Improving the efficiency and sustainability of water harvesting technologies in Sudan:

Diagnosing the existing harvesting systems used in Sudan – Financial, Capacity, and Market Sustainability Assessment Proposal Report

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aid environment

RICOS Engineering

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Executive Summary

Sudan faces escalating challenges in water resource management due to prolonged conflict, climate variability, and economic instability. These issues have led to the deterioration of water infrastructure, erratic rainfall patterns, and increasing droughts and floods. In response, a variety of water harvesting (WH) technologies have been implemented across the country, though their long-term viability is hindered by uncertain financial sustainability, limited market readiness, and weak technical capacity.
This report assesses the financial and market aspects, and capacity dimensions of existing WH technologies in Sudan.

The assessment covers:

- CAPEX & OPEX Analysis: Evaluating construction and operational costs of different WH technologies including *Hafirs, terraces, sand and subsurface dams, percolation tanks, check dams, recharge basins, road and roof harvesting, and Maya'a ponds*. Hafirs and storage dams were identified as the most expensive, while terraces and natural ponds offer lower-cost alternatives.
- Operation and Maintenance (O&M) Costs: Costs vary by technology, with fuel, labor, and material availability being critical cost drivers. Some technologies (e.g., terraces, traditional ponds) are low maintenance, while others (e.g., improved Hafirs) require constant inputs.
- Materials and Markets: Most construction materials (cement, steel, gabion mesh, chemicals) are imported, leading to high costs driven by inflation, customs, and security-related transport issues. Local supply chains are currently limited and/or disrupted.
- Financial Sustainability: WH projects are primarily funded by federal and state governments, NGOs, and international donors. Community contributions exist for smaller structures. However, only ~40% of Hafirs currently collect tariffs, and pricing is insufficient to cover major repairs. Public-private partnerships and tariff reforms are proposed.
- Market Assessment: Market demand differs regionally. The report emphasizes analyzing local needs, capacity to invest, and potential for scale-up. Key barriers include economic constraints, security risks, and weak institutional coordination.
- Methodology: A mixed-methods approach is proposed, including field visits, stakeholder interviews, and quantitative surveys using tools like Kobo Toolbox. Desk research and comparative cost-benefit analysis will complement primary data collection.

The report concludes that a holistic understanding of financial feasibility, market dynamics, and local capacities is essential to enhance the sustainability and scale-up potential of water harvesting technologies in Sudan. Targeted investments, capacity building, and policy reforms are critical to ensure that WH systems contribute meaningfully to climate resilience, livelihoods, and water security.

Introduction

Sudan faces serious challenges in water resources management, particularly in the context of the ongoing conflict, which has led to the destruction of critical water infrastructure. These issues are further exacerbated by dramatic shifts in climate, including erratic rainfall patterns, rising temperatures, prolonged droughts, and episodes of severe flooding. In recent years, several states have experienced worsening environmental stress compounded by deep economic instability and complex socio-political dynamics, placing additional pressure on already scarce water resources.

In response, Sudan has adopted a range of water harvesting technologies to improve water availability and support climate adaptation. While these technologies are promising, their long-term sustainability remains uncertain due to limited evidence on financial viability, market readiness, and operational costs. This has hindered the potential for broader implementation and replication across regions.

The success of water harvesting projects varies significantly depending on local financial capacity, regional economic conditions, security dynamics, gender roles, and the technical capabilities of implementing institutions. To support more effective scaling and resilience-building, there is a clear need for comprehensive assessments that reflect these diverse influencing factors.

This report aims to chart a way forward by assessing the financial, market, economic, gender, and capacity dimensions that shape water harvesting outcomes. It proposes practical methods for gathering reliable, context-specific data to better understand the impacts of water harvesting interventions, evaluate their potential for scale, and strengthen stakeholder engagement. Tools such as mobile-based surveys (e.g., Kobo Toolbox) and structured field assessments will play a central role in informing more sustainable water resource practices within Sudan's evolving climate and conflict-affected landscape.

Objective

The objective of the project is to improve the efficiency and sustainability of water harvesting technologies in Sudan by providing technical assistance in terms of enhancing technology transfer, capacity building, and research collaboration. The response plan for this intervention was developed by the proponents WRC of the University of Khartoum and DLWHRC of the ARC and approved by the CTCN; it defines the following technical assistance:

- Assess existing water harvesting technologies and practices in Sudan.
- Assess capacity needs and identify gaps in knowledge and skills related to water harvesting.
- Diagnose the effectiveness and suitability of different water harvesting techniques in Sudan's diverse climatic conditions.
- Identify appropriate and innovative water harvesting technologies suitable for the Sudanese context and summarize this information into a catalog or database.
- Facilitating the transfer of these technologies to local stakeholders through training programs, workshops, and demonstrations.

CAPEX, OPEX and financial sustainability

The objectives of the financial sustainability assessments are to assess the feasibility of the water harvesting technologies from an economic perspective in the context of Sudan. The assessment will consider two scales; one focusing merely on the capital and overall initial investments; the second scale focusing on the operational aspects which is a more long-term process.

The specific objectives in the financial and sustainability assessment are:

- To analyze the cost of the water harvesting projects by assessing the initial costs, operation and maintenance costs along with other associated costs such as materials and labor costs considering the inflation of the currency and overall economic instability in the context of Sudan.
- To identify the funding sources and evaluate their potential for future investment in water harvesting thematic sector and evaluate any local funding schemes that aims to promote water harvesting in more sustainable manner. Also recognize the reasons of funding limitations and understand funding mechanism and their concern.
- To get more information about any expected potential for cost recovery and generate revenue for water harvesting projects. This assessment will review users' fees or any community committee's fees to promote operational and maintenance of the projects.
- To register the risks and measure its impacts on short and long term which could impact the financial sustainability in Sudan.

Material and market assessment

This assessment will focus on the markets' demand in the context of Sudan. Indeed, the global market is different from the countries' specific market. Therefore, there is need to assess the market needs per each specific state and review the potential of the water harvesting technologies to scale-up.

The specific objectives in the market and sustainability assessment are:

- To analyze the market demand at state level and country level with focus on vulnerable areas where water harvesting is in high needs and there is potential for agricultural, livestock and human dependence. This assessment will evaluate the demands of small local farmers, herders and households and address their level of capacity to invest in such technologies.
- To review the critical barriers that hinder effective adoption of the water harvesting projects from economic perspective and conduct SWOT analysis to recognize the possibilities for market expansion.
- To identify the market key actors and understand the competitions between service providers and suppliers aiming to understand the relations between governmental bodies, NGOs and community with private sector, suppliers and service providers.
- To get information regarding market potential for growth in short- and long-term aspects. This assessment will identify the market readiness during emergencies and their potential collaboration with key stakeholders.

Methodology

This section outlines the steps for using a combined approach that includes both financial and market perspectives, based on qualitative and quantitative data collection. The goal is to gather reliable information and involve key partners working on water harvesting projects, especially in light of ongoing conflict and climate challenges in the region.
The assessment will be comprehensive and includes on-site field visits, interviews, and group discussions with government institutions and local stakeholders such as farmers, herders, and other water users. It will also include a survey to gather quantitative data, which will help evaluate the sustainability of water harvesting projects and support a cost-benefit analysis, taking into account the country's high inflation.
In addition, some data will be collected off-site through meetings with key stakeholders in the water sector. The methodology will focus on combining both qualitative and quantitative data sources.

A. Data Collection Approach

a. Field Visits and Site Observation - On-Site Assessments

Field visits will be conducted by visiting pre-defined water harvesting technologies in places where the security situation allows it. Local authorities will be engaged in all field visits across different states in Sudan. The field visit will focus on key issues as follows:

- Site observation by photo reporting and gathering all technical data in relation to the water harvesting system.
- Stakeholder engagement with formal and informal stakeholders such as leaders, local farmers and local authorities.
- Documentation of the technological performance and any existed practices with overall impact on the community within the region.

In the context of the conflict situation in Sudan, 14 states are considered as high risk regions and 4 states are considered relatively safe areas. Thus, the site visiting will be conducted in coordination with governmental entities and local communities as well. The visiting plans will be done according to their guidance and security protocols.

b. Stakeholder Surveys and Interviews - Off-Site Assessments

Direct survey and interviews with local staff and community:

- Institutions at State Level.
- Institutions at Locality Level.
- Local Communities and end users.

The overall aim is to conduct an in-depth interview with key stakeholders to identify the funding gaps, obtain information about the operational concerns at both short and long term. Additionally, group discussions will be established with local farmers, households and herders to measure community willingness to pay for their water harvesting projects and gather diverse information regarding their preferences of technologies in terms of their costs and future operational costs considering the high inflation rate.

C. Secondary Data Collection - Desk Study

This assessment will rely on obtaining historical data from governmental entities, NGOs and local partners at field level to get more insights on the previous rainfall patterns, fuel costs, operational and initial costs overall and other records related to the sustainability level of the technologies, cost structure and challenges faced by other stakeholders.

CAPEX and OPEX

Construction costs

The investment required for construction of water harvesting technologies varies based on infrastructure type. However, with the same technology, the material and design consideration dictate cost requirement.

Hafirs

In general, Hafirs are the most expensive water harvesting measures in Sudan. For a Hafir with a storage capacity of around 80,000 m^3 the cost can reach up to 120,000 USD. While for the smaller size (e.g. 30,000 m^3) the cost ranges between 45,000-60,000 USD. These estimates increase by around 20% if the water treatment component is added to the Hafir. These components typically consist of a slow sand filter, a pump, an elevated tank and a chlorination unit. The average cost for a water treatment unit mounted to a Hafir is around 12,000 USD.

Primary cost drivers

Hafirs average between 1.5-2.5 USD/m^3. Excavation work contributes approximately 60% to 80% of the overall cost. Excavation works are typically caried out using heavy machinery which makes diesel prices the main influencing factor. Other cost items are the civil work associated with inlet and outlet wells as well as pumping conduits. Labor cost is 10-15% of the total cost while the design and engineering cost is less than 6% on average. In recent year, the diesel prices have significantly increased due to government decision to remove subsidies from petroleum products.

Other cost drivers:

Storage capacity: While total costs increase with the increase of storage capacity, this increase is not linear. The cost relationship follows a flat U shape. The costs for harvesting a m^3 of water is higher in smaller Hafirs in compared to mid-size Hafirs where the cost reduces by 30% before it increases again in larger Hafirs. In a small Hafir, the embankment cost is substantial in comparison to the overall cost. As the size increases, more volume of work is associated with excavations while embankment costs become less significant. In larger Hafirs the unit rate for extraction increases significantly in compared to smaller ones. This is because larger Hafirs tend to have higher depth which would require the deploying of more machinery (e.g. two steps lowering).

Soil type: Hafirs at rocky soils, which are found in many Hafirs in Red Sea state, are the most expensive to construct. A Hafir on stiff soils like black cotton soil is expensive, these soil types are abundant in Al Gadarif, Blue Nile and sinner.

Lining: Excavation of medium texture soils is the cheapest in compared to other soil profiles. Additionally, this type of soils is typically associated with a higher permeability which requires lining using natural material (e.g. clay blanket) or manufactured material (e.g. geomembrane).

Figure 1, Overview of estimated costs divided by the capacity of a Hafir

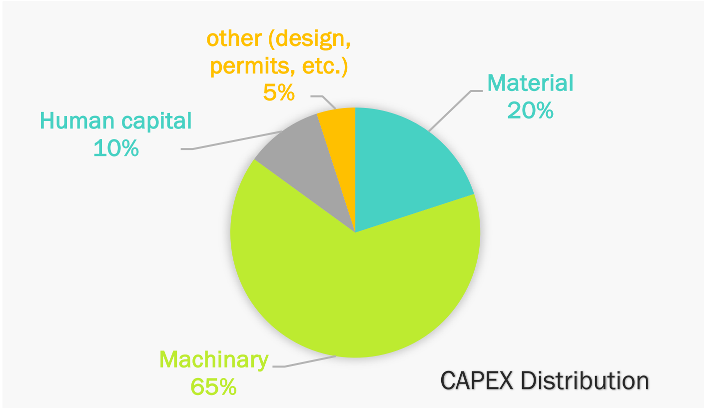


Figure 2. Share of the total costs of the various cost items for a Hafir

Terraces (crescent terraces)

Small to medium terraces and modified terraces have the lowest capex cost among all existing off-stream water harvesting interventions in Sudan. The cost for the construction $100m^2$ of terraces ranges from 20 to 30 USD. Exact estimates of water retained by this technology vary significantly depending on slope, soil type etc. However, terraces are typically used to sustain crop water requirements for the designated plots where terraces are implemented. On average, terraces improve water retention in one acre of rainfed plots (60% irrigated) of sorghum and maize crops, by an average of 25 cm (soil moisture depth). This is equivalent to 600 m3 per total acre bringing the cost to around 2 USD/m^3.

Primary drivers

Soil type: On the long run, soil type is the most influential factor in determining the lifetime of a terrace. Cohesive soils with proper texture could enable terraces to last up to 5 years without the need for repairs or reconstruction. However, loose soils could support irrigation of one season requiring an annual 100% reinvestment cost.

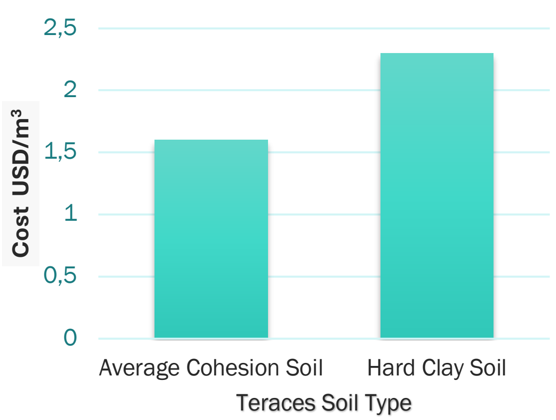


Figure 3. Overview of estimated costs divided by the capacity of terraces

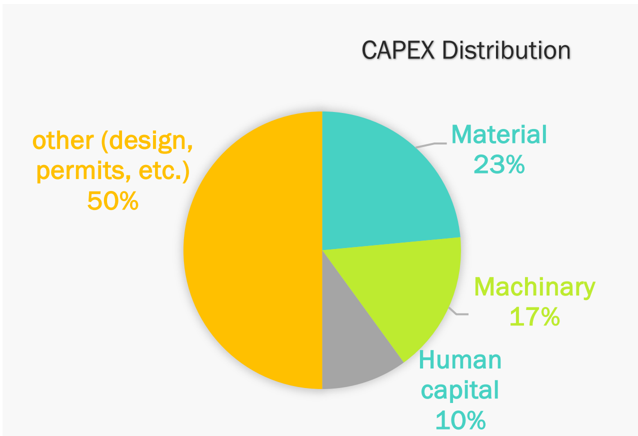


Figure 4. Share of the total costs of the various cost items for terraces

Subsurface and Sand dams

The cost of subsurface dams' construction ranges from 0.1 USD/m^3 up to 1.8 USD/m^3 for subsurface dams and 1.7 USD/m^3 up to 3 USD/m^3 for sand dams. However, for both technologies, these figures involve a substantial uncertainty regarding harvested/recharged amounts vs collected water. While significant amounts can be recharged to the groundwater, a smaller amount would be collected by end users. This is heavily dependent on different factors (e.g. method of collection, seepage to lower aquifers, evaporation).

Primary cost drivers

Construction material: for subsurface dams, geomembrane boxes filled with sand provide the cheapest construction option. Deep reinforced concrete dams have the highest cost and are up to 20 times more costly than sand filled boxes.

Other cost drivers*:* Excavation works represent 20-30% of the total capital cost. However, the topography and shallow aquifer properties play an even more important role in determining the cost for each m^3 harvested. Gentle slopes and wider rivers/creeks/wadis tend to bring lower construction costs, compared to steeper slopes and or shallower streams.

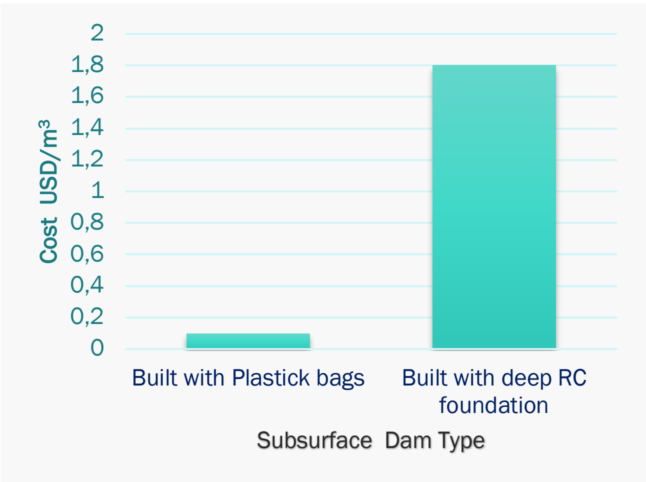


Figure 6, Overview of estimated costs divided by the capacity of a subsurface dam

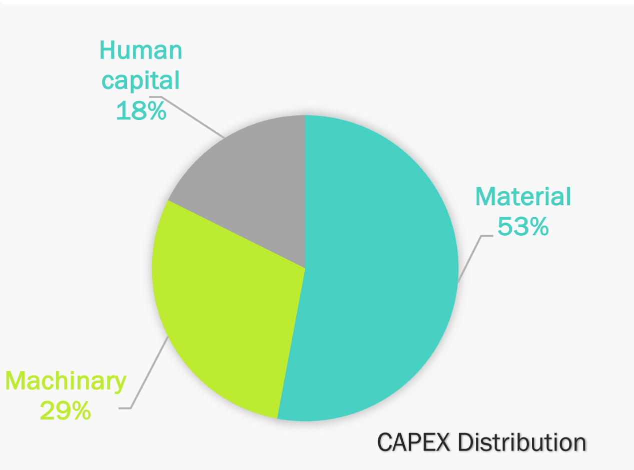


Figure 5, share of the total costs of the various cost items for a Subsurface dam

Percolation tanks (collection dams)

Percolation tanks are typically built using mortar masonry or reinforced concrete, this step comprises nearly 60% of the total construction cost. The size varies significantly amongst the surveyed structures and across the country from 30,000 m^3 up to + 7 million m^3. Supporting parts (e.g. side embankments, erosion protection, and sluice gates) contribute to about 30-40% of the total cost. The construction costs range between 0.15 USD/m^3 to 3.2 USD/m^3.

Primary cost drivers

Material costs, especially cement, and steel reinforcement dictates the overall price of water. As most interventions are constructed in relatively remote areas, sourcing these materials comes at an elevated cost (e.g. transportation, customs, higher taxes, protection from vandalism).

Other cost drivers: Topography plays a great role in the efficiency and the design. Reservoir depth-volume-surface ratio and stream width are the main factors in determining storage capacity and dam dimensions and therefore in the costs.

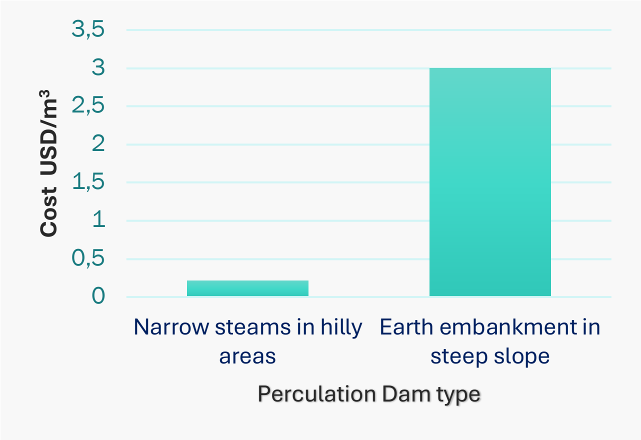


Figure 8. Overview of estimated costs divided by the capacity of a percolation dam

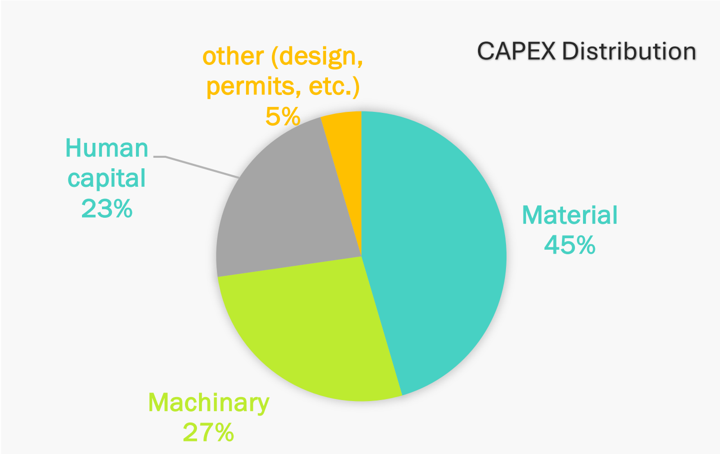


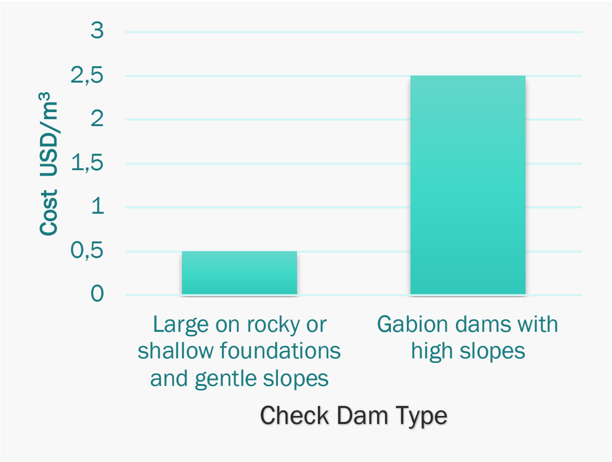
Figure 7. Share of the total costs of the various cost items for a percolation dam

Check dams

Check dams have a wide range of capex profiles, mainly stemming from different construction material and structure sizes. Loose rock check dams are the cheapest, reaching as low as 1,000 USD due to absence of cement and steel. These structures compose mainly of stones and supporting wooden posts. Small loose rock dams are usually built with community support as volunteering effort. A more expensive option are gabion check dams with a m^3 of gabion costing around 2,000 USD to 10,000 USD.

Primary cost drivers

Check dams show a wide range of CAPEX profiles, most of the surveyed small check dams had a relatively high costs, reaching around 2.5 USD/m^3. However, typical costs associated with large(r) check dams are around 0.45 USD/m^3. This relatively large difference is explained by the fact that most of the surveyed small dams were built in high slope streams (>5%). This reduces water storage and buffering (storage) significantly, compared to dams built in flatter streams.



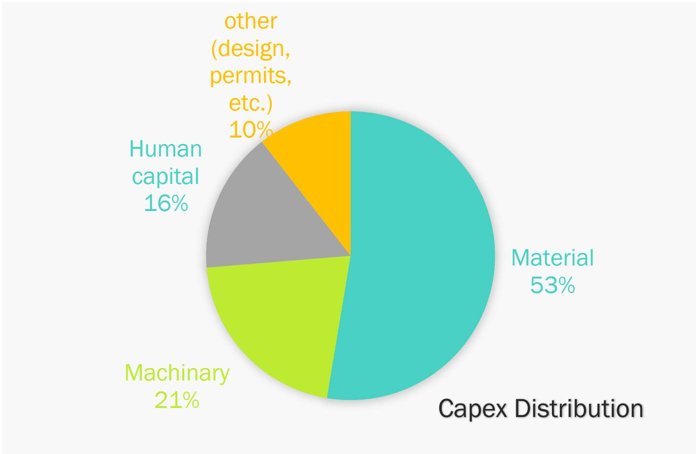


Figure 9. Overview of estimated costs divided by the capacity of a check dam

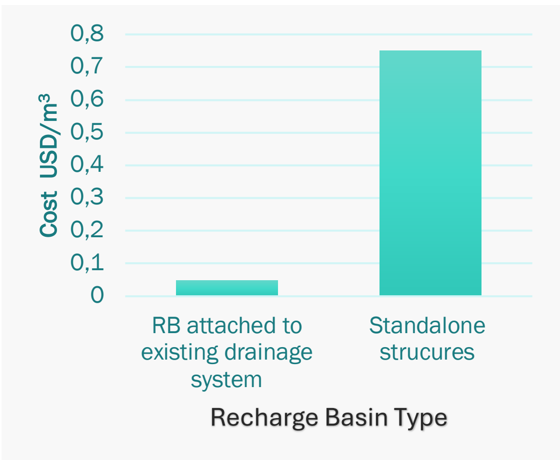
Figure 10. Share of the total costs of the various cost items for a check dam

Recharge basins

Most of the surveyed artificial basins were located at the end of the drainage canals of the AlGash spate irrigation scheme. The pre-existence of a conveying system had a substantial influence in reducing the construction cost of recharge basins, to average around 0.05 USD/m^3, in compared to similar structures like Hafirs. Most of the surveyed basins did not require significant inlet works, benefiting from readily available agricultural drainage systems. However, a standalone recharge basin would still achieve a better USD/m^3 ratio in compared to Hafirs, due to its low evaporation, large subsurface storage capacity and minimal earth works.

Primary cost drivers

Most of the expenses go to removing top-soil layers which typically consist of impermeable soils e.g. clay, silt. The thicker the layer, the higher the cost of establishment. A smaller investment is required for basin embankments which are typically formed from the excavated materials.



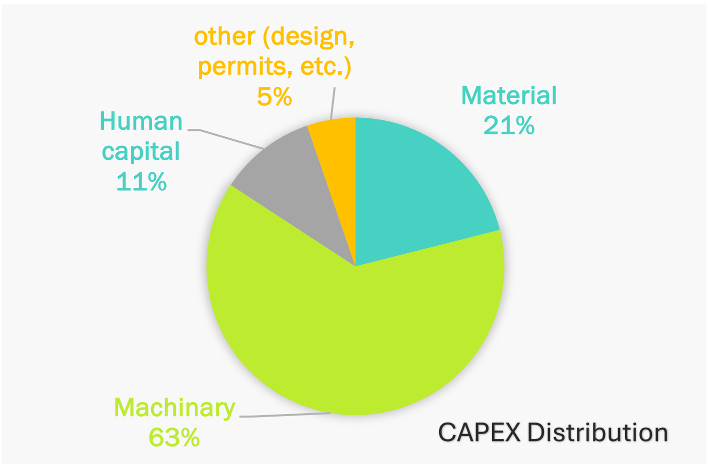


Figure 11. Overview of estimated costs divided by the capacity of a recharge basin

Figure 12. Share of the total costs of the various cost items for a recharge basin

Maya'a (Natural ponds)

Maya'a's naturally occurring nature helps reducing its construction cost to less than 0.1 USD/m^3. Most of the expenses go to covering manual labor and sometimes machinery used in reshaping the small embankments on a seasonal, annual or bi-annual basis.

Maya'a's ponds are usually used for livestock drinking and typically located in remote areas which increase the cost of machinery. Additionally, the need for a large labor force also challenges timely construction (before the rainy season).

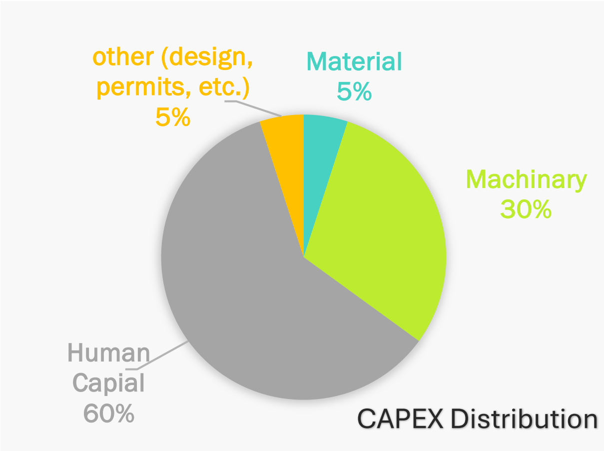


Figure 12. Share of the total costs of the various cost items for a maya'a

Road Water Harvesting

In case of repurposing existing borrow pits, investment in road water harvesting focuses on protection and reshaping activities which make it an effective technology with an average construction cost of 0.8 USD/m^3. However, this value increases significantly if the project is established from scratch and therefore includes excavation or, sometimes, diversion structures.

Primary cost drivers

Inlet works including structures as well as road protection works represent more than 50% of project expenses. Dry pitching, which costs around 30 USD/m^2 is usually used to protect adjacent roads embankment. Mortared masonry which costs around 150 USD/m^3 is used for inlet works.

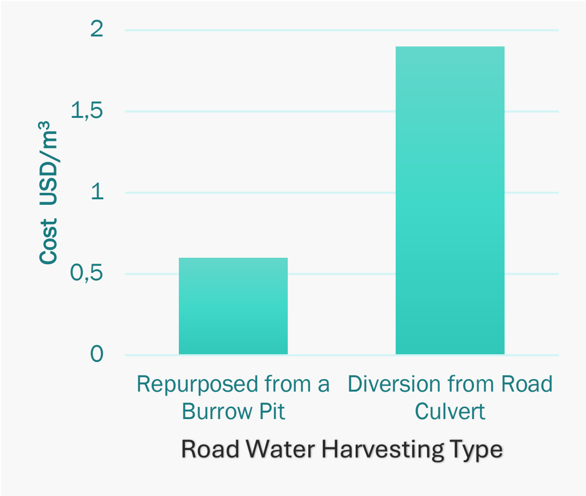


Figure 14. Overview of estimated costs divided by the capacity of a road water harvesting structure

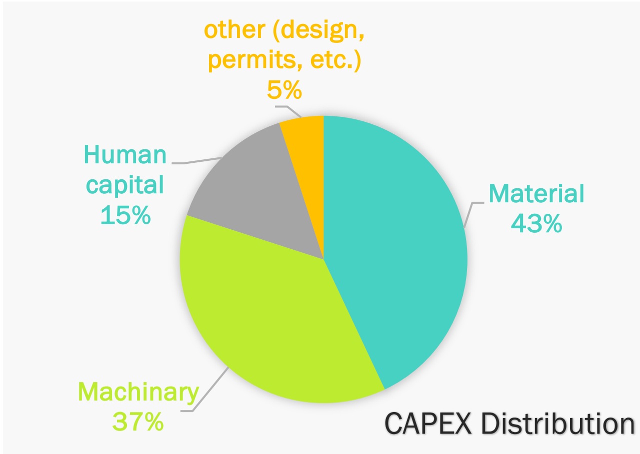


Figure 13. Share of the total costs of the various cost items for a Road water harvesting structure

Roof Water Harvesting

The costs of roof water harvesting are often spilt between flow conveying units such as pipes and fittings and storage structures, usually plastic tanks. On some occasions, water proofing is required to prevent water leakages from the roof. Other households store the collected water in several small buckets. The cost for the fitting of a roof water harvesting to one cottage (Goty'a) ranges from 150 to 450 USD. Flat roofs which mostly use zink sheets and local wood roofs (Areesha) require higher costs to cover waterproofing with epoxy or bituminous materials.

Primary cost drivers

Roof protection works and storage units are the main cost drivers for roof water harvesting. Thus, it is more efficient to construct these technologies in steep sloped roofs which omit the need for leakage protection. The survey respondents reported inflation, customs and overall security and economic instability as the primary barriers for resource mobilization for roof water harvesting.

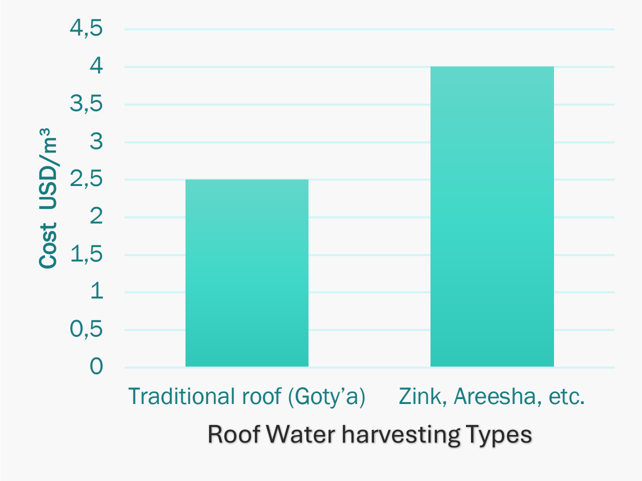


Figure 16. Overview of estimated costs divided by the capacity of a roof water harvesting structure

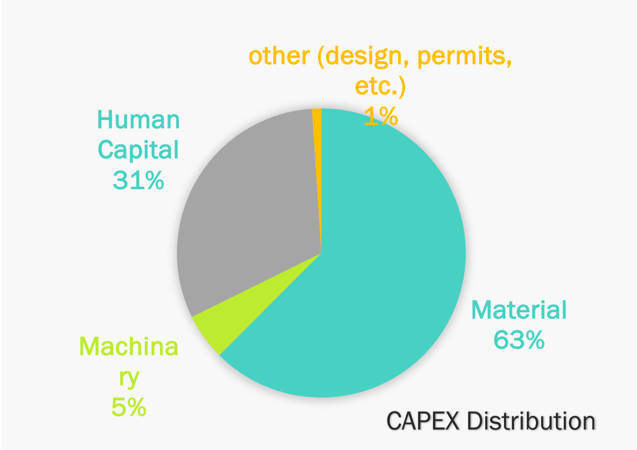


Figure 15. Share of the total costs of the various cost items for a roof water harvesting structure

Operation and maintenance costs

Operation costs vary significantly based on several factors including (but not limited to); technology type, method of water collection, type of users, management model, and proximity to urban centers. Improved hafirs and storage dams are the costliest WH technologies to maintain due to the need for human resources and material input at a daily level to sustain water pumping and treatment requirements.

For example, the surveyed Hafirs reported the need to have at least 8 liters of fuel daily with a price ranging from 1.2 to 1.4 USD per liter. The monthly operator fees are around 100 USD. Most of the improved Hafirs rely on in-kind support, the government or humanitarian actors to provide chlorination / disinfection materials.

On the other hand, traditional Maya'a, half-moon terraces and subsurface dams require little to no operation costs at daily level. Terraces in general, Crecent, half-moon, traditional, require frequent repairs, often sub-seasonally, and replacement costs, from 2 to 5 years. In general, off-stream technologies require labor intensive repair which is often done manually. Table 1 gives an overview of annual cost estimates for a wide range of interventions.

Table 1, Operation and maintenance costs for different water harvesting techniques

Operation	Cost USD/Year	Maintenance	Cost USD/Year
Hafirs			
Operators Fuel Oil and lubricants	1,00 - 2500 5,000 - 15,000 800 - 1,000	Inlet and outlet pipes cleaning Desilting Embankment reshaping Fencing repair	3,000 4,000 1,000 500

		Regular maintenance for plumping works	300
Water spreading weirs			
Operator (seasonal)	800 - 1,200	Control structure repair Protection repair Reshaping embankment	800 - 1,500 500 1,200 - 1,500
Recharge basin			
Operators (seasonal)	800 - 1,200	Basin Desalination Pre-sediment tank cleaning Diversion canal cleaning Embankment reshaping	2,000 500 1,500 800 - 1,000
Terraces			
		Cleaning roof periodically Chlorine tablet (in case drinking water use) Waterproof repair (3 years on average)	
Storage dams (+ 5 million m^3)			
Operators: Fuel: Oil and lubricants	Operated by SWC 20,000 - 35,000 2,000 - 3,000	Desilting (rarely implemented) Spillway repair and embankment reshaping Regular maintenance for plumping works	10,000 - 15,000 2,000 - 4,000 500

Materials and Markets

Steel Rebar

Reinforcement steel bars were produced locally in multiple factories in Khartoum and then distributed across the country. However, after the 2023 war, production was suspended and the whole supply chain shifted towards imports. Most of the supplies are currently sourced from Egypt and Saudi Arabia. In some western states, east of Jabal Marra, steel is mainly supplied from Libya. As such, inter-state transportation, worsened by the security situation, adds significantly to steel cost. Adding up to 25%, compared to steel prices at a seaport.

Figure 17, Steel bar in local shop, Kassala

Table 2, Estimated price and origin of steel bars in Sudan in April 2025

Local price range	Global/Regional price	source
1,050 USD per ton	750 USD per ton	Imported from KSA and Libya

Cement

Prior to 2017, around 65% of Sudan's demand for cement was covered locally by cement factories all located in River Nile state due to the abundance of available raw material there (e.g. silica). Due to economic and politically instability, some local factories were shut down, shifting the supply chain to rely on imports. Currently, around 50% of cement is imported either from Egypt or Saudi Arabia to cover the gap in most of Sudan. Additionally, some supplies from Libya and Chad cover demand in west, north and south Darfur.

Cement is available in most local markets and similar to steel, transportation and inter-state tariffs plays a role in increasing prices as products move from north and eastern states to southern and western states. This way, between 10% to 20% is added to its manufacturing prices.

Table 3, Estimated price and origin of Cement in Sudan in April 2025

Local price range	Global/regional price	source
220 USD per ton	80 USD per ton	Locally produced and imported

Figure 19 Imported cement shipment in Northern State

Figure 18 Atbara Cement Factory, River Nile State

Sand

In most states, construction sand is available locally and supplied via specialized vendors. Few states like Aljazeera, Blue Nile and most of Sinar state and Al Gadarif rely on supply chains from neighboring states which increase prices. Strong monopolies control construction sand varieties which exacerbate prices and overall construction cost.

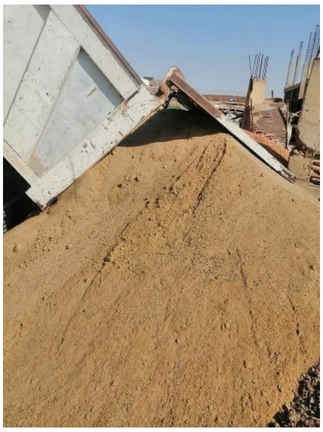


Figure 21. Yellow construction Sand Category, Red Sea State

Figure 21 Red construction Sand Category, Red Sea State

Table 4, Estimated price and origin of Sand in Sudan in April 2025

Average local price range	source
9 - 15 USD per m^3	Local quarries

Gabion mesh

Gabion boxes are not manufactured locally in a dedicated form. Instead, they are typically assembled on-site using galvanized steel mesh that is originally produced for fencing, rather than specifically designed for gabion applications. At present, there are no operational factories in Sudan that produce gabion mesh or gabion boxes. As a result, most of the materials are imported, primarily from China, Egypt, and Saudi Arabia.

Table 5, Estimated price and origin of Gabion mesh in Sudan in April 2025

Average local price range	Global/regional price	source
65 USD per box (2x1x1)	30 USD per box	Imported from Egypt, UAE

Figure 23 Gabion stock at warehouse

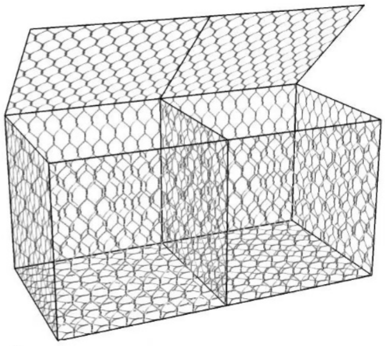


Figure 23 standard gabion box 2m x 1m x 1m

Granite rocks, natural and crushed stones

Granite rocks are the most common type of stones used in mortared masonry construction. Granite provides high strength stones with sizes ranging from 5 up to 50 mm diameter. Granite is abundant in all states. Natural aggregate stones are abundant in most of the states except east Darfur, Al-Gadarif Sinar and Blue Nile. Stone quarries produce crushed stones in most states for commercial uses. In some states e.g. east Darfur, west Kordofan, temporary quarries owned by private contractors are sourcing crushed stones for dedicated projects with a small part of the production made available for public market. In this case, crushed stones will be higher than average prices.

Figure 24 Granite crushed stone, Algirba

Table 6, Estimated price and origin of Granite in Sudan in April 2025

Local price range	Source
17 - 25 USD per m^3	Local quarries

Lining and grouting materials and concrete chemical add mixtures

Lining is commonly used in improved hafirs to prevent seepage of stored water into permeable soils. Grounding materials are common in foundation works of surface storage dams or any other retaining structures, while chemical add mixtures are commonly used in high temperature curing and excessive soleplate locations where rust is a common problem (e.g. Red Sea State). All these materials are imported from neighboring markets and are subject to increased customs and impact from inflation over the past 10 years.

Table 7, Estimated price and origin of Lining in Sudan in April 2025

Local price range	Global/regional price	source
7.5 – 32 USD per Kg	2 – 10 USD per Kg	Imported

Financial sustainability

Funding sources

In general, most of the surveyed technologies were funded through government agencies, both local and federal. However, for some specific types of structures other funding sources were dominant. Storage dams, percolation tanks and improved Hafirs are mostly, up to 80%, funded by the Federal Ministry of irrigation and Water Resources or its state-level counterparts. While the majority of traditional Hafirs are built by either non-governmental organizations, civil society organizations or the farming private sector (farmer associations, large scale farmers). Sand dams, subsurface dams, check dams and other recharge related water harvesting infrastructure are mostly constructed by international and local NGOs, especially over the past 15 years. Two recorded subsurface dams were funded by the government over the past decade. However, the government made a larger contribution to subsurface dam construction prior to 1990 especially in eastern Sudan.

Community-built infrastructure is dominantly terraces and small diversion weirs. These types of technologies are commonly constructed in rainfed regions in Darfur, Kordofan, Kassala and Red Sea states. The dominant users are farmers and pastoralists in addition to a small numbers of mud brick makers.

Road water harvesting structures are usually repurposed from burrow bits dug for road construction. Most of the surveyed road WH structures were local water vendors who reshape, clean and prepare the inlet channels and the storage pond.

Flagship funds:

- **Federal government Zero Thirst Program:**
  The program started in 2006, aiming to achieve 100% coverage with clean water within 10 years. The program adopted water harvesting technologies as core interventions to supply water in rural areas. The program successfully implemented more than 200 water harvesting projects. It is estimated that the program has invested 250 million dollars in water harvesting across the country.
- **EU funding UNEP and Practical Action to implement Wadi Elku Program:**
  With an investment of 15 million the project put emphasis on water spreading infrastructure and sand dams across the North state. The program focused on community participatory approaches for water harvesting technologies development.
- **UK-Aid and EU funding rural water for Sudan program:**
  The program invested nearly 20 million USD in developing more than 200 water harvesting and Managed Aquifer Recharge (MAR) interventions. The program had

strong community-led IWRM approaches which helped implementing more than 11 different types of water harvesting and MAR with a total catchment footprint covering 20% of Sudan's total area.

Tariff

Collection of tariffs from water sources is typically regulated by state level legislation councils and implemented by state water corporations. However, SWC focuses on tariff collection, typically on a monthly bill basis, within urban centers and large towns. In rural areas tariffs are typically collected from water yards in coordination with locality offices and community committees. For surface storage water harvesting structures, like improved Hafirs, tariffs are determined locally, by community management committees and are collected flexibly. The primary objectives of the tariffs are to cover daily operation costs (fuel for water pump and operator daily fees). Major repairs are rarely accounted for when deciding on a hafir tariff. Tariffs are currently collected at only ~40% of all Hafirs. The tariff enforcement differs substantially between states and even within state localities. For example, White Nile, Blue Nile and Al Gadarif have a higher percentage of tariff collection in hafirs as compared to Red Sea, Kassala and Darfur region. Traditional hafirs (with no pumps or water treatment units) are typically not tariffed.

Financial performance

Table 8, overview of costs, capacity and drivers of cost for eight different technologies in the Sudanese context.

Technology	Implementation Cost (USD)	Annual Upkeep Cost (USD/year)	Typical Storage Capacity (m^3)	Cost per m^3 Stored (USD/m^3)	Primary Driver of Cost
Hafir	$45,000–$120,000 (30–80,000 m^3)	$12,300–$17,500	30,000–80,000	$1.5–$2.5	Excavation, diesel prices
Recharge Basin	~$5,000	~$5,100	~100,000	~$0.05 ($0,7 for standalone structure)	Topsoil removal, minimal inlet/embankment works
Terraces (Crescent)	$20–30 per 100m	Minimal (manual repair every 2–5 yrs)	~600 m^3 per acre	~$2.00	Soil type (affects frequency of repair)
Storage Dam	*Very high*	$22,000–$38,000	>5,000,000		Fuel, large-scale maintenance, pumping, desilting
Water Spreading Weir	*~20,000-50,000*	$2,100–$4,200	*No storage*		Operator fees, repair of control/protection structures
Subsurface Dam	$20.000	Very low	*~20,000*	$0.10–$1.80	Construction material type (e.g., concrete vs. sand boxes)
Sand Dam	$40.000	Very low	*~20,000*	$1.70–$3.00	Construction material and topography
Check Dam (Gabion)	$2,000–$10,000 per dam	Low to moderate	*~5,000*	$0.45–$3.00	Construction material, slope of streambed

Conflict impact cost

Prewar

Over past 10 years, Sudan has experienced challenging economic and political conditions. Following the secession of South Sudan in 2011, the Sudanese economy was severely impacted by the loss of most of its oil production revenue. From 2011 to 2018 the country tried to diversify its economy by investing in and developing the agricultural and mining sector. This had a positive impact on the adoption of water harvesting across the country as it supports agricultural production and livestock. Along with agriculture, the federal government established a *Zero Thirst Program* which aimed to achieve access to clean water for all citizens in a 5 years' timeline. A substantial number of water harvesting technologies, mainly hafirs and storage dams, were constructed under this program. However, from 2017 to 2020, the country experienced a record inflation coupled with multiple rounds of currency devaluation. This halted development efforts, especially investments in water harvesting. While water harvesting technologies continued to be adopted by the mining sector, its impact was limited to private sector mining operations with very limited supply for surrounding communities. During the same period, the government gradually removed subsidies from fuel and electricity leading to a substantial increase in diesel prices. As a result, the costs for implementing and operating a water harvesting technology skyrocketed. Especially for structures requiring excavation and embankments, such as hafirs and storage dams, prices went up 200-300%.

2023 war onwards

The outbreak of widespread armed conflict in April 2023 has had a severe and paralyzing effect on the construction, rehabilitation, and operation of water harvesting infrastructure across Sudan. Within the first six months of the conflict, the sector experienced a near-complete halt in activity. The supply of essential construction materials, including cement, steel, fuel, and spare parts, was disrupted, making it very difficult to procure inputs for ongoing or planned projects. Governance structures collapsed or ceased to function in many areas, leading to the absence of institutional continuity and the withdrawal of oversight and support from public water agencies.

At the same time, many technical and administrative staff were displaced, or forced to abandon their posts due to insecurity or halting of salaries. The widespread breakdown of electricity supply further compounded the crisis, especially for mechanized water systems reliant on pumps, chlorination units, and other powered components. Costs for fuel and basic inputs soared, driven by scarcity, risk premiums, and logistical challenges, effectively making new water harvesting infrastructure financially unviable.

In this context, access to most field sites became impossible, particularly in the fourteen states classified as high-risk zones. Even in relatively safer areas, the ability to implement or maintain water harvesting interventions was extremely limited. As a result, the country's capacity to deliver water infrastructure has been reduced to isolated, small-scale interventions, typically implemented by communities with minimal support. The broader system of institutionalized water harvesting, once driven by coordinated public, private, and donor investment, has largely collapsed, and its recovery will require not only improved security but also renewed governance, international support, and reestablishment of core infrastructure and supply systems.

Conclusion

This report has provided a comprehensive assessment of the financial, technical, and institutional dimensions of water harvesting technologies in Sudan. Through the analysis of capital and operational costs, market dynamics, and conflict-related disruptions, it becomes evident that while a broad set of technologies is in use across the country, their long-term viability varies significantly depending on purpose, location, and economic conditions.

A key outcome of this assessment is the comparative cost and performance table of eight water harvesting interventions, presenting implementation costs, annual upkeep, typical storage capacities, and the cost per cubic meter of water stored. The data, drawn directly from field assessments and technical documentation, reveals significant variation between interventions. For example, hafirs, widely used for drinking water in rural areas, have a storage capacity of 30,000–80,000 m^3 and a cost of $1.5–$2.5 per m^3, but also incur high annual operating costs (primarily due to diesel-fueled pumping and treatment). In contrast, recharge basins, which often utilize existing irrigation channels, offer a much lower cost per cubic meter, approximately $0.05 per m^3, while maintaining high storage capacity, making them financially attractive where conditions allow.

Technologies such as terraces play an entirely different role: rather than storing water for drinking, they retain soil moisture and improve water infiltration, directly enhancing agricultural productivity. Their unit cost is approximately $2 per m^3 of water retained, with minimal upkeep. This reinforces the critical point that not all water harvesting serves the same purpose. Water harvesting for agricultural productivity (e.g., terraces) must be evaluated with different benefit metrics than technologies intended for drinking water access.

However, the sustainability of any intervention has been deeply affected by macroeconomic instability and ongoing conflict. From 2017 to 2020, Sudan experienced record inflation and a series of currency devaluations that drastically increased the cost of construction materials, labor, and fuel. These effects were compounded by the removal of fuel subsidies, which raised diesel prices and significantly increased the operating costs of water harvesting systems, particularly those reliant on mechanized pumping.

Since the outbreak of violent conflict in April 2023, the situation has deteriorated further. Construction costs have surged due to disrupted supply chains, widespread insecurity, and the collapse of governance structures in much of the country. Skilled personnel have been displaced, electricity is unavailable in many regions, and access to implementation sites has become nearly impossible. As a result, both public and donor-supported investments in water infrastructure have come to a near standstill, and the burden has shifted toward informal or community-managed systems with limited scalability or support.

In this context, future planning for water harvesting in Sudan must be grounded in realistic financial models, purpose-driven technology selection, and conflict-sensitive implementation strategies. Interventions should be carefully matched to water use goals: technologies for domestic water supply must prioritize durability, quality control, and cost-efficiency, while those for agricultural water productivity should focus on low-cost, locally maintainable systems that increase yield resilience.

Despite the challenges, this report demonstrates that cost-effective and scalable solutions do exist, particularly where existing infrastructure and local capacities can be leveraged. By aligning technology selection with specific water needs, understanding true lifecycle costs, and designing for resilience in fragile environments, water harvesting in Sudan can play a critical role in strengthening both livelihoods and water security.