies. These innovative methods help harness and store rainwater, reducing the reliance on traditional water sources and contributing to water conservation efforts.
National Water Act (2003)	The act advocates for enhanced catchment management through increased stakeholder participation and decentralization of water resource management. The Act also mandates the development of a Water Resources Master Plan to provide stakeholders with the necessary tools for sustainable water management. Additionally, it makes it obligatory to establish River Basin Authorities.
Water Pollution Control Regulations (2010)	These regulations aim to provide legal guidance on the water quality objectives for Eswatini. It covers water quality objectives, discharge of effluents, sampling, testing, and monitoring of water etc.
NATIONAL DOCUMENTS AND ALIGNMENT	
National Development Strategy	Promotes initiatives for water harvesting, encourage optimization of available water resources, promotes safe and clean drinking water and the need for more irrigation infrastructure.
Updated NDC (2021)	Promotes several adaptation initiatives and water related climate change technologies such as improving water governance and compliance, water pricing, early warning systems, catchment adaptation plans, water storage infrastructure etc.

Document	Brief description
National Climate Change Strategy and Action Plan (2014-2019)	This mainly aim to establish a structured approach for addressing the detrimental impacts of climate change in a way that actively contributes to realizing sustainable development, poverty alleviation, and the bolstering of the nation's adaptive capabilities for both its citizens and the country. The plan places significant emphasis on prioritising crucial climate change adaptation and mitigation measures across diverse sectors within Eswatini, including the water sector.
Adaptation communication	Provides information on national circumstances, including climate risks, vulnerabilities, and impacts in Eswatini's water sector among other sectors; and elaborates on ongoing and proposed adaptation measures and actions. It also provides a comprehensive overview of the actions and measures taken and proposed by Eswatini to address the impacts of climate change in the water sector, such as flood control, irrigation systems, climate-proofed infrastructure, strengthening protected areas, water governance and compliance, improving water use efficiency, catchment management plans and strategies.
GCF country programme	The GCF Country Programme is a multifaceted approach that aims to enhance the country's resilience to climate change, drive sustainable development, and ensure that Eswatini plays its part in the global effort to combat climate change. It offers a contextual overview of the climate change effects on the nation, shedding light on the financial requirements essential for advancing climate action. The document further shows alignment of the GCF impact area (health, food, and water security) and the nations priorities such as integrated water resources management (including water harvesting and conservation, adoption of water efficiency technologies like drip and micro irrigation.
National Development Plan	The document emphasizes two main strategies for better water resource management. The first is to manage and regulate water resources effectively and efficiently. This involves implementing measures to ensure proper utilization and conservation of water, as well as establishing effective regulatory frameworks to monitor and control water usage. The second strategy involves enhancing the capacity of bulk water storage through the construction of multi-purpose dams. By investing in these dams, the goal is to increase the overall water storage capacity, which can help in mitigating water scarcity during dry periods and supporting various purposes such as irrigation, hydroelectric power generation, and domestic water supply.
Irrigation policy (2015)	The main objective is to establish a clear course of action within the irrigation sub-sector. It outlines precise directives pertaining to the actions required for expanding the national irrigated area and enhancing the management of agricultural water resources, along with upgrading existing irrigated farming. This, in turn, aims to amplify the efficiency of labour and natural resources in Eswatini, ultimately leading to increased productivity. Additionally, the policy strives to encourage and cultivate irrigation practices that are aligned with the realities of both domestic and international markets, while also fostering the growth of value-added food processing.
Eswatini National Agricultural Investment Plan (SNAIP)	The primary objective of SNAIP is to enhance the role of agriculture in fostering economic growth while concurrently diminishing rural poverty and the prevalence of food insecurity. SNAIP outlines critical domains of agricultural investment spanning a decade, aimed at tackling issues such as low productivity and food insecurity. This includes a focal emphasis on investing in natural resource management, facilitating market access, ensuring food security, advancing research and extension, and effectively managing knowledge.
Eswatini National Energy Efficiency Strategy and Action Plan (NEESAP)	The NEESAP identifies obstacles specific to the country's context that hinder implementation and outlines the necessary steps to enhance effectiveness and ensure lasting sustainability in energy efficiency. It identifies technologies that can be applied in the water and agriculture sector to ensure efficiency. An example includes utilizing solar and wind power technologies for water pumping, both for potable and irrigation purposes, which has the potential to decrease the reliance on the electrical grid for meeting water demand.

Institutional arrangements in the water sector

The key institutions involved in water resource management (WRM) in Eswatini are presented in Figure 3, followed by a summary of their key responsibilities and/or mandates.

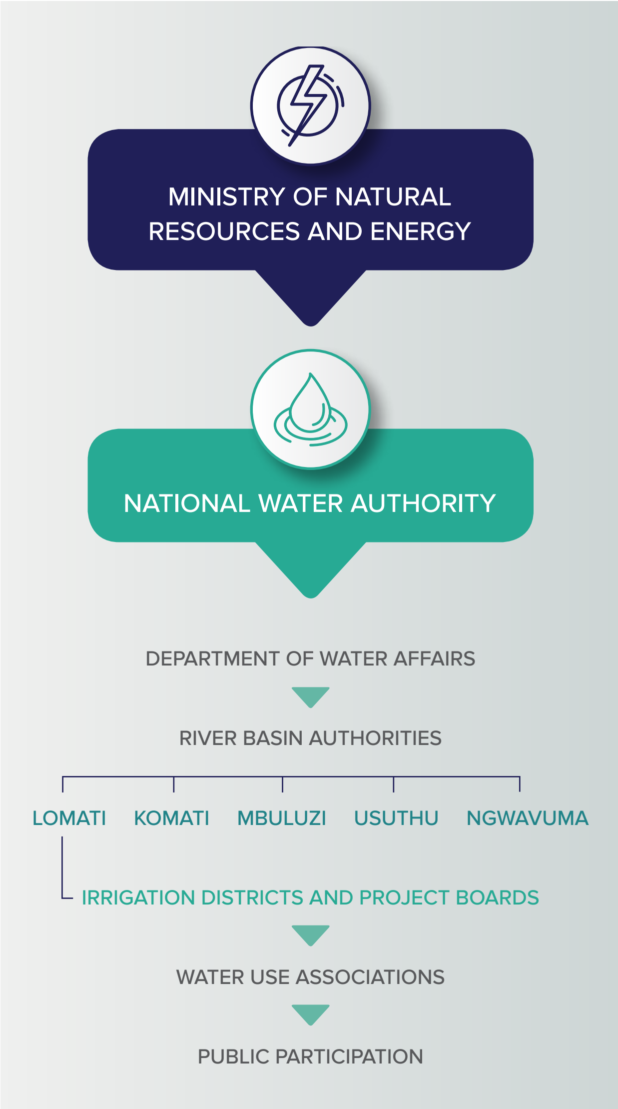

FIGURE 3: Institutional arrangement in the water sector.

1. Ministry of Natural Resources and Energy (MNRE): Responsible for overall water resources development, policy plans, budgeting, assessment, monitoring, allocation, and management of the country's water resources.

2. National Water Authority (NWA): Coordinates and supervises activities related to water resource management.

3. Department of Water Affairs (DWA): Provides technical secretariat support to the NWA. It manages bulk water infrastructure, ensures water supply to communities, safeguards national water resources from climate change impacts, and manages transboundary water flows.

4. River Basin Authorities (RBA): Comprised of representatives from relevant water sectors, these authorities develop and manage River Basin Management Plans, allocate water, monitor water use and pollution, collect levies and charges, and regulate water permits. They report to the NWA.

5. Joint River Basin Authorities Project Board: Established to provide technical and secretarial services to the RBAs, ensuring effective implementation of their roles as defined by the Water Act 2003.

6. Irrigation Districts: is responsible for overseeing the operation and upkeep of infrastructure within the designated area, as well as the allocation of authorized water quantities in alignment with permits, all for the advantage of individuals within the district.

7. Water Users Associations: Formed by permit holders in a defined area to maximize the benefits from water permits, but they are not statutory bodies.

8. Public Participation: The users and guardians of water responsible for conservation and protection of water resources.

9. Other key institutions involved in WRM include the Ministry of Agriculture, Ministry of Health, Ministry of Tourism and Environmental Affairs (MTEA), Ministry of Finance (MoF), Eswatini Water Services Corporation (EWSC), Eswatini Environment Authority (EEA), Eswatini Water and Agricultural Development Enterprise (ESWADE), National Disaster Management Agency (NDMA), Meteorology Department (MET), Climate Change Unit (CMU), bilateral and multilateral development partners, non-governmental organizations (NGOs), traditional leadership, and community-based organizations.

3

Water technologies and reprioritization

Technology prioritization

In addressing climate-related water challenges, a wide array of potential adaptation technologies is available. The responsibility lies with decision makers, practitioners, managers, technology adopters, and other stakeholders to assess these technologies and adopt the most suitable for a specific water challenge.

The prioritisation process typically considers various factors, including the nature of the water challenge, the feasibility of the intervention from a technological standpoint, its compatibility with the socio-economic context, and available resources. This task can be challenging due to the complexity of water interactions across multiple sectors and the diverse range of users and stakeholders who rely on water and its ecosystem services. Effectively reconciling these diverse needs and ensuring that the chosen adaptation technology effectively addresses the underlying water challenge requires robust approaches to evaluating and prioritising the available adaptation technologies.

Eswatini, through MTEA, conducted a technology needs assessment (TNA) (Available at https://tech-action.unepccc.org/wp-content/uploads/sites/2/2019/03/swaziland-adaptation-tna-report.pdf) for key priority sectors including water, agriculture, forestry, and biodiversity in 2015. In each of these sectors, technology options were identified and prioritised. This was done through a stakeholder led process using a multi criteria analysis (MCA). Key steps of the MCA process included identification of the technologies, screening through some identified criteria and weighting among several steps. In the water sector, technologies were evaluated based on several criteria to determine their ranking. These criteria included water efficiency, capital costs, job creation, maturity, environmental sustainability, social acceptability, and gender equity. Among these criteria, the highest weight was assigned to environmental sustainability (30%), followed by water efficiency (20%). Capital costs and job creation were given equal weight (15%) (Government of Eswatini, 2015). Stakeholders assessed each technology based on how well they met each of these criteria. The ranks assigned to each criterion were weighted, and the average rank was calculated to determine the final score. The results of the prioritised water technologies are presented in Table 3. The resulting TNA informed several important documents such as the Technology Action Plan which included a "project pipeline" that outlined the prioritised technologies, the updated NDC, GCF country program, etc.

TABLE 3: Prioritised technologies in 2015.

Rank	Option	Weighted score
1	Integrated river basin management	87.3
2	Artificial groundwater recharge	83.2
3	Wetland restoration	78.6
4	Water efficient technologies	77.0
5	Leakage detection	67.5
6	Rooftop rainwater harvesting	65.0
7	Sand dams	47.0
8	Water recycling and reuse	45.7
9	Long distance water transfer	16.3
10	Earth dam lining	12.1

Methodology for reprioritization

The UNFCCC Secretariat offers various tools to facilitate decision-making in relation to climate change adaptation. These tools include the following: policy exercise, cost-benefit analysis, cost-effectiveness tool for environmental assessment and management, adaptation decision matrix, screening of adaptation options, and Multi-Criteria Analysis (MCA). Considering the pros and cons of each of these methods, this work employed one of MCA tools (Figure 4 and Figure 5) as has been developed, tried and tested by the UNEP CCC since 2001, the Analytic Hierarchy Process (AHP) for prioritising the water-related adaptation technologies, which was developed by (Saaty, 2014). This is a similar approach used in the 2015 prioritization process.

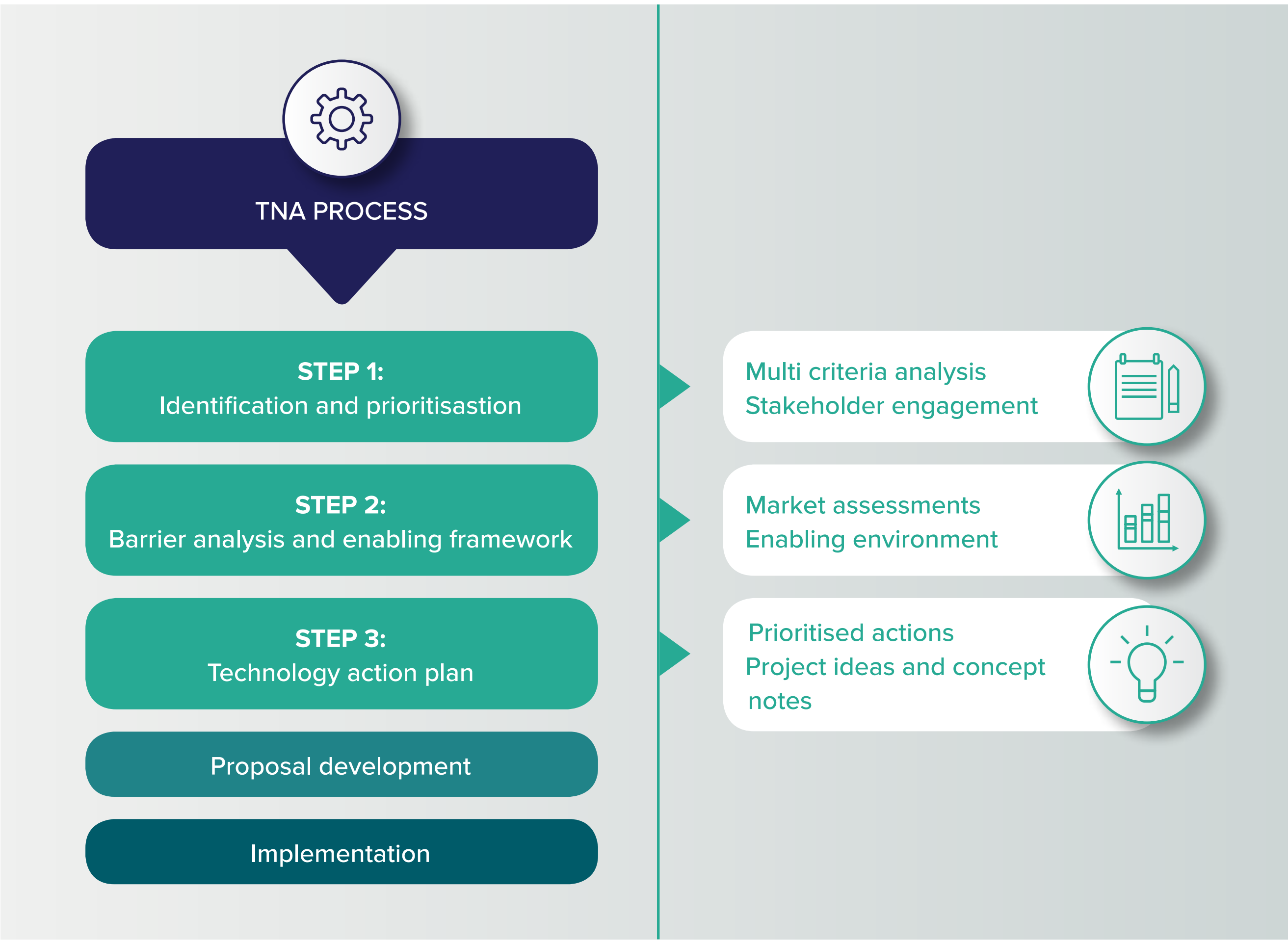

FIGURE 4: The TNA process (modified from TNA Methodology - Technology Needs Assessment (unepccc.org)).

FIGURE 5: The technology prioritization process adapted from (Saaty, 2014).

Water-related adaptation technologies options

The identification of technologies was informed by several processes which included a review of national documents (such as the adaptation communication, updated NDCs, national development plans etc), brainstorming with stakeholders, and scientific reports/publications. A long list with over 100 water-related adaptation technologies were identified and shared with national stakeholders for prioritisation. This long list served as a reference for stakeholders during the prioritization process.

Selection criteria

MCA offers a systematic framework for evaluating and comparing various adaptation technologies based on multiple criteria. One significant advantage of employing MCA in prioritising adaptation technologies is its capacity to incorporate the preferences of stakeholders participating in the process. This underscores the significance of ensuring the inclusion of appropriate stakeholder representation throughout the prioritization process. Henceforth, after extensive deliberation with stakeholders, the criteria along with their weights for selecting technologies were agreed upon and are shown in Table 4 below.

TABLE 4: Selection criteria for water-related adaptation technologies.

Criteria	Weight
Affordability	10
Coherence to national priorities	10
Social acceptability	10
Reduce vulnerability to drought	15
Enhance resilience to floods	10
Environment sustainability	10
Gender equity	5
Maturity	10
Potential for scale up/replicability	10
Address climate change (mitigation co-benefits)	5
Capacity	5
Total	**100**

Scoring and weighting

The ranking of technologies was determined based on the outcomes of the scoring by the national stakeholders using the weighting procedure outlined in Table 5. Each technology was evaluated against every criterion, considering both the overall and specific priorities obtained through the weighting process. Subsequently, the technologies were arranged in order according to their priorities, with the highest weight indicating the highest priority.

Water adaptation technologies encompass both the implementation of technological tools and equipment, as well as approaches and management strategies relevant to climate change adaptation. These adaptation technologies can be broadly categorized into three groups, as identified by (Lars et al., 2011):

1. Hardware: This refers to the "hard" technologies, which involve physical infrastructure and technical equipment on the ground. Examples include water storage systems, dams, irrigation networks, and water treatment facilities.

2. Software: This category comprises "soft technologies" that encompass approaches, processes, and methodologies for adaptation. It includes planning and decision support systems, models, knowledge transfer, and capacity-building activities aimed at developing the necessary skills for effective adaptation.

3. Orgware: Orgware represents the organizational technologies needed for the successful implementation and long-term sustainability of adaptation solutions. This involves establishing appropriate organizational, ownership, and institutional arrangements to support and manage adaptation efforts effectively. It includes governance structures, policy frameworks, institutional partnerships, and stakeholder engagement mechanisms.

For this work, classification of technologies followed five (5) broad water challenges experienced by Eswatini as guided by (CTCN, 2017) which are unknown climate risks, water scarcity, too much water, pollution and disaster preparedness. By considering all three dimensions, hardware, software, and orgware, and the broad water challenges, stakeholders can holistically address the challenges of climate change and ensure the effective implementation and sustainability of water adaptation technologies.

4

Results and discussion

Prioritization results

Table 5 presents a prioritised list of technologies based on their total scores and corresponding ranks. Flood risk assessment and mapping secured the top rank with a total score of 920, highlighting its crucial importance. Communication strategies, including workshops and stakeholder dialogues, followed closely in second place with a score of 908, emphasizing the significance of effective information dissemination. The third place was taken by the Central Data Storage facility at a score of 900, underlining the need for robust data management.

Optimization of reservoir operations obtained fourth place with a score of 895, highlighting its potential for enhancing water resource management. Smart urban forests secured the fifth spot with a score of 880, showcasing the value of nature-based solutions. Water-saving toilets followed in sixth place at 870, contributing to efficient water usage.

National and community disaster management plans, surface infiltration technologies, and disaster risk assessment using high-resolution DEM, all tied for the seventh to ninth positions with a score of 868 to 863. Wetland restoration and hydro-geological studies shared the tenth place with 855, alongside continuous monitoring of licensing compliance.

The subsequent technologies held lower ranks with gradually decreasing scores. The results illustrate the focus on flood and disaster management, sustainable water use, and innovative data management. This prioritization aids in directing attention and resources toward the most impactful technologies for integrated water resource management and resilience against environmental challenges.

The prioritization results outlined in the table above were derived through a systematic process involving active engagement with various stakeholders, as depicted in Figure 6. This inclusive approach ensured a well-rounded perspective by categorizing stakeholders into four distinct groups, namely Group 1 to Group 4. Each of these groups was entrusted with the task of individually identifying and ranking their top 20 preferred technologies, adhering to the predefined criteria that had been established. By employing this approach, the prioritization process gathered diverse insights from stakeholders with varying expertise and interests, contributing to a comprehensive evaluation of the technologies under consideration. The distinct categorization of stakeholders into groups facilitated a varied examination of preferences and priorities across the spectrum of stakeholders, ensuring that the final rankings were well-informed and representative of multiple viewpoints. This participatory method not only promoted transparency and collaboration but also enhanced the legitimacy of the resulting prioritization outcomes. The systematic alignment of stakeholder preferences with established criteria generated a well-structured and actionable list of technologies.

The results of the prioritization for each group are shown in the appendix section (Table A 1 to Table A 4). From each group, the top 10 technologies were selected to come up with the final list of the water-related adaptation technologies (Table 5). For technologies that appeared more than once in the final list (suggesting more than one group prioritised them), an average for each of the criteria score was used. An example of the averaging process is shown below.

$$Criteria_i = \left(\sum_{i=1}^{n} Score\right)/n$$

Where *n* represents the number of groups that selected the technology. The final selection consisted of a total of 30 technologies, which are listed and ranked in Table 5 and in the annexes (Table A 5).

FIGURE 6: Stakeholders discussing technologies over two consultative workshops.

TABLE 5: Prioritised technologies and their ranking.

Technologies	Total	Rank
Flood risk assessment and mapping	920	1
Communication via workshops, presentations, stakeholder dialogues, etc	908	2
Central Data Storage facility	900	3
Optimization of reservoir operations	895	4
Smart urban forests	880	5
Water saving toilets	870	6
National and community disaster management plans	868	7
Improve and practise Surface infiltration Technologies	865	8
Disaster risk assessment using high resolution DEM (preferably LIDAR)	863	9
Wetland restoration	855	10
Hydro-geological studies to inform optimal groundwater usage	855	10
Monitoring of licensing and permits compliance on a continuous basis	855	10
Urban green spaces	850	13
Surface reservoirs and Dams	840	14
Climate change vulnerability assessments	810	15
Source water protection and water safety plans	810	15
Model predictions on available seasonal water supply	803	17
Estimations of the minimum amount of water required for irrigation	800	18
Multipurpose dams	795	19
Roof top harvesting and Runoff harvesting	795	19
Real-time monitoring networks	788	21
Drought risk assessment and mapping	785	22
Water allocation quotas	780	23
Membrane Bioreactors	770	24
Advanced domestic wastewater treatment tanks	745	25
Drip irrigation	737	26
Flood hazard assessment and mapping	695	27
Water quality compliance regulations	683	28
Green Landscaping	683	28
Boreholes/groundwater	655	30

In addition to their ranking, the prioritised technologies were thoughtfully categorized based on their specific roles and functions within the broader context of disaster preparedness and addressing multifaceted water-related challenges. This strategic taxonomy aimed to provide a clear overview of how each technology contributes to distinct areas, encompassing concerns like water scarcity, excessive water or too much water, unknown climate risks, and water pollution. The resulting categorization is presented in Table 6, offering a comprehensive framework for understanding the strategic placement of each technology.

The selected technologies (Figure 8) primarily focus on addressing challenges related to water scarcity, with a majority of 13 technologies dedicated to this issue. Among these, 7 technologies fall under the hardware category, while 6 belong to the software category. Following this, the technologies address challenges associated with too much water (5 technologies, with 4 under the hardware category and a single technology under software), unknown climate risks (5 technologies, all under software category), disaster preparedness (4 technologies, with 2 hardware and 2 software) and water pollution (3 technologies). In Figure 7, which displays the types of natural disasters experienced by Eswatini from 2000 to 2022, it is evident that storms and droughts were the most prevalent. Droughts affected 970,000 in 2001 and has been the most occurring disaster with large impacts (2001, 2007, 2016 and 2019). According to the 2020 State of the Environment Report, approximately 14% (equivalent to 180,000 people) of the nation's populace is currently at risk of drought impacts, and this figure is projected to increase to 33% by the year 2050. Moreover, an average of 15% of the country's GDP (amounting to USD 0.5 billion) is presently susceptible to the effects of drought, and this proportion is anticipated to surge to 41% by 2050. On another note, the 2021 floods from tropical cyclone Eloise resulted to losses in excess of USD 0.3 million in the water sector (NDMA, 2021).

These events align with the challenges of too much water and water scarcity, which could explain the prioritization of technologies in the respective categories. The challenges can be mitigated by implementing adaptation technologies that enhance the understanding and assessment of climate change's effects on water resources in specific areas such as river basins, communities, locations, or ecosystems. By gaining a better understanding of the impacts and their spatial distribution, it becomes possible to identify the most suitable adaptation responses and technologies to address these challenges effectively.

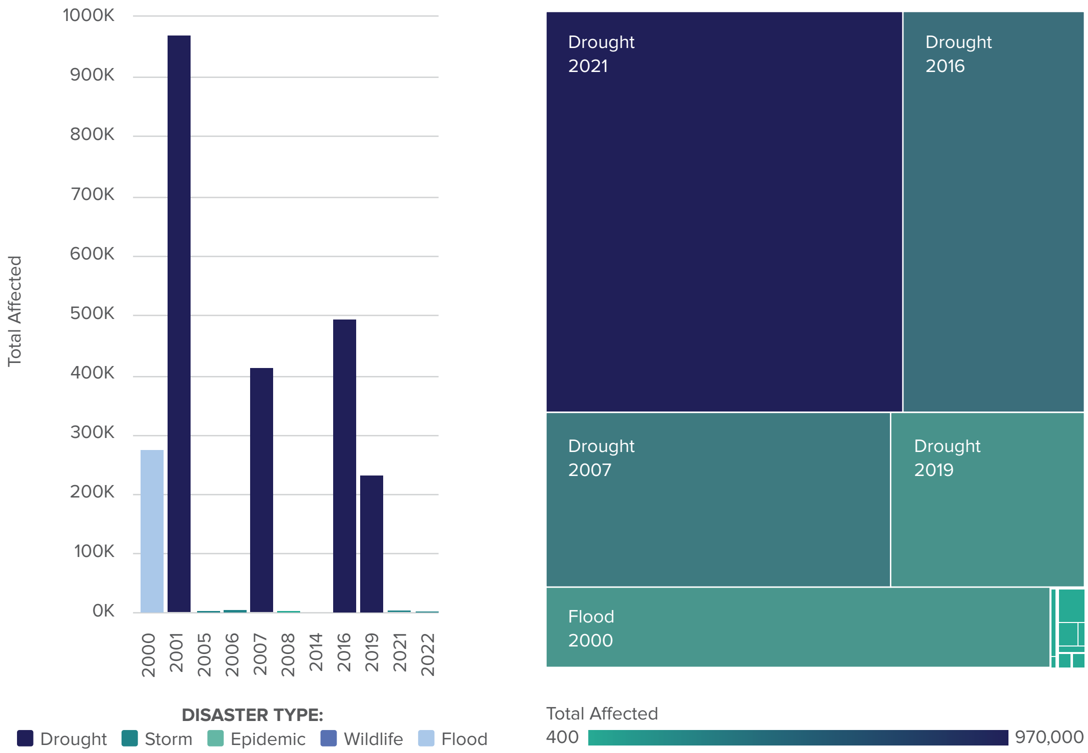

FIGURE 7: Statistics of disasters in Eswatini since 2000 (Centre for Research on the Epidemiology of Disasters, 2023).

TABLE 6: Prioritised technologies according to the different categories and taxonomy.

		Technology taxonomy				
Technology category	Technologies	Disaster preparedness	Too much water	Uknown climate risks	Water pollution	Water scarcity
Hardware	Advanced domestic wastewater treatment tanks				3	
	Boreholes/groundwater					1
	Central Data Storage facility	1				
	Drip irrigation					3
	Green Landscaping					2
	Improve and practise Surface infiltration Technologies		1			
	Membrane Bioreactors				1	
	Multipurpose dams		2			
	Real-time monitoring networks	2				
	Roof top harvesting and Runoff harvesting					2
	Smart urban forests		1			
	Surface reservoirs and Dams Urban green spaces					1
	Urban green spaces		1			
	Water saving toilets					1
	Wetland restoration					2
Software	Climate change vulnerability assessments			2		
	Communication via workshops, presentations, stakeholder dialogues, etc	2				
	Disaster risk assessment using high resolution DEM (pref LIDAR)			2		
	Drought risk assessment and mapping			3		
	Estimations of the minimum amount of water required for irrigation					2
	Flood hazard assessment and mapping			2		
	Flood risk assessment and mapping			1		
	Hydro-geological studies to inform optimal groundwater usage					1
	Model predictions on available seasonal water supply					3
	Monitoring of licensing and permits compliance on a continuous basis					1
	National and community disaster management plans	2				
	Optimization of reservoir operations		1			
	Source water protection and water safety plans				1	
	Water allocation quotas					1
	Water quality compliance regulations					2

NB: the number in each cell refers to the number of groups that prioritised the technology.

	Technology category	
Technology taxonomy	**Hardware**	**Software**
Water scarcity	7	6
Too much water	4	1
Uknown climate risks	0	5
Disaster preparedness	2	2
Water pollution	2	1

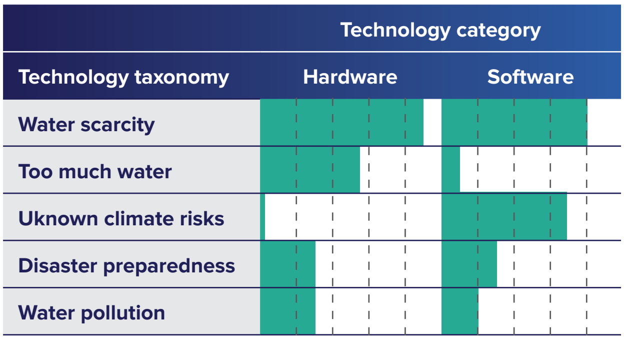

FIGURE 8: Summary of prioritised technologies.

Discussion of prioritised technologies

Water technologies were classified according to their water challenges taxonomy, which included disaster preparedness, water scarcity, too much water, unknown climate risks and water pollution as shown in Figure 9.

Disaster preparedness

Presently, hydrological disasters comprise most natural disasters globally, resulting in numerous fatalities and causing significant economic devastation amounting to billions of dollars each year. Among all hazards, floods impact the largest number of individuals worldwide (UNISDR, 2015). The anticipated effects of climate change are projected to intensify these damages through factors such as heightened occurrences of floods and droughts. The poverty reduction strategy of Eswatini (MEPD, 2006) notes that the major causes of food insecurity in the country is the lack of preparedness for natural disasters such as drought, floods and other inclement weather conditions. To address these challenges, Eswatini has implemented various strategic measures. These actions include enhancing disaster preparedness and management capabilities to ensure effective responses at all levels, as articulated in the national climate change strategy and action plan (MTEA, 2015), updated NDC (Eswatini First NDC (Updated submission) | UNFCCC), Eswatini country strategic plan (2020-2024) (World Food Programme, 2019) etc. It is no surprise therefore that several adaptation technologies are proposed to address the challenges associated with natural disasters.

In response to the disaster preparedness challenge, these technologies were identified, namely central data storage, real-time monitoring networks, communication systems, national and community management plans, and source water protection plans (Table 7). These technologies are in harmony with important national documents in the water sector. For example, the revised national water policy of 2018 has put forward a plan for dam disaster preparedness for each reservoir in the country, along with regular monitoring to ensure its implementation.

Water scarcity

Eswatini has faced water scarcity issues, impacting both household and agricultural usage, with an observed increase in the frequency and severity of droughts (Centre for Research on the Epidemiology of Disasters, 2023; Government of Eswatini, 2019), as shown in Figure 7. The most severe drought periods were recorded in 1985-1986, 2005-2006, and 2015-2016. The El Niño drought in 2015/2016 was particularly devastating, resulting in crop failure, livestock losses, and heightened food insecurity. During this period, a significant portion of the population, estimated at 638,251 individuals (approximately 50% of Eswatini's population), was affected by the drought (ESEPARC, 2021).

It is, therefore, not surprising that most of the technologies fell under this water challenge. There were 16 technologies including boreholes, drip irrigation, green landscaping, multipurpose dams, rooftop and runoff harvesting, smart urban forests, surface reservoirs and dams, urban green spaces, water saving toilets, wetland restoration, estimating minimum water for irrigation, hydro-geological studies, seasonal water supply modelling, monitoring license and water permits, water allocation quotas and water quality compliance regulations (Table 8). Among the adaptation contributions of the water sector

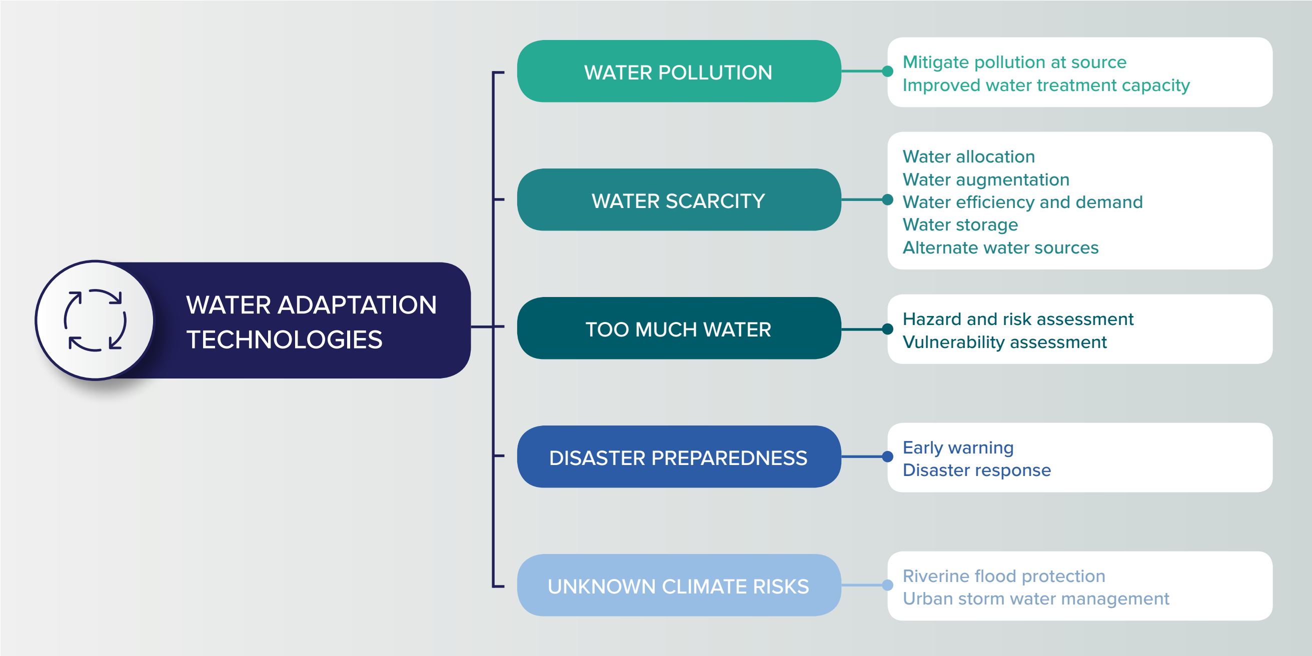

FIGURE 9: Overview of climate challenges and their response in Eswatini. (Modified from (CTCN, 2017))

TABLE 7: Technologies for disaster preparedness.

Technology	Description
Central data storage facility	This refers to a centralized location where data related to water resources, such as water quality, water levels, and rainfall, is collected, stored, and managed. This allows for efficient data analysis and decision-making for water management.
Real-time monitoring networks	These involve the use of sensors and data collection systems to monitor water resources continuously. This allows for the real-time measurement of parameters like water levels, flow rates, and water quality. Real-time monitoring networks provide valuable data for decision-making and early warning systems.
Communication via workshops, presentations, stakeholder dialogues, etc	Effective communication is crucial in ensuring that climate change information and risks are understood by all stakeholders. Workshops, presentations, stakeholder dialogues, and other forms of communication provide platforms for sharing knowledge, discussing concerns, and developing collaborative solutions. These activities allow for the exchange of information, ideas, and perspectives among scientists, policymakers, community members, and other relevant stakeholders.
National and community disaster management plans	They outline strategies and actions to prepare for, respond to, and recover from disasters. These plans consider the specific risks and vulnerabilities of a region and involve collaboration among various stakeholders, including government agencies, emergency services, community organizations, and the public. Disaster management plans ensure a coordinated and effective response to disasters, reducing the impacts on human lives, infrastructure, and the environment.

in the updated nationally determined contribution (Government of Eswatini, 2021b) are improving water governance and compliance to help manage water resources more efficiently and effectively to adapt to resultant water shortages, designing and constructing water storage infrastructure for multiple use, which indicates an alignment with the proposed technologies. Several of the proposed technologies are already practiced in the country, moreover, there is a need to strengthen and to further promote. Examples of these are the use of boreholes, rooftop and rainfall harvesting, drip irrigation, multipurpose dams etc.

Additionally, cities and towns in Eswatini have limited prior experience in implementing adaptation measures like green infrastructure and green spaces. The implementation of such adaptation efforts in these urban areas is hindered by significant obstacles, such as an inadequate enabling environment (Government of Eswatini, 2020). Both the cities and towns across the country and the national institutions

TABLE 8: Technologies for water scarcity.

Technology	Description
Drought risk assessment and mapping	This involves evaluating the likelihood and potential impacts of drought events in a particular region. It considers factors such as historical climate data, precipitation patterns, soil moisture levels, and vegetation health. Drought risk mapping helps identify areas prone to drought and can assist in developing water management strategies, such as implementing water conservation measures, improving irrigation techniques, or promoting drought-resistant crops.
Boreholes/Groundwater	These are narrow, deep wells drilled into the ground to access groundwater. This is a common method of obtaining water in areas where surface water is scarce. Groundwater is stored in underground aquifers and can be pumped to the surface for various purposes such as household water supply or irrigation.
Drip irrigation	This is an irrigation method that delivers water directly to the plant root zone in small, precise amounts. This method conserves water by reducing evaporation and ensuring efficient water use. It is commonly used in agriculture and garden irrigation systems.
Multipurpose dams	These are large structures built across rivers or streams to provide various benefits. They can serve purposes such as flood control, water supply, hydropower generation, and irrigation. Multipurpose dams play a crucial role in water resource management and regional development.
Roof top harvesting and runoff harvesting	This involve collecting rainwater from rooftops and storing it for later use. Runoff harvesting refers to capturing and storing surface runoff from roads, parking lots, or other impervious surfaces. Both methods help utilize rainwater as a valuable water resource.
Water-saving toilets	These are also known as low-flow toilets, are designed to use less water per flush compared to traditional toilets. They incorporate technologies like dual-flush mechanisms or reduced water volume to conserve water without compromising functionality.
Wetland restoration	Involves the rehabilitation or creation of wetland ecosystems that have been degraded or lost due to human activities. Wetlands provide valuable ecosystem services, including water filtration, flood control, and habitat for various species. Restoring wetlands helps improve water quality and biodiversity.
Estimations of the minimum amount of water required for irrigation	This involve determining the optimal amount of water needed to sustain crop growth and productivity. This estimation considers factors such as crop types, evapotranspiration rates, soil characteristics, and climatic conditions. By calculating the minimum irrigation requirements, farmers and water managers can ensure efficient water use, reduce water waste, and mitigate the impacts of water scarcity.
Hydro-geological studies to inform optimal groundwater usage	This involve analysing the characteristics of groundwater systems, such as aquifer properties, recharge rates, and groundwater flow patterns. These studies provide valuable information for managing and optimizing groundwater resources. By understanding the hydrogeology of an area, water managers can develop strategies for sustainable groundwater usage, such as implementing recharge projects, monitoring water levels, and regulating pumping rates.
Model predictions on available seasonal water supply	This involve using hydrological models to forecast water availability during different seasons. These models consider factors such as precipitation patterns, snowmelt, evaporation rates, and river flow. By predicting the seasonal water supply, water managers can plan for water allocation, reservoir operations, and water conservation measures.
Monitoring of licensing and permits compliance on a continuous basis	This ensures that water users adhere to regulations and guidelines for water use. This monitoring involves regular inspections, data collection, and reporting to ensure that water users are using water resources sustainably and within the allocated quotas. Continuous monitoring helps identify any violations and allows for timely enforcement actions.
Water allocation quotas	They involve establishing limits or allocations for water use in specific sectors or regions. These quotas ensure equitable distribution and sustainable use of water resources. They consider factors such as water availability, demand patterns, and environmental requirements. Water allocation quotas help prevent overuse, reduce conflicts among water users, and promote efficient water management.
Water quality compliance regulations	Establish standards and guidelines for maintaining the quality of water resources. These regulations specify limits for various pollutants and parameters, such as bacteria, chemicals, or nutrient levels. Water quality compliance ensures that water resources are safe for human consumption, protect ecosystems, and meet regulatory requirements. Regular monitoring and enforcement of these regulations help maintain and improve water quality.

supporting them face challenges in accessing crucial information for effective decision-making. This includes understanding the intricacies of the policy and regulatory framework at both the national and municipal levels, assessing the ecological condition of green infrastructure within urban areas, recognizing the ecosystem services they provide, and comprehending the risks and vulnerabilities associated with key green infrastructure. Nonetheless the uptake of these technologies is expected to be high as they also formed part of the updated NDC (Government of Eswatini, 2021b).

Too much water

It is anticipated that climate change will contribute to a rise in the intensity of rainfall, along with greater variability in the seasonal distribution of precipitation. The increasing temperatures result in the atmosphere's capacity to hold more moisture, thereby leading to higher levels of potential rainfall and consequently increasing the risks associated with flooding. According to the Climate Change vulnerability assessment study of the water sector conducted in 2016, the study projects a potential increase in the probability of flooding from 12% to 18% by the 2050s. Thus, it is crucial that the country adopts technologies that would address such a challenge. The prioritised technologies under this water challenge include improving and practicing surface infiltration techniques, multipurpose dams, smart urban forests, urban green spaces, and optimization of reservoir operations (Table 9).

Unknown climate risks

Risk and uncertainty pose inherent challenges for water managers and investors in adaptation technologies, and these challenges are further amplified by the impacts of climate change. There were five (5) technologies prioritised including climate vulnerability assessments, disaster risk assessment using high resolution DEM, flood hazards and risks mapping (Table 10). Dlamini (2021) has conducted a climate risk assessment for Eswatini. The assessment identified a range of risks including droughts, floods, epidemics, fire, heat waves, invasive species, landslides, and storms. However, it is worth noting that these assessments were conducted using low spatial resolution digital elevation models, which may have limitations in accurately determining the spatial distribution of these risks. To enhance the accuracy of such assessments, particularly in smaller areas like Eswatini, the utilization of high spatial resolution images such as LiDAR would be instrumental (Table 10).

Water pollution

Membrane bioreactors, source water protection and water safety plans, and advanced domestic wastewater treatment tanks fall within the water pollution category (Table 11). These technologies offer solutions for maintaining water quality by treating wastewater effectively. Most human activities whether domestic, agricultural, or industrial have an influence on water quality. Vulnerability to increased water stress exists where effluent discharge from industries may increase water pollution. On another note, water pollution due to flooding and rapid urbanization increases the risk of epidemics such as cholera. Potential sources of point-source water pollution in Eswatini include agriculture, industry, landfills, wastewater treatment facilities and mining. Potential sources of non-point-source water pollution include forestry, irrigated agriculture, livestock, and sanitation.

One area of concern lies in the vulnerability to increased water stress, particularly when industries discharge effluents that can contribute to water pollution. Additionally, water pollution stemming from flooding and rapid urbanization (and migration of people from rural areas to cities) escalates the risk of epidemics like cholera. In Eswatini, potential sources of point-source water pollution encompass agriculture, industry, landfills, wastewater treatment facilities, and mining (Eswatini Environment Authority, 2013). Non-point-source water pollution, on the other hand, arises from diffuse sources such as forestry, irrigated agriculture, livestock, and sanitation. To combat these issues, stringent regulations should be in place to govern these sectors, and existing water safety plans should be updated and strengthened. For example, the Water Pollution Control Regulations of 2010 that aims to provide legal guidance on the water quality objectives for Eswatini needs to be updated to factor in the accelerated impacts of climate change.

Furthermore, alongside the technical solutions, education and public awareness could play a vital role in addressing water pollution challenges. Although communication through workshops and stakeholder engagements was mentioned under disaster preparedness, it is also critical for the water pollution challenge. Communities should be educated about

TABLE 9: Technologies for too much water.

Technology	Description
Climate change vulnerability assessments	This involve analysing the potential impacts of climate change on a particular region or system. This assessment helps identify the areas or sectors that are most vulnerable to climate change, such as agricultural systems affected by temperature changes, or communities prone to extreme weather events. These assessments use a combination of climate models, socio-economic data, and vulnerability indicators to evaluate the potential risks and develop strategies for adaptation and resilience.
Urban green spaces	This refers to parks, gardens, and other green areas within urban areas. They provide numerous benefits, such as improving air quality, reducing urban heat, and promoting mental well-being. Urban green spaces also play a role in stormwater management and biodiversity conservation.
Green landscaping	This involves designing and maintaining landscapes in an environmentally friendly and sustainable manner. It focuses on using native plants, conserving water, reducing chemical use, using permeable surfaces, rain gardens, green roofs etc. Green landscaping practices help conserve water and promote ecological balance, subsequently reduces the volume of water flowing into storm drains and ultimately helps prevent localized flooding.
Surface infiltration technologies	These aim to enhance the infiltration of rainwater into the ground, reducing surface runoff and promoting groundwater recharge. Examples include permeable pavement, rain gardens, and infiltration trenches. These technologies help manage stormwater and prevent water loss.
Smart Urban forests	Combine technology and nature to create sustainable urban green spaces. They utilize sensors and data analysis to monitor and manage urban forests effectively. Smart urban forests provide numerous benefits, such as reducing urban heat island effects and improving air and water quality, improves the infiltration of water which minimises runoff etc.
Surface reservoirs and dams	Surface reservoirs and dams are large water storage structures built on the surface of the land. They collect and store water from rivers, streams, or rainfall for various purposes, including water supply, irrigation, and hydropower generation.
Optimization of reservoir operations	This involves managing the release and storage of water in reservoirs to meet various demands, such as irrigation, domestic water supply, hydropower generation, and environmental flow requirements. During periods of heavy rainfall, water can be released from the reservoir at a controlled rate, which helps prevent sudden and excessive increases in downstream river flow. In addition, reservoirs can be managed to maintain lower water levels during periods of heavy precipitation. By keeping the reservoir at a lower level when significant rainfall is expected, there is more room to store incoming runoff, which reduces the risk of overflow and flooding.

TABLE 10: Technologies for unknown climate risks.

Technology	Description
Disaster risk assessment using high-resolution Digital Elevation Model (DEM)	DEMs, often obtained through technologies like LIDAR (Light Detection and Ranging), provide detailed information about the topography and elevation of a specific area. High-resolution DEMs are valuable in assessing the risk of disasters such as landslides, avalanches, or storm surges. By analysing the terrain and combining it with other data like precipitation patterns or soil stability, experts can identify areas at high risk and develop strategies for disaster preparedness and response.
Flood hazard assessment and mapping	This involves identifying areas at risk of flooding based on factors such as topography, rainfall patterns, river discharge, and infrastructure vulnerability. Flood hazard mapping provides valuable information for land-use planning, emergency response planning, and infrastructure development. By understanding the areas prone to flooding, authorities can implement measures to mitigate flood risks, such as constructing flood control infrastructure, improving drainage systems, or implementing early warning systems.
Flood risk assessment and mapping	Combines flood hazard information with vulnerability data to evaluate the potential impacts of flooding on human populations, infrastructure, and the environment. It considers factors such as population density, land-use patterns, and the resilience of infrastructure. Flood risk mapping helps identify areas at high risk and provides valuable information for land-use planning, emergency preparedness, and floodplain management.

TABLE 11: Technologies for water pollution.

Technology	Description
Source water protection and water safety plans:	This involve implementing measures to safeguard the quality and quantity of water sources, such as lakes, rivers, or groundwater aquifers. This protection ensures that the water sources remain free from contamination and degradation. Water safety plans involve assessing potential risks to water sources, implementing preventive measures, and developing contingency plans to ensure the delivery of safe and reliable drinking water to communities.
Membrane bioreactors (MRBs)	These are advanced wastewater treatment systems that combine biological processes with membrane filtration. They consist of a biological reactor where microorganisms break down organic matter, and a membrane filtration unit that separates the treated water from the activated sludge. The membrane acts as a barrier, allowing clean water to pass through while retaining suspended solids and microorganisms. MBRs offer several advantages, including high-efficiency removal of pollutants, compact design, and the ability to produce high-quality treated water. They are widely used in various applications, including municipal wastewater treatment, industrial processes, and water reuse.
Advanced domestic wastewater treatment tanks	These are innovative systems used to treat domestic wastewater. These tanks employ a combination of biological processes and advanced filtration techniques to effectively remove pollutants and produce high-quality treated water. They are designed to be compact and efficient, making them suitable for residential applications. With their ability to treat wastewater effectively and provide clean water for reuse, these tanks contribute to sustainable water management practices in households.

the significance of water conservation, responsible waste disposal, and the adverse effects of water pollution. By fostering a sense of environmental stewardship, individuals can actively contribute to the protection and enhancement of water quality.

Barrier analysis of prioritised technologies

Since the inception of the negotiation process for the United Nations Framework Convention on Climate Change (UNFCCC), the development and transfer of technologies to support national action on climate change have been deemed crucial. Ongoing discussions on climate policy involve international collaboration aimed at facilitating the advancement, transfer, and adoption of climate technologies in developing countries. Previous studies conducted under UNFCCC have identified various obstacles to climate technology transfer (UNEP DTU, 2018). These barriers encompass issues such as inadequate financing and motivation on both the supply and demand sides, legal and regulatory challenges, conflicting prioritization, fragmented information, and institutional frameworks, limited human skills and capacity, intellectual property rights, lack of awareness, divergent cultural backgrounds, limited private sector engagement and insufficient leadership in transboundary governance.

Identifying barriers involves the process of tracing the underlying causes that hinders the transfer and dissemination of technologies. There is substantial evidence that affirms the notion that the diffusion of innovative adaptation technologies necessitates comprehensive support from the entire ecosystem. This section presents a brief description of the barrier analysis and the accompanying actions aimed at promoting the implementation of the selected technologies. It includes discussions of the barriers identified by stakeholders and mitigation measures for each of the technologies (refer to Figure 10). Additionally, it utilizes an extensive examination of existing literature to identify the various barriers impeding the adoption of technologies in developing nations. Similar to the assessments by UNEP DTU (2018) and the barrier analysis conducted for the prioritised technologies in 2016, the barriers encompassed issues such as limited capacity and infrastructure, fragmented policy frameworks, lack of awareness, lack of funds, stakeholder collaborations etc.

The identified technologies consistently highlighted financial limitations, encompassing both installation and operational costs, as the primary factor constraining the application and widespread adoption of the water adaptation technologies. Other common barriers were the lack of technical capacity and expertise to apply the identified technologies, poor institutional and regulatory capacity, and the lack of public awareness with some of the technologies (Figure 10). The lack of sufficient experience in planning and managing climate change-related projects across

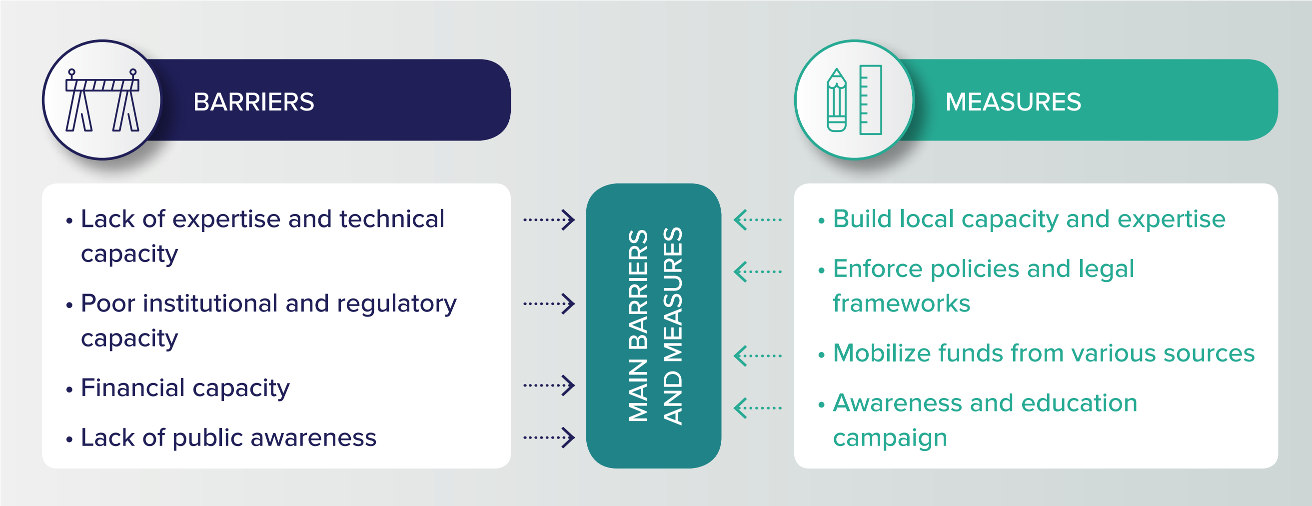

FIGURE 10: Main barriers and measures of the selected water technologies.

various sectors is undermining the effectiveness of adaptation efforts in the country. For example, climate-related projects often involve intricate systems, diverse stakeholders, and multifaceted technologies. Inexperienced project managers may struggle to grasp the complexities involved, leading to poor project design, execution, and outcomes. Similar to findings from this barrier analysis, weak institutional coordination has been identified as a significant barrier to successful adaptation in other sectors in Eswatini (Government of Eswatini, 2017; MTEA, 2022). To address these challenges, it is essential to establish an enabling policy framework and enhance institutional capacity. Moreover, most of the barriers that have been identified can be effectively addressed through a combination of public awareness initiatives and capacity-building efforts focused on developing funding proposals and promoting the practical application of these technologies.

SWOT analysis of prioritised technologies

The SWOT analysis (in Table 12) evaluates the feasibility and potential of the prioritised technologies. The Central data storage facility is a potential strength due to its consolidated data storage and security emphasis, although limited access, trust issues, and slow technology adoption are weaknesses. Leveraging existing infrastructure such as the Royal Eswatini Technology Park and integrating advanced analytics offer opportunities, while data security concerns and rapid technological changes pose threats. Real-time monitoring networks offer immediate information access and improved decision-making, but challenges in regulation, data sharing, and remote deployment are weaknesses. Regulatory integration and predictive analytics present opportunities, while security concerns and evolving technology are potential threats. Communication strategies effectively engage stakeholders but demand resources, and opportunities for hybrid models and digital integration contrast with threats like misinformation and stakeholder opposition. National and community disaster management plans provide structure but face complexity and resource challenges, with inclusivity and collaboration as opportunities and limitations in engagement and funding as threats. Flood risk assessment and mapping offer accurate information but require reliable data sources, and integration with real-time monitoring and community collaboration present opportunities, while regulatory barriers and climate uncertainty are potential threats. For detailed information, the reader is referred to Table 12.

TABLE 12: SWOT analysis for the identified technologies.

Technology	Strengths	Weaknesses	Opportunities	Threats
Central Data Storage facility	Provides consolidated data storage for water management. Emphasizes data security and traceability. May utilise existing infrastructure, such as the Royal Science and Technology Park for cost savings.	Limited data access due to security concerns. Trust issues from data leaks undermine provider confidence. Slow adoption of new technologies. Challenges in finding suitable land and infrastructure.	Enhanced data access protocol can improve sharing. Potential for cost savings through streamlined data management. Integration with advanced data analytics.	Data security concerns and cyber threats could lead to breaches. Lack of funding may hinder facility development and operations. Rapid technological advancements may require frequent updates.
Real-time monitoring networks	Immediate access to up-to-date information. Enhanced situational awareness and response capabilities. Improved decision-making based on real-time data. Early detection of anomalies and issues.	Lack of specific regulations might hinder implementation. Inefficient data sharing and stakeholder cooperation. Deploying sensors in remote/hazardous areas requires expertise. Dependency on reliable communication infrastructure.	Prioritising network development in regulatory frameworks. Establishing protocols for better data sharing. Integration with data analytics for predictive insights. Expansion into various sectors for holistic monitoring.	Absence of regulations might slow down progress. Poor collaboration can limit network effectiveness. Data security and privacy concerns. Technical failures or system malfunctions. Rapidly evolving technology landscape.
Communication via workshops, presentations, stakeholder dialogues, etc	Effective in conveying information and fostering engagement. Facilitates direct interaction and feedback from stakeholders. Supports knowledge dissemination and awareness-raising. Builds relationships and collaborations.	Requires time and resources for organization. Effectiveness may vary depending on participant engagement. May not address individual concerns adequately.	Sensitization drives to empower communities on tech's role. Integration with digital platforms for broader dissemination. Hybrid models for combining in-person and virtual engagement. Collaboration with diverse stakeholders for comprehensive dialogue.	Competing priorities and busy schedules. Misinterpretation of information leading to misunderstandings. Potential resistance or opposition from certain stakeholders.
National and community disaster management plans	Provides a structured framework for disaster preparedness and response. Enhances coordination and collaboration among stakeholders. Addresses specific vulnerabilities and risks of communities. Offers guidelines for timely and effective disaster response.	Complexity in implementation due to multi-stakeholder involvement. May face challenges in resource allocation and funding. Plans could become outdated without regular updates.	Policies & legal frameworks for disaster management. Gender-sensitive, inclusive planning. Funds mobilization, private sector collaboration. Inclusion of local knowledge and indigenous practices. Collaboration with non-governmental organizations and international agencies.	Limited community engagement leading to ineffective plans. Political interference or changes affecting plan implementation. Gender issues not well-incorporated. Funding limits plan execution. Capacity gaps for plan development. Inadequate training and capacity building for disaster response teams.
Flood risk assessment and mapping	Utilizes advanced remote sensing and GIS technologies. Provides accurate and detailed flood risk information. Enables proactive disaster preparedness and response. Enhances community safety and resilience.	Dependent on reliable and up-to-date data sources. Complex modelling processes requiring expertise. Can be resource-intensive in terms of time and cost. Vulnerable to inaccuracies if not properly calibrated.	Integration with real-time monitoring for early warnings. Collaboration with local communities for data collection. Increasing demand due to climate change and urbanization. Potential for improved land use planning and zoning.	Regulatory barriers or political resistance. Incomplete coverage of remote or inaccessible areas. Data privacy concerns and public acceptance. Uncertainty in climate change projections affecting accuracy.
Boreholes/ groundwater	Provides reliable and consistent water supply. Less vulnerable to external factors like weather. Suitable for both urban and rural areas. Can be a cost-effective solution for water scarcity.	Need for licenses or approval procedures. Affordability as a socio-economic factor. Arsenic, fluoride risk. High costs associated with geophysical techniques and borehole drilling. Complexity of geophysical techniques. Requirement for population, groundwater knowledge.	Create central groundwater database. Better coordination with partners. Improve affordability via finance options. Test water quality for contamination. Integration with other water sources for a diversified supply. Potential for using renewable energy for pumping.	Over-exploitation leading to aquifer depletion. Conflicts over water rights and access. Climate change impacts on groundwater recharge. Lack of regulatory frameworks and enforcement.
Drip irrigation	Efficient water use and reduced water wastage. Improved crop yields and quality. Suitable for various crop types and terrains. Precise application minimizes weed growth.	Initial setup costs can be high. Requires technical knowledge and maintenance. Vulnerable to clogging if not properly managed. Dependent on a reliable water source. Drip sensitivity to water quality. Dependence on water, electricity.	Adoption in areas with water scarcity. Integration with smart irrigation technologies. Government incentives for sustainable farming. Potential for increased food production. Training, farmer-to-farmer knowledge sharing, and local production can improve technology access and knowledge.	Limited access to finance. Insufficient services may limit technology adoption. Resistance to change among traditional farmers. Complexity may discourage use. Limited resources may impede adoption. Risk aversion hampers innovation. Skill gaps affect system use.
Green Landscaping	Enhances aesthetics and biodiversity. Improves air quality and reduces heat. Mitigates urban heat island effect. Provides recreational and social spaces.	Lack of policies supporting green landscaping adoption. Resistance to change from traditional landscaping practices. Limited awareness about the concept and its benefits. Potential higher upfront costs for native plants and eco-friendly materials. Limited expertise and knowledge in green landscaping techniques.	Increasing demand for sustainable urban spaces. Integration with urban planning initiatives. Public and private sector partnerships. Positive impact on property values.	Budget constraints for green infrastructure. Lack of expertise in green landscaping. Risk of invasive species introduction. Competition with built infrastructure projects.

Technology	Strengths	Weaknesses	Opportunities	Threats
Multipurpose dams	They offer multifaceted benefits: water supply, hydroelectric power, flood control, irrigation, recreation. Enhances water availability for various sectors. Electricity generation contributes to renewable energy sources. Can reduce downstream flooding and erosion.	Interjurisdictional conflicts may hinder implementation. Complex approvals may cause uncertainty. Risk of displacing local communities. Vulnerability to extreme weather events and climate change. High initial costs. More complex than single purpose. Lack of climate-proofing expertise.	Collaboration between countries for transboundary water management. Integration with sustainable development goals. Employment opportunities during construction. Funding from public-private partnerships or international organizations.	Lengthy approval processes can lead to project uncertainty. Social resistance due to displacement or cultural concerns. Environmental damage to ecosystems and aquatic life. High costs could impact the feasibility of multipurpose dam projects. Complexity in planning and operation may result in inefficiencies and challenges.
Roof top harvesting and Runoff harvesting	Utilizes available rainwater for various purposes. Reduces strain on traditional water sources. Mitigates urban runoff and flooding. Supports water conservation and sustainability. Suitable for both urban and rural settings.	Lack of infrastructure codes and standards can hinder adoption. Costs may limit implementation. Water quality fears may deter adoption. Potential for adverse hydrological impacts downstream. Risk of poor water quality due to surface storage and runoff. Economic challenges due to increased storage capacity needs. Inadequate or unsuitable roofing and lack of space for storage containers.	Establishing codes and standards. Advances in rainwater harvesting technology. Integration with building design and landscape planning. Education campaigns on water conservation. Incentives for implementing harvesting systems. Collaboration with local communities for adoption. Adapting to changing climate patterns.	Lack of infrastructure codes and standards might hinder technology adoption. Costs and water quality could limit uptake. Increased storage costs due to precipitation variability. Technical challenges in retrofitting existing buildings. Inadequate roofing and space limitations can impede implementation. Uncertainties in future rainfall patterns. Competing water uses and allocation challenges.
Smart urban forests	Enhances urban green spaces with technology integration. Improves monitoring, management, and sustainability. Supports biodiversity, ecosystem services, and air quality. Aligns with smart city initiatives and urban planning. Offers potential for real-time data-driven decision-making.	Governance issues could hinder. Limited awareness slows adoption. Complex integration of technology with natural ecosystems. Requires technical expertise for maintenance and operation. Potential challenges in securing funding and resources. Balancing technological benefits with ecological preservation. Perceptions of technological invasion in natural spaces.	Collaboration between stakeholders can address space limitations and soil quality issues. Funding, incentives to overcome costs. Capacity building may boost tech expertise. Collaboration with urban planners, environmental agencies, and tech companies. Public engagement through interactive exhibits and education. Funding opportunities from sustainable urban development programs. Enhanced ecosystem services through informed management.	Resistance from traditionalists and conservationists. Technical glitches affecting smart systems' functionality. Negative perceptions if technology overshadows natural benefits. Potential disruption of wildlife and ecosystems with technology.
Surface reservoirs and Dams	Effective in storing and regulating water supply for various uses. Provides water for irrigation, drinking water, and hydropower generation. Offers flood control and mitigation benefits. Creates opportunities for recreational activities. Supports fish habitat and aquatic ecosystems. Can contribute to regional development and economic growth.	Environmental impacts such as habitat disruption and alteration of natural flows. Potential displacement of communities and loss of cultural heritage. High initial construction and maintenance costs. Vulnerability to extreme weather events and dam failures. Sediment accumulation reducing reservoir capacity over time. Regulatory and approval challenges due to environmental concerns.	Growing demand for water storage and management solutions. Advances in dam design, materials, and construction techniques. Integration of renewable energy generation (e.g., solar) on dam structures. Potential for multipurpose reservoirs to address multiple needs. Expansion of reservoirs for water-based recreation and tourism.	Complex regulatory processes could hinder project progress. Community displacement and flooding could lead to opposition. Mosquito breeding and disruption of water dynamics may pose environmental risks. High construction and maintenance costs could limit feasibility. Lack of technical expertise could impact project quality and effectiveness.
Urban green spaces	Enhance urban aesthetics and well-being. Provide recreational opportunities. Improve air quality and biodiversity. Mitigate urban heat island effect. Promote social interaction and community cohesion.	Fragmented ownership and management could hinder effective implementation. Inadequate planning and design might result in ineffective green spaces. Costs could impede development and maintenance. Limited space in densely populated areas. Vulnerability to pollution and vandalism. Limited technical capacity could impact success.	Integration with sustainable urban planning. Addressing health and wellness trends. Collaborations with local businesses for sponsorship. Enhancing eco-tourism and local economies. Implementation of smart technologies for better management.	Urban development pressure on green spaces. Climate change impacts affecting plant health. Budget cuts affecting maintenance. Lack of awareness or support from the community. Conflicting land use priorities.
Wetland Restoration	Enhances ecosystem services, including water purification and flood control. Supports biodiversity and habitats for various species. Provides recreational and educational opportunities. Contributes to carbon sequestration and climate change mitigation. Restores cultural and historical values associated with wetlands. Can improve overall landscape resilience.	Complexity in restoring natural hydrology and species composition. Requires long-term monitoring and adaptive management. Initial restoration efforts may be resource intensive. Potential conflicts with existing land use and stakeholders. Challenges in recreating historical conditions due to human impact. Difficulties in establishing suitable conditions for restored wetlands.	Increasing recognition of wetlands' value and ecosystem services. Advances in restoration techniques and scientific understanding. Collaboration with local communities for restoration and stewardship. Potential for funding through grants, partnerships, and initiatives. Integration of wetland restoration into regional planning and policy. Enhancement of natural habitats in urban and rural areas.	Competition for land use and resource allocation. Regulatory challenges related to permitting and land ownership. Fragmentation and degradation of remaining wetland areas. Invasive species impacting restoration success. Uncertainties in long-term resilience and success of restoration. Changing hydrological patterns due to climate change and human activity.

Technology	Strengths	Weaknesses	Opportunities	Threats
Estimations of the minimum amount of water required for irrigation	Helps optimize water use and prevent over-irrigation. Supports efficient resource allocation in agriculture. Contributes to water conservation and reduced wastage. Can improve crop yield and quality through proper irrigation. Provides a scientific basis for sustainable water management. Aligns with water scarcity and sustainability goals.	Variability in irrigation needs based on crop type, soil, and climate. Requires accurate data on local conditions and crop water requirements. Limited effectiveness if data inputs are inaccurate or outdated. Challenges in reaching consensus on standardized estimation methods. Potential misinterpretation of results leading to under-irrigation. Farmers' resistance to adopting new irrigation practices.	Increasing emphasis on efficient water use in agriculture. Advances in data collection methods and technology. Integration with precision agriculture and smart irrigation systems. Partnerships with agricultural organizations and research institutions. Potential for reducing water-related production costs for farmers. Incentives and support programs for adopting water-efficient practices.	Lack of awareness and education about proper irrigation practices. Competition for water resources among different sectors. Challenges in implementing and enforcing water management policies. Resistance from farmers due to unfamiliarity or perceived complexity. Climate variability affecting accuracy of estimation models. Dependence on accurate and up-to-date data for reliable estimates.
Hydro-geological studies to inform optimal groundwater usage	Provides critical insights into groundwater availability and dynamics. Supports sustainable management of groundwater resources. Informs decision-making for efficient groundwater use. Essential for addressing water scarcity and ensuring water security. Can lead to informed policies and regulations for groundwater management.	Requires specialized technical expertise for accurate assessments. Data collection and analysis can be time-consuming and costly. Uncertainties in long-term groundwater behaviour and responses. Limited availability of up-to-date hydro-geological data. Potential challenges in predicting impacts on interconnected surface waters. Possible resistance to implementing regulatory changes based on findings.	Growing recognition of groundwater's importance and vulnerability. Advances in remote sensing and geospatial technologies for data collection. Integration with water management systems and decision support tools. Collaboration with local communities for data collection and validation. Funding opportunities for research and groundwater conservation efforts. Potential for using hydro-geological studies in climate change adaptation.	Competition for groundwater resources among various users. Regulatory hurdles and political resistance to implementing findings. Variability in local geological conditions affecting study accuracy. Changing land use patterns and their impacts on groundwater quality. Potential conflicts arising from differing stakeholder interests. Uncertainties in predicting long-term impacts of groundwater use.
Model predictions on available seasonal water supply	Provides data-driven insights into seasonal water availability. Supports informed water resource planning and allocation. Helps manage water scarcity and drought conditions. Enables proactive decision-making for various sectors. Utilizes data for sustainable water management strategies. Aligns with adaptive approaches to climate variability.	Reliability of predictions can be affected by data accuracy. Complex models require skilled technical expertise. Limited predictive accuracy during extreme or rare events. Challenges in incorporating changing climate patterns. Model uncertainty can impact decision-making confidence. May face resistance if findings conflict with existing practices.	Advances in data collection, remote sensing, and modelling techniques. Integration with decision support and monitoring. Collaboration with multiple organizations. Funding opportunities for research and predictive modelling efforts. Enhancing water security and disaster readiness. Potential for cross-sectoral use in agriculture, industry, and urban planning.	Limited historical data for modelling. Regulatory barriers or political resistance to model-based decisions. Perception challenges if model outcomes differ from local knowledge. Climate pattern uncertainties. Uncertainty in long-term projections and model assumptions. Data dependence for accuracy.
Water allocation quotas	Offers a systematic approach to water management. Supports sustainable water management and conservation. Prevents over-extraction and depletion of water sources. Provides a clear framework for managing competing demands. Aligns with water scarcity and resource optimization goals.	Implementation challenges due to varying local conditions. Requires robust monitoring and enforcement mechanisms. Potential resistance from stakeholders facing allocation reductions. Limited accuracy in predicting future water demands. Can lead to conflicts over resource allocation decisions.	Advances in technology for accurate water measurement. Integration with smart water management systems. Collaboration with water user associations and stakeholders. Incentives for efficient water use and conservation. Potential for reducing water-related conflicts and disputes. Adaptation to changing water availability patterns.	Regulatory hurdles and resistance to allocation changes. Lack of sufficient data for informed allocation decisions. Variability in water demands due to climatic factors. Socioeconomic disparities affecting allocation fairness. Conflicts over prioritising water allocation among sectors. Changes in water availability due to climate change.
Water quality compliance regulations	Ensures safe and clean water for various uses. Protects public health and the environment. Provides a framework for consistent monitoring and standards. Supports sustainable water resource management. Aligns with environmental and health regulations.	Challenges in enforcing regulations consistently. Limited resources for monitoring and enforcement. Complex and evolving nature of water contaminants. Potential gaps between regulatory limits and emerging pollutants. Possible conflicts between economic interests and compliance.	Advances in water quality testing and monitoring. Integration with real-time data collection and analysis. Industry partnerships for self-monitoring. Public awareness on water quality importance. Incentives for cleaner production practices. Adapting to evolving water quality issues.	Industry resistance to change. Lack of political will/resources for enforcement. Emerging new contaminants. Varied water quality standards. Local vs. national quality conflicts. Water quality changes due to pollution/climate.
Monitoring of licensing and permits compliance on a continuous basis	Ensures adherence to regulatory requirements. Prevents unauthorized and harmful activities. Supports effective resource management and protection. Provides real-time data for informed decision-making. Aligns with environmental and legal obligations.	Challenges in continuous monitoring and data collection. Limited resources for consistent enforcement. Potential gaps in detecting covert non-compliance. Complexity of tracking and verifying permit conditions. Resistance to continuous monitoring from stakeholders.	Advances in remote sensing and real-time monitoring technology. Digital platforms for reporting and alerts. Industry partnerships for self-monitoring. Enhanced compliance transparency. Better deterrence and adaptation.	Opposition from industries to continuous monitoring. Lack of funding for monitoring infrastructure. Rapid changes in industry practices and technology. Variability in enforcement across different sectors. Conflicts over interpretation of permit conditions. Changes in activity patterns due to economic factors.

Technology	Strengths	Weaknesses	Opportunities	Threats
Water saving toilets	Significant reduction in water consumption per flush. Contributes to water conservation and sustainable resource use. Can lead to lower water bills for users. Supports environmental protection and reduces strain on water sources. Fits well in water-scarce regions and areas with water restrictions. Advances in design and technology allow for efficient flushing.	Initial cost of purchase and installation might be higher. Perception challenges related to flushing effectiveness. Compatibility with existing plumbing and sewage systems. Potential need for more frequent cleaning due to reduced water flow. Limited consumer awareness and education about water-saving toilet options. Cultural preferences and resistance to changing traditional toilet designs.	Growing demand for sustainable and efficient water use practices. Technological advancements leading to improved flushing efficiency. Integration with smart technologies for better water management. Increasing public awareness of water scarcity and conservation. Incentive programs or regulations promoting water-saving fixtures.	Competition from traditional toilets that are perceived as more effective. Fluctuations in water prices and availability. Regulatory challenges or limitations on toilet design and performance. Slow adoption due to lack of awareness and misconceptions. Uncertainties in long-term performance and durability. Potential resistance from industries or groups with vested interests in existing toilet technologies.
Improve and practise Surface infiltration technologies (porous pavements and roads, mulching, green landscaping)	Enhances stormwater management and flood control. Reduces runoff and soil erosion. Improves groundwater recharge and quality. Integrates green infrastructure for urban resilience. Aligns with sustainable water management goals.	Requires proper design and maintenance for effectiveness. Dependent on suitable site conditions and soil types. Potential variability in performance due to climate. Limited public awareness of benefits and importance. Challenges in retrofitting existing infrastructure.	Advances in green infrastructure design and technology. Urban planning integration. Municipal and community collaboration. Public awareness on the benefits of infiltration. Incentives for adopting sustainable stormwater practices. Adaptation to changing rainfall patterns.	Resistance from stakeholders to new tech. Lack of funding for implementation and maintenance. Variability in performance based on local conditions. Land use and infrastructure conflicts. Climate change affects infiltration. Potential project prioritization conflicts.
Optimization of reservoir operations	Enhances water resource utilization and management. Improves reservoir efficiency and performance. Supports water supply reliability and energy generation. Aligns with sustainable water management goals. Utilizes data-driven decision-making.	Challenges in integrating complex modelling. Dependent on accurate data and hydrological knowledge. Potential conflicts between different water uses. Resistance to changes from traditional operation methods. Resource-intensive in terms of technology and expertise.	Advances in modelling and optimization technology. Real-time data and forecasting integration. Stakeholder collaboration for shared gains. Incentives for optimized strategies. Adapting to climate and demand changes. Enhanced reservoir safety and risk.	Industry and stakeholder resistance. Funding gaps for modelling and implementation. Inflow variability and hydrological patterns. Conflicts over water use priorities. Reservoir performance shifts from climate change. Uncertainty in long-term impact prediction.
Climate change vulnerability assessments	Provides insights into areas most vulnerable to climate change impacts. Supports informed adaptation and resilience strategies. Enables prioritization of resources and interventions. Aligns with global climate adaptation goals. Enhances community preparedness for future challenges. Enhance capacity by raising awareness of climate risks.	Requires technical expertise to conduct assessments. Uncertainty in future predictions and the use of variables could affect accuracy. Limited data availability for comprehensive assessments. Difficulties in quantifying non-economic vulnerabilities. May not address all localized vulnerabilities.	Advances in climate modelling and remote sensing technologies. Integration with disaster preparedness and development planning. Collaboration with local communities and indigenous knowledge. Funding opportunities for adaptation and resilience projects. Integration with broader sustainable development strategies.	Political influences affecting the prioritization of assessments. Lack of awareness might limit assessment effectiveness. Inadequate addressing of equity and social justice could undermine assessments. Lack of consistent funding for vulnerability studies. Challenges in translating assessments into actionable policies.
Disaster risk assessment using high resolution DEM (preferably LiDAR)	Provides accurate and detailed terrain data. Enhances precision in disaster risk assessment. Supports effective disaster preparedness and response. Enables better land use planning and vulnerability mapping. Aligns with modern technology advancements.	Dependence on availability of LiDAR data. Limited coverage in certain regions. Requires technical expertise for processing and analysis. Cost-intensive data acquisition and processing. Challenges in updating data for changing conditions.	Advances in LiDAR technology and data availability. Integration with GIS and remote sensing. Collaboration with disaster management agencies. Incentives for acquiring and sharing LiDAR data. Adaptation to evolving disaster scenarios and risks. Enhancing community resilience through accurate assessment.	Limited funding for data acquisition and processing. Resistance to new technology adoption. Variability in LiDAR data quality and resolution. Data security and privacy concerns. Changes in disaster risk assessment regulations. Uncertainty in translating LiDAR data into actionable insights.
Flood hazard assessment and mapping	Enhances understanding of flood-prone areas. Enables effective disaster preparedness and response. Supports land use planning and development. Provides data-driven insights for risk mitigation. Aligns with modern geospatial technology.	Dependence on accurate and up-to-date data. Challenges in predicting extreme events accurately. Resource-intensive data collection and analysis. Limited coverage in remote or inaccessible areas. Potential discrepancies in different flood models.	Advances in remote sensing and data collection. GIS and real-time integration. Collaboration with disaster management agencies. Incentives for public and private data sharing. Adaptation to changing climate patterns. Enhancing community resilience through accurate mapping.	Limited funding for data collection and analysis. Resistance to new technology and methods. Variability in flood model accuracy. Data security and privacy concerns. Changes in flood risk assessment regulations. Uncertainty in predicting future flood patterns.
Drought risk assessment and mapping	Enhances understanding of drought-prone areas. Enables effective drought preparedness and response. Supports water resource management and planning. Provides data-driven insights for risk mitigation. Aligns with modern geospatial technology.	Dependence on accurate and up-to-date data. Challenges in predicting drought severity accurately. Resource-intensive data collection and analysis. Limited coverage in remote or inaccessible areas. Potential discrepancies in different drought models. Lack of skill capacity, data, and infrastructure might affect technology adoption.	Advances in remote sensing and data collection. GIS and real-time integration. Collaboration with water management agencies. Incentives for public and private data sharing. Adaptation to changing climate patterns. Enhancing community resilience.	Limited funding for data collection and analysis. Resistance to new technology and methods. Variability in drought model accuracy. Data security and privacy concerns. Changes in drought risk assessment regulations. Uncertainty in predicting future drought patterns.

Technology	Strengths	Weaknesses	Opportunities	Threats
Source water protection and water safety plans	Safeguards vital water sources from contamination. Supports long-term sustainability of water resources. Enables proactive response to potential risks. Integrates with modern water management strategies. Aligns with environmental conservation goals.	Dependence on accurate data for effective planning. Challenges in predicting all potential contamination sources. Resource-intensive data collection and analysis. Limited enforcement and monitoring capacity. Potential conflicts with land use and development.	Advances in water quality testing and monitoring. Integration with real-time data collection and analysis. Collaboration with water agencies and stakeholders. Incentives for industries to adopt cleaner practices. Adaptation to changing pollution and climate patterns. Enhancing community awareness and engagement.	Limited funding for water protection measures. Resistance to stricter regulations from industries. Variability in water quality standards and enforcement. Data security and privacy concerns. Changes in water resource management policies. Uncertainty in predicting future contamination risks.
Membrane Bioreactors	Efficient wastewater treatment process with simultaneous solids removal and filtration. High-quality treated water for reuse. Compact design and small footprint. Effective in removing a wide range of contaminants. Ideal for decentralized and small-scale use. Enables advanced treatment for stringent water quality standards.	High initial and operational costs. Energy-intensive with aeration and cleaning. Fouling affects efficiency and maintenance. Complexity demands skilled personnel. Familiarity may hinder adoption. Design challenges for larger capacities.	Growing demand for water reuse and stringent water quality standards. Advances in membrane technology and fouling mitigation strategies. Potential for energy recovery and optimization to reduce operational costs. Increasing awareness of environmental sustainability and pollution control. Innovation in design and operation for improved efficiency and cost-effectiveness.	Competition from other wastewater treatment technologies. Energy price fluctuations affecting costs. Regulatory changes or limitations in discharge standards. Public perception challenges related to using treated wastewater. Uncertainties in long-term performance. Environmental impact concerns.
Advanced domestic wastewater treatment tanks	Efficiently treats domestic wastewater to high-quality effluent. Compact design with smaller footprint. Can be integrated into existing wastewater treatment infrastructure. Removes a wide range of contaminants. Offers potential for decentralized wastewater treatment. Contributes to environmental protection and water resource conservation.	Initial capital investment can be relatively high. Requires regular maintenance and operational oversight. Energy consumption may be necessary for aeration and mixing. Skilled personnel are needed for proper operation and maintenance. Limited public awareness and understanding of advanced treatment systems. Adoption barriers in regions with conventional sanitation practices.	Increasing demand for sustainable and efficient wastewater treatment. Advancements in treatment technologies for improved efficiency and performance. Potential for energy recovery and resource reuse. Growing emphasis on water quality standards and pollution control. Integration with smart technologies for remote monitoring and control.	Competition from traditional wastewater treatment methods. Energy price fluctuations affecting costs. Regulatory changes or challenges in meeting discharge standards. Public perception challenges related to treated wastewater. Uncertainties in long-term performance and reliability. Potential environmental impacts related to technology materials and components.

5. Conclusion

This report presented the process that was undertaken to reprioritise water related technologies for the Kingdom of Eswatini. It presents the methodology that was adopted, which included the review of existing documents related to the water sector of the Kingdom, review of the previous prioritised technologies, how the prioritization was undertaken. Then it presents how through rigorous stakeholders' consultations, the reprioritization was undertaken, with the updated technologies presented according to priority, and categorized into either hardware or software, and further broken down to the water challenge being addressed.

The top ten reprioritised technologies are flood risk assessment and mapping, communication via workshops, presentations and stakeholder dialogues, central data storage facility, optimisation of reservoir operations, smart urban forests, water serving toilets, national and community disaster management plans, improve and practise surface infiltration technology, disaster risk assessment using high resolution digital elevation model, and wetland restoration.

The prioritised technologies were further categorized using their respective roles in disaster preparedness and addressing specific water-related challenges (i.e., too little water scarcity, too much water, unknown climatic risks, and water pollution). Most prioritised technologies primarily focus on addressing challenges related to too little water scarcity, 13 in total. Of these, 7 technologies fall under the hardware category, while 6 fall under the software category. The next most set of prioritised technologies address challenges associated with too much water, 5 in total. Of these, 4 fall under the hardware category and a single technology under software. In addition, 5 technologies were prioritised that respond to unknown climate risks, all under software category. Lastly, three technologies were prioritised to respond to water pollution.

Notably, there were no technologies prioritised that fell under the orgware category. This could be attributed to the strong legal framework and institutional arrangement in the country's water sector. Despite the existing legal frameworks, it is noted that weak institutional coordination is a significant barrier to successful adaptation from the barrier analysis.

The report also presents a barrier analysis for each of the prioritised water adaptation technologies. The barrier analysis of the technologies consistently highlighted financial limitations, encompassing both installation and operational/maintenance costs, as the primary factor constraining the application and widespread adoption of these technologies. Other identified common barriers included the lack of technical capacity and expertise to apply the identified technologies, poor institutional and regulatory capacity, and the lack of and/or poor public awareness with some of the technologies.

Lastly a SWOT analysis was presented to evaluate the feasibility and potential of the prioritised technologies. In conclusion, the SWOT analyses conducted for various technologies in Eswatini highlight both their potential and challenges in contributing to sustainable development and improved resource management. These analyses have shed light on the strengths, weaknesses, opportunities, and threats associated with each technology, helping us better understand their roles in addressing critical issues such as water resource management, disaster preparedness, and environmental conservation.

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Annexes

ANNEX 1 – PRIORITIZATION FROM THE DIFFERENT GROUPS

TABLE A 1: Prioritization for Group 1

No	Group 1	Affordability	Coherence to notional priorities	Social acceptability	Reduce vulnerability to drought	Enhance resilience to floods	Environment sustainability	Gender equity	Maturity	Potential for scale up/ replicability	Address climate change (mitigation co-benefits)	Capcity	Total	Technology rank
1	Estimations of the minimum amount of water required for irrigation	70	100	80	135	90	90	50	90	80	50	35	870	1
2	Climate change vulnerability assessments	80	100	80	120	80	90	50	90	80	50	40	860	2
3	Drought risk assessment and mapping	80	100	80	120	50	90	50	90	80	50	40	830	3
4	Water quality compliance regulations	70	100	80	120	80	90	50	80	80	40	40	830	3
5	Disaster risk assessment using high resolution DEM (pref LIDAR)	80	100	80	105	70	90	50	90	80	50	30	825	5
6	Flood hazard assessment and mapping	80	100	80	75	80	90	50	90	80	50	40	815	6
7	Water efficient technogies, eg taps	60	100	90	120	80	80	40	80	80	50	35	815	6
8	Communication via workshops, presentations, stakeholder dialogues, etc	70	100	90	120	80	80	40	80	80	40	35	815	6
9	Source water protection and water safety plans	70	100	80	120	80	80	40	80	80	40	40	810	9
10	Green Landscaping	80	80	80	120	80	80	40	80	80	40	40	800	10
11	Minimising evaporation	60	100	60	120	70	90	50	80	80	45	30	785	11
12	Zoning and land development limitations	70	100	50	120	80	90	40	80	80	40	35	785	11
13	Early warning and forecasting tools for drought and flood	60	100	70	120	80	90	50	50	80	50	30	780	13
14	Model predictions on available seasonal water supply, eg GIS Tech	60	100	70	120	80	90	50	50	80	50	30	780	13
15	Water recycling and re-use	70	100	50	120	80	90	40	70	80	45	35	780	13
16	National and community disaster management plans	80	80	70	120	80	70	45	70	80	45	40	780	13
17	Structural barriers to flooding – damns, dikes, levees, including runoff control structures	60	90	70	120	80	80	35	80	80	40	40	775	17
18	Water pricing	60	100	60	105	70	70	50	90	80	45	40	770	18
19	Decentrallised community run early warning systems (including indigenous knowledge, information dissemination, stacking sandbags	70	80	60	120	80	70	45	80	80	40	40	765	19
20	Real-time monitoring networks	40	70	60	120	80	70	45	70	80	40	30	705	20

TABLE A 2: Prioritization for Group 2

No	Group 2	Affordability	Coherence to notional priorities	Social acceptability	Reduce vulnerability to drought	Enhance resilience to floods	Environment sustainability	Gender equity	Maturity	Potential for scale up/ replicability	Address climate change (mitigation co-benefits)	Capcity	Total	Technology rank
1	Model predictions on available seasonal water supply	100	100	100	180	80	90	25	100	100	20	25	920	1
2	Disaster risk assessment using high resolution DEM (pref LIDAR)	70	90	100	195	80	100	25	100	100	20	20	900	2
3	Central Data Storage facility	80	100	100	210	90	90	25	80	80	20	25	900	2
4	Optimization of reservoir operations	90	90	90	210	90	80	25	90	90	20	20	895	4
5	Water saving toilets	100	100	80	210	40	80	25	90	100	25	20	870	5
6	Real-time monitoring networks	70	90	80	275	100	90	20	80	80	20	15	870	5
7	Improve and practise Surface infiltration Technologies (porous pavements and roads, mulching, green landscaping)	80	90	80	210	90	100	25	60	80	25	25	865	7
8	Sub-surface Drip irrigation	60	100	70	225	70	100	25	70	80	25	25	850	8
9	Urban green spaces	70	100	80	195	80	90	25	80	90	25	15	850	8
10	Surface reservoirs and Dams	40	100	60	225	100	80	25	90	80	20	20	840	10
11	Boreholes (Country Aquifer mapping necessary)	80	100	90	225	70	60	25	80	80	15	15	840	10
12	Wetland restoration	90	100	50	275	90	100	25	20	70	25	70	825	12
13	Smart water metering	40	100	50	210	90	100	75	30	100	75	20	820	13
14	Inter-basin transfers	40	90	60	210	80	90	25	80	90	25	20	810	14
15	Zoning and land development limitations	100	100	50	150	90	100	25	60	90	25	20	810	14
16	Runoff harvesting	70	90	80	210	80	90	20	40	70	20	15	785	16
17	Implementing leak detection systems (telemetry system)	a0	100	50	195	60	100	25	80	80	20	25	775	17
18	Advanced domestic wastewater treatment tanks	50	100	60	150	60	100	25	70	90	20	20	745	18
19	Change in agricultural practices (e.g., limiting fertilizer application, (precision farming)	70	100	50	135	60	100	25	70	80	25	15	730	19
20	Structural barriers to flooding - dams, dikes, river bank protections	70	80	70	180	70	70	25	60	70	15	15	725	20

TABLE A 3: Prioritization for Group 3

No	Group 3	Affordability	Coherence to notional priorities	Social acceptability	Reduce vulnerability to drought	Enhance resilience to floods	Environment sustainability	Gender equity	Maturity	Potential for scale up/ replicability	Address climate change (mitigation co-benefits)	Capcity	Total	Technology rank
1	Multipurpose dams	80	100	100	150	60	70	35	80	80	45	45	845	1
2	Water allocation quotas	100	100	70	105	40	80	40	80	80	45	40	780	2
3	Wetland Restoration	70	90	60	120	80	90	45	60	80	45	30	770	3
4	Climate change vulnerability assessments	40	90	90	120	80	70	40	80	70	40	40	760	4
5	Estimations of the minimum amount of water required for irrigation	100	100	60	120	20	80	30	60	80	45	35	730	5
6	Roof top harvesting and Runoff harvesting	60	70	80	105	0	80	40	80	80	35	40	670	6
7	Boreholes/groundwater	30	70	80	120	20	60	40	70	80	45	40	655	7
8	Model predictions on available seasonal water supply	40	100	70	90	80	60	30	40	60	45	35	650	8
9	Drip irrigation	30	90	70	120	0	70	40	60	60	45	34	620	9
10	Drought risk assessment and mapping	40	90	40	120	0	70	35	50	80	40	40	605	10
11	Implementing leak detection systems	40	70	60	120	0	90	30	50	60	35	25	580	11
12	Flood hazard assessment and mapping	40	90	50	0	80	70	35	50	80	40	40	575	12
13	Green landscaping	50	40	30	90	60	80	40	50	50	45	30	565	13
14	Monitoring of licences and permits on a continues	30	70	50	75	40	70	35	50	70	40	30	560	14
15	Grey water re use	40	80	50	105	0	60	35	40	70	35	30	545	15
16	Change in agricultural practices (e.g., limiting fertilizer application, sediment control)	70	80	80	0	0	80	40	70	90	5	30	545	16
17	Water quality compliance regulations	40	60	30	90	40	90	30	40	50	40	25	535	17
18	Smart water metering	40	60	50	105	30	80	25	30	50	40	20	530	18
19	Pressure control	30	70	60	105	0	80	25	40	40	40	20	510	19
20	Advanced domestic wastewater treatment tanks	60	60	60	0	0	60	35	60	50	30	35	450	20

TABLE A 4: Prioritization for Group 4

No	Group 4	Affordability	Coherence to notional priorities	Social acceptability	Reduce vulnerability to drought	Enhance resilience to floods	Environment sustainability	Gender equity	Maturity	Potential for scale up/ replicability	Address climate change (mitigation co-benefits)	Capcity	Total	Technology rank
1	Communication via workshops, presentations, stakeholder dialogues, etc	100	100	100	150	100	100	50	100	100	50	50	1000	1
2	National and community disaster management plans	70	100	100	150	100	100	50	90	100	50	45	955	2
3	Flood risk assessment and mapping	80	100	100	150	100	80	50	100	70	50	40	920	3
4	Drought risk assessment and mapping	90	100	100	150	70	100	50	100	70	50	40	920	4
5	Roof top harvesting and Runoff harvesting	100	80	100	150	70	90	50	90	100	50	40	920	5
6	Wetland restoration	80	100	90	150	90	100	50	100	50	50	25	885	6
7	Smart urban forests	90	100	90	135	80	100	50	90	60	50	35	880	7
8	Hydro-geological studies to inform optimal groundwater usage	60	80	90	150	70	90	50	100	80	50	35	855	8
9	Monitoring of licensing and permits compliance on a continuous basis	100	100	70	105	70	90	50	70	100	50	50	855	8
10	Model predictions on available seasonal water supply	90	100	90	75	100	100	50	70	70	50	45	840	10
11	Use of GIS technology to model	60	70	80	135	90	90	50	100	80	50	35	840	10
12	Implementing leak detection systems	70	80	100	150	60	90	50	80	70	50	30	830	12
13	Improved point of use water treatment	90	70	100	105	50	60	50	80	100	50	45	800	13
14	Water recycling and re-use	50	80	70	135	50	90	50	90	70	50	40	775	14
15	Membrane Bioreactors	40	100	60	120	80	90	50	70	90	50	20	770	15
16	Multipurpose dams	50	80	80	120	100	50	50	90	50	50	25	745	16
17	Drip irrigation	50	100	80	75	50	90	50	100	70	50	25	740	17
18	Smart water metering	20	80	80	120	70	90	50	80	70	50	25	735	18
19	Model socio economic scenarios	70	100	80	30	90	70	50	80	80	40	40	730	19
20	Minimising evaporation through mulches, plastic dam covers and solar panel floating on water channels	30	50	50	135	80	90	50	70	60	50	35	700	20

TABLE A 5: Combined prioritization of water technologies

Technologies	Occurance	Affordability	Coherence to national priorities	Social acceptability	Reduce vulnerability to drought	Enhance resilience to floods	Environment sustainability	Gender equity	Maturity	Potential for scale up/ replicability	Address climate change	Capacity	Total	Rank
Flood risk assessment and mapping	1	80	100	100	150	100	80	50	100	70	50	40	920	1
Communication via workshops, presentations, stakeholder dialogues, etc	2	85	100	95	135	90	90	45	90	90	45	43	908	2
Central Data Storage facility	1	80	100	100	210	90	90	25	80	80	20	25	900	3
Optimization of reservoir operations	1	90	90	90	210	90	80	25	90	90	20	20	895	4
Smart urban forests	1	90	100	90	135	80	100	50	90	60	50	35	880	5
Water saving toilets	1	100	100	80	210	40	80	25	90	100	25	20	870	6
National and community disaster management plans	2	75	90	85	135	90	85	48	80	90	48	43	868	7
Improve and practise Surface infiltration Technologies	1	80	90	80	210	90	100	25	60	80	25	25	865	8
Disaster risk assessment using high resolution DEM (pref LIDAR)	2	75	95	90	150	75	95	38	95	90	35	25	863	9
Wetland restoration	2	85	100	70	188	90	100	38	65	60	38	23	855	10
Hydro-geological studies to inform optimal groundwater usage	1	60	80	90	150	70	90	50	100	80	50	35	855	10
Monitoring of licensing and permits compliance on a continuous basis	1	100	100	70	105	70	90	50	70	100	50	50	855	10
Urban green spaces	1	70	100	80	195	80	90	25	80	90	25	15	850	13
Surface reservoirs and Dams	1	40	100	60	225	100	80	25	90	80	20	20	840	14
Climate change vulnerability assessments	2	60	95	85	120	80	80	45	85	75	45	40	810	15
Source water protection and water safety plans	1	70	100	80	120	80	80	40	80	80	40	40	810	15
Model predictions on available seasonal water supply	3	77	100	87	115	87	83	35	70	77	38	35	803	17
Estimations of the minimum amount of water required for irrigation	2	85	100	70	128	55	85	40	75	80	48	35	800	18
Multipurpose dams	2	65	90	90	135	80	60	43	85	65	48	35	795	19
Roof top harvesting and Runoff harvesting	2	80	75	90	128	35	85	45	85	90	43	40	795	19
Real-time monitoring networks	2	55	80	70	173	90	80	33	75	80	30	23	788	21
Drought risk assessment and mapping	3	70	97	73	130	40	87	45	80	77	47	40	785	22
Water allocation quotas	1	100	100	70	105	40	80	40	80	80	45	40	780	23
Membrane Bioreactors	1	40	100	60	120	80	90	50	70	90	50	20	770	24
Advanced domestic wastewater treatment tanks	3	50	100	60	150	60	100	25	70	90	20	20	745	25
Drip irrigation	3	47	97	73	140	40	87	38	77	70	40	28	737	26
Flood hazard assessment and mapping	2	60	95	65	38	80	80	43	70	80	45	40	695	27
Water quality compliance regulations	2	55	80	55	105	60	90	40	60	65	40	33	683	28
Green Landscaping	2	65	60	55	105	70	80	40	65	65	43	35	683	28
Boreholes/groundwater	1	30	70	80	120	20	60	40	70	80	45	40	655	30

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