Improving the efficiency and sustainability of water harvesting technologies in Sudan

Knowledge, Skills and Capacity Gaps Assessment

September 2025

aid environment

RICOS Engineering

Executive Summary

Sudan's water harvesting sector is essential for rural communities facing acute water scarcity, but it is severely strained by prolonged conflict, climate variability, institutional disruptions, and economic instability. Techniques such as Hafirs, check dams, and roof catchments provide critical access to water for drinking, farming, and livestock; yet, systemic weaknesses in planning, construction, and maintenance lead to high failure rates, potentially leaving ~80% of the infrastructure non-functional post-conflict. This capacity-needs-assessment, evaluates the missing capacity and knowledge gaps through a mixed-methods approach, combining a desk review of key documents with 13 key informant interviews (KIIs) spanning federal agencies, state governments, NGOs, academia, and contractors. The analysis adapts a UNDP-FAO three-level capacity framework (enabling environment, organizational, and individual) to rate competencies as latent, emerging, or established, with a focus on Levels B and C to pinpoint actionable gaps.

A. Key Findings

Interviews and reviews reveal five interconnected themes underscoring the sector's capacity gaps and needs:

- Gap in suitable design references and manuals**:** Outdated or generic Hafir manuals dominate with little to no manuals for other types of water harvesting technologies. Sudan's diverse landscapes—ranging from clayey plains to sandy wadis, with rainfall ranging from 50 to 1000+ mm—demand comprehensive manuals and adaptive design tools that integrate local hydrology, geology, and socio-cultural factors, such as gender roles in water use or pastoralist land norms. Past efforts, such as the 2015 Khartoum Water Research Centre manual, stalled due to funding and conflict, resulting in common flaws, including poor spillway designs and inadequate siting.
- Limited knowledge sharing from national to state/regional level**:** Federal entities such as the Dam Implementation Unit and the Regional Centre for Water Harvesting have established design and innovation capabilities, but these do not extend to state-level bodies. State Water Corporations and Groundwater and Wadi Departments are rated as emerging or latent in operations and maintenance. They are hindered by staff turnover, loss of institutional memory, and limited training. NGOs including Practical Action and ZOA have strong field experience but face challenges in implementing and sustaining operational and maintenance protocols. The design, supervision, and operation chain is often disrupted, with local contractors struggling to adapt plans due to resource constraints.
- Maintenance and Sustainability Shortfalls: Unclear roles from federal oversight to community upkeep, combined with a lack of dedicated budgets accelerate infrastructure degradation due to siltation and mismanagement. Political instability further dissolves effective units and erodes expertise. While contractors are effective with small-scale projects, they often lack the capacity for innovative solutions such as subsurface dams, especially under economic constraints.
- Need for Local Participation and Adaptation: Community involvement is essential, but top-down approaches often overlook regional differences, such as farmer-led systems.. User fees from hafirs rarely support maintenance due to mistrust and insufficient planning. Engineers frequently lack facilitation skills, limiting the integration of technical and social expertise needed for local ownership.
- Fragmented Knowledge Exchange: Knowledge sharing remains ad hoc, with no national platform to consolidate pilots, data, and lessons learned. This results in repeated assessments across states. Regional disparities, such as Kassala's IWRM hub compared to gaps in Gadarif, highlight the need for a centralized, mobile-accessible repository that integrates GIS maps, videos, and peer forums.

These gaps, intensified by the 2023 war and prior instabilities, limit the capacity to adapt to the changing climate: erratic rains overwhelm unadopted structures, while conflict disrupts supply chains and displaces skilled workers.

B. Strategic Directions and Recommendations

The assessment recommends a decentralized, learning-focused model that prioritizes local knowledge over static manuals. Mobilizing undocumented expertise from practitioners and communities will help Sudan build resilient systems capable of withstanding shocks.
Prioritized actions include:

- Knowledge Tools: Launch digital hub, featuring flexible checklists for zone-specific adaptations (e.g., check dams for the Red Sea Hills) and user-uploaded case studies, monitoring and maintenance reports.
- Skills Building: Embed hands-on training at demo sites, targeting engineers and operators annually on low-maintenance techniques, with community "champions" for handover during disruptions.
- Organizational Fixes: Clarify O&M roles in MWRI policies, advocate for budget allocation for O&M training, and rewarding high-performing sites to build accountability amid governance weaknesses.
- Community Integration: Mandate participatory mapping in projects, to align designs with local governance and channel fees into site funds.

Contents

1. Introduction

Sudan's water harvesting sector stands at a critical crossroads. As the country grapples with the compounding effects of prolonged conflict, institutional disruption, and climate variability, sustainable management of its scarce and unevenly distributed water resources has become both a necessity and a challenge. Water harvesting, ranging from small-scale roof catchments to larger infrastructure such as hafirs and check dams, has long been a cornerstone of rural water access and resilience. Yet the current state of practice reveals deep systemic gaps in planning, implementation, and sustainability.

This report, developed as part of Objective 2.1, synthesizes key findings from interviews with Sudanese experts, practitioners, and stakeholders actively engaged in the water harvesting sector. It complements earlier literature-based assessments with grounded insights from those directly involved in the design, operation, and support of water harvesting interventions across Sudan. Particular attention is paid to how contextual realities, technical, environmental, institutional, and socio-cultural, shape outcomes on the ground.

Rather than providing a purely technical evaluation, this report aims to reflect the lived experience of implementation and identify where interventions succeed or fail, and why. Across all interviews, five critical themes emerged:

1. The absence of reliable, context-specific **manuals and guidelines**, and the need to shift from generic documentation to adaptive knowledge-sharing mechanisms;
2. Severe and widespread **capacity gaps,** from federal to community level, undermining the effectiveness and sustainability of interventions;
3. Persistent **maintenance and sustainability challenges**, exacerbated by unclear responsibilities, weak local ownership, and lack of technical skills;
4. The central importance of **participation and local adaptation** as prerequisites for long-term functionality;
5. The need for a **revitalized national knowledge platform** to connect actors, consolidate learning, and support localized innovation.

The findings outlined in the following chapters are not only diagnostic but also directional. They help point toward a more decentralized, learning-oriented model of water harvesting support. One that values local knowledge, enables adaptive practices, and builds durable institutions around water infrastructure.

The findings outlined in the following chapters point toward a more decentralized, learning-oriented model of water harvesting, one that values local knowledge, supports adaptive practices, and strengthens institutions. *Deliverable 3.1* offers a detailed review of existing manuals and guidelines in Sudan. While that analysis highlights important gaps, it also reinforces the central conclusion of this report: that manual production alone should not be the main priority. Instead, the focus must shift toward mobilizing and sharing local knowledge, and supporting implementers in adapting solutions to diverse and evolving contexts.

2. Methodology

The capacity assessment used a mixed method approach to collect data, analyse it and draw results and conclusion.

- **Stage 1:** desk review of secondary date to inform data collection planning.
- **Stage 2:** selection of key organizations and individuals to target with data collection.
- **Stage 3:** conducting key informant interviews both physically on-site and remotely.
- **Stage 4:** analysing collected data by tailoring established frameworks

2.1. Desk review:

The consultant initiated the assessment by conducting a desk review of available literature. Several resources were reviewed including:

- Country transformational strategy for water supply and water resources management. Ministry of Water Resources and Irrigation
- Community based management system for sustainable water harvesting facilities in the rural areas of Sudan- Project document. (AKSAD, RCWH)
- Water for three states program- Scoping study. FCDO (DFID)
- Enhancement of Integrated Water Resources Management Project- Final report. JICA
- Water and Sanitation sector assessment, policy and strategy development- Project report. New tech Consulting
- Prefeasibility study for regional water and sanitation program- WSUP, UNHCR and UNICEF
- Sudan Multi-Indicator Cluster Surveys (MICS)
- Water Harvesting Systems in Sudan-Research project. Hydraulic Research Centre

The desk study focused on focused on several thematic areas including:

a) technical capacities (organizational and individual capacity on design and management of various harvesting technologies)
b) human resource needs (e.g., training in hydrological modeling or maintenance)
c) institutional frameworks (e.g., level of policy enforcement)
d) socio-economic barriers
e) funding gaps and investment barriers.

The desk study encountered limitation in accessing updated assessments covering situation prior to the 2023 war and the 2018-2020 political instabilities which could have resulted in potential biases. Additionally, the literature provided limited information on organizations and human resources capacity needs at the level of different individual water harvesting technologies. These limitations were mitigated by refining key informant interviews scope and design to bridge literature gaps and verify insights with updated information from active and expert organizations and individuals.

2.2. Key informant Interviews

Interviewees were selected to represent key stakeholder groups involved in water harvesting in Sudan, including government institutions, NGOs, academia, and consultants. This mix ensured coverage of both policy and field-level perspectives. Government officials provided institutional context, NGOs and consultants contributed hands-on implementation experience, and academics shared insights on training and knowledge systems. The goal was not statistical representation but a balanced, practice-oriented understanding of the enabling environment.

Table 1, Overview of the conducted interviews.

Date	Interviewee	Organization	Sector
15/02/2025	Isam Khogali	State Water Corporation- Kassala	State Government
10/04/2025	Khalid Tagelsir	Agriculture Department- Ministry of Production and Economic Resources	State Government
05/03/2025	Abdalagadir Mohamed	Groundwater and Wadis-Kassala	State Government
03/05/2025	Abdelrahim Alfaki	Dam Implementation Unit	Federal Government
11/02/2025	Ali Karrar	Sudan Vision NGO	Local NGO
08/01/2025	Mohamed Ismail	MI Abnaouf Contracting	Contractor
01/11/2024	Omer Musa	Envirotech Consulting	Consultant
16/06/2025	Mohammed Badr	LM International	NGO / Consultant
17/06/2025	Wifag Mahmoud & Hatim Badri	University of Khartoum & UNESCO Water Harvesting Centre	Academic / Multilateral
18/06/2025	Musa Ibrahim	Practical Action	NGO
18/06/2025	Ishraga Osman	University of Khartoum	Federal MIWR
19/06/2025	Ahmed Hassan	Dam surveillance unit	Government
26/06/2025	Mohamed Banaga Hejazi	ZOA	NGO

Figure 1 consultation meeting with Sudan Vision NGO

2.3. Analysis framework

The assessment adopts a tailored UNDP and FAO three-level capacity assessment model to perform systematic analysis of KIIs and desk study results. The model defines three levels of capacity:

- Level A, the enabling environment level:
  which analyses relevant policy orientation at government level, the socio-economic conditions that enable or constrain water harvesting development and the efficiency and effectiveness of legal framework. This level was previously covered in *Activity 1.4* of this project and findings are concluded in the *Mapping of stakeholders*
- Level B: organizational level:
  which refers to the wide range of organizations involved in water harvesting such as water user organizations, research groups, government extension agencies and private companies that share common objectives such as improved livelihoods at the farming level, improved water management or increased agricultural productivity at a national level. The capacity of an organization is embedded in the ability of its individuals to work together within established rules and values and to interact with other organizations.
- Level C, the individual level:
  is the most structured and familiar part of capacity development and includes education and training of the various stakeholders, from farmers to local professionals.

The three levels provide a structure that allows capacity development to be examined and analysed. In addition, they provide possible entry points for support from donors and technical cooperation. However, they are clearly linked, for example, water user organizations are shaped as much by society (laws, regulations) as by individuals (skills, leadership, relationships).

The TA focuses on assessing the capacity needs of the different organizations and entities involved in water harvesting agenda in Sudan.

Rating criteria were defined for each indicator area to support the assessment and to identify capacity assets and needs. Three ratings were differentiated:

- Latent: There is little or no capacity in this indicator area | *significant capacity building required.*
- Emerging: There is some capacity in this indicator area | *capacity building required.*
- Established: There is sufficient capacity in this indicator area | *capacity building optional*.

Figure 2 UNDP and FAO three-layer model for capacity needs assessment

3. Findings:

3.1. Competency analysis

Table 2, Overview of the competency analysis. Each organization is rated established, emerging or latent on three different criteria.

	Design Principles for Water Harvesting Structures	Operational and Maintenance Protocols	Adoption of Innovative Technologies
Federal: Ministry of Water Resources and Irrigation : -Dam implementation Unit (DIU) -Dam Safety Unit (DSU)	**Established**. The ministry draws on both local and international expertise when developing water harvesting infrastructure..	**Established.** The DIU does not directly manage WH structures. However, the DSU provides highly skilled professionals for maintenance upon request from state-level authorities, who typically manage WHs.	**Emerging.** DIU introduced relatively new technologies e.g. subsurface dams in several regions for the first time.
Research: Regional Centre for Water Harvesting	**Established**. The centre conducted several studies and capacity building projects aimed at improving local skills and knowledge on WH, demonstrating a high institutional capacity	**Established.** The centre produced several assessments and recommendations, protocols for WH improvement	**Established.** he centre has promoted the introduction of newer WH technologies in Sudan through several projects to Sudan.
University of Khartoum: Water Research Centre U of K Consultancy Corporation	**Established**. The curriculum of several colleges provides robust scientific base for WH design and management. WH is a recurring research topic, featured in both undergraduate and graduate projects	**Established.** Many research projects, especially graduate students' thesis, discuss operation and maintenance challenges and provides relevant recommendations and insights for WH O&M improvement.	**Emerging.** Research on new technologies is limited, highlighting the need for greater exposure and capacity building for researchers.

State: State Water Corporation Ministry of infrastructure	**Emerging.** The SWC, across the country, have a set of standard design specification for Hafirs. The soundness of designs for other types of WH technologies depends on the capacity of available engineers and practitioners, which is often limited.	**Latent**. Availability and use of protocols for O&M have eroded over the years due to the high turnover and loss of institutional memory and the lack of staff appointment especially at the infrastructure location (site supervisor and operator in charge of O&MO.	**Latent**. Fewer states adopted newer technologies. Usually, the adoption is introduced by external actors e.g. Local NGO, international NGOs
State: Groundwater and Wadis	**Latent.** As the government regulator of groundwater resources, GWWD demonstrated little presence in the WH sector. Although the GWWD is mandated to review and issue permits for any interventions affecting groundwater and non-Nilotic seasonal water course, the department rarely enforces their mandates.	**Latent.** The staffing gap is significantly impacting the department's ability to carry out its functions in monitoring groundwater resources and enforcing corrective actions, penalties, or supporting operation in general.	**Emerging.** When consulted, the department often suggest WH interventions which are relatively new/innovative to the local context. However, these advices are rarely adopted.
United Nation Environment Program	**Established.** UNEP resorts to international expertise to provide knowledge transfer on WH. The Wadi El Ku Program developed several WH technologies and piloted community-led water infrastructure management based on IWRM principles.	**Emerging**. UNEP programs typically advocates and support participatory water infrastructure management, specially WH in rural Sudan. These programs provide strong training and capacity building component focused on O&M However, the sustainability, continuity and effectiveness of these training and participatory management committee remain uncertain.	**Established**. UNEP led introduction of several concepts, frameworks and technologies innovative to the local context.
International NGO: Practical Action	**Emerging.** PA built a strong track record in developing successful WH in Darfur region and Kassala state. PA depends on a combination of local in-house expertise and external consulting firms to provide infrastructure design services.	**Latent.** PA conduct regular training on O&M for water sources operators. However, protocols for WH technologies O&M are rather limited and required updating.	**Established.** PA introduced several WH technologies in North Darfur and Kassala state. PA emphasis on documenting sharing lessons learned from innovative WH construction led to the adoption of several new technologies by local stakeholders.

International NGO: ZOA International	**Emerging.** in south and north Darfur, ZOA constructed several WH technologies following strict engineering principles. In Algadairf, ZOA has a strong experience in Hafeer construction and rehabilitation. However, Hafirs usually follow standard designs with limited flexibility to adjust to local conditions, such as canal hydraulics or sediment load.	**Latent.** O&M protocols are weak, with limited systematic application or updating.	**Established.** ZOA introduced dozen of innovative WH technologies for different uses e.g., domestic drinking water, groundwater recharge, grazing, flood management. Several of their introduced technologies were copied and replicated by local stakeholders specially in south Darfur (check and sand dams) and Algadairf (deep chiselling)
National NGO: SOS Sahel	**Established.** SOS has a well-trained construction team specialized sand dam, subsurface dams and check dams construction. The organization also poses in-house capacity with good understanding engineering and socio-dynamic aspects of WH technologies design.	**Emerging.** unlike typical WH technologies constructed by humanitarian field actors, SOS tends to aim to design structures with low operation and maintenance requirement. Reducing the influence of human operation usually improve the lifetime of these technologies.	**Established.** SOS pioneered the introduction of several new water harvesting technologies in west, south, north Kordofan. Norh Darfur and Red Sea state.
MI Ibnaouf Contracting	**Emerging.** local contractors often seek designs approval from local ministry of infrastructure. MI contracting, as a sample of local contractors, often finds difficult to suggest changes in the infrastructure scope or alter design. WH designs are often standardized, with limited use of formal engineering references or manuals for design development.	**Emerging.** construction contractors are rarely hired for operation and maintenance. However, in some state, Blue Nile state, private sector contractors were hired to operate Hafirs on one-year contracts awarded through public tenders. This model provided a financial incentive to ensure continuously operation Hafirs.	
Practical Engineering Consulting	**Established**. PE has designed numerous WH structure for government, NGO and private sector. PE designs often demonstrate a robust engineering methods and approaches.	**Emerging**. PE recommendation for O&M of WH are rather limited. The suggested protocols often involve the presence highly skilled operators which is hardly achieved in rural Sudan	**Latent**. PE rarely introduces innovative WH technologies, likely due to client preferences, data scarcity, and limited market demand.

3.2. Findings from the KII:

3.2.1. Manuals and Guidelines – Gaps and Opportunities

Interviewees consistently emphasized a severe lack of up-to-date, context-specific manuals to guide the planning, implementation, and operation of water harvesting technologies in Sudan. Beyond outdated and simplistic hafir manuals, little written guidance is accessible or reliable, and what exists is typically fragmented across institutions or based on personal experience. In the absence of a national standard, implementers often rely on international guidelines (e.g., FEMA, ICOLD), which fail to account for Sudan's unique socio-environmental contexts. These include highly diverse soil structures ranging from clayey plains to sandy wadis, erratic and regionally varied rainfall patterns(50-1000+mm), and socio-cultural norms shaping land use and water governance. For example, what works in Western Sudan may not be suitable for the Red Sea region due to terrain and community differences.
Implementers must navigate hydrology, geology, ownership systems, gender roles, and traditional practices. These complex layers underscore the need for guidance that is both technically grounded and socially attuned, yet such materials are rarely available or used.
Efforts to produce local manuals have repeatedly faltered due to funding shortages and conflict. For example, the *Khartoum Water Research Center* began drafting a comprehensive manual in 2015, but the work was abandoned. Similarly, the Dam Surveillance Unit's attempt to produce dam safety guidelines stalled following institutional instability (due to the war).
The consequences are visible: design flaws (particularly around spillways), poor siting, and a lack of documentation all hinder long-term sustainability. Many interviewees stressed that instead of a single national manual, Sudan needs adaptable frameworks tailored to different contexts, tools that match techniques to local hydrology, geology, and governance. Shallow wells may be suited for the East; check dams for the Red Sea Hills; roof catchments for arid zones. Manuals should advise when and how to adapt, not prescribe rigid templates.

My assessment, based on the interviews, is that the focus should shift from manual production to the mobilization of existing know-how. Lessons from past pilots, academic research, and field implementation are underutilized. Given Sudan's ecological and socio-cultural diversity, even a large set of adapted manuals would still require further local adjustment. Therefore, rather than aiming for comprehensive documentation, a more effective approach would be to provide guidance ranges: which techniques are suitable under which conditions. International manuals, such as the Rain manual, *Water Harvesting: Guidelines to Good Practice*, and *Smart Water Harvesting Solutions*, offer a starting point, but must be reinterpreted through Sudanese experience.

Instead of manual generation it is more crucial to collect, curate, and distribute local knowledge. Interviewees highlighted that much experiential insight, held by practitioners, engineers, and communities, remains undocumented. If curated and shared through a centralized mechanism, it could offer powerful support for implementers. This support must include not just documents but also advisory services, access to environmental data, and platforms for peer learning.
Sudan's diversity makes universally applicable manuals unrealistic Manuals can only guide local adaptation, which depends heavily on the implementer's technical judgment. Therefore, these tools must be framed as flexible supports, not prescriptive solutions. Practitioners need both the tools and the support to make informed decisions on-site. This means pairing guidance with institutional and technical support: from training and advisory services to peer exchange.

Pilots are key to this approach. When implemented with care and documentation, they become living manuals. If well-supported, these can be replicated in similar and nearby contexts, building local

ownership and technical familiarity. But such replication requires more than pilot success. It needs follow-up, capacity-building, and documentation, forms of structured support that many interviewees say are currently lacking.
As further detailed in chapter 3.2.5, a centralized knowledge platform can help anchor this adaptive model. It would consolidate technical references, implementation experiences, and local adaptations, enabling Sudan's implementers to learn from one another and strengthen water harvesting practices in context-sensitive ways.

3.2.2. Capacity and Knowledge Transfer

Sudan's water harvesting sector suffers from a significant erosion of institutional and technical capacity. While some federal institutions retain experienced staff, especially within legacy departments and universities, this expertise is not distributed across states or to local actors. Since the outbreak of conflict, many professionals have left, and institutional memory is breaking down. This has led to a critical disconnect in the design-supervision-operation chain. Local contractors often lack the training to interpret or adapt designs. Government or NGO staff may be tasked with maintenance or inspection without any background in how to operate structures, resulting in improper handling and early degradation.

Interviewees consistently described how training efforts are fragmented and short-term. Institutions like Khartoum University and Practical Action have delivered trainings in Darfur, Kordofan, and Kassala, but these are rarely part of a sustained strategy. Training materials are often lost or forgotten. The ongoing war has only worsened these trends.

Importantly, capacity-building must be embedded in practice. Interviewees emphasized that field-based learning is more effective than classroom training. Practical demonstration sites serve as training hubs where local implementers, engineers, and community members can learn by doing. Follow-up via mobile messages, videos, and mentoring was also recommended.
Community-level training is equally critical. Many structures are operated by local users, not professionals. Interviewees recommended training two or three individuals per site, often young people or respected figures, who can take responsibility and pass on knowledge. This grassroots approach is scalable, builds ownership, and ensures continuity despite institutional gaps.

3.2.3. Maintenance, Sustainability, and the Post-War Imperative

An estimated 80% of water infrastructure in Sudan may be non-functional in a potential post-war situation. As such, stakeholders emphasized that restoring and maintaining existing structures must be prioritized before heavily investing in new ones. This approach is not only more cost-effective but also essential for rebuilding trust in public and aid institutions.
Beyond damage directly caused by the conflict, many structural failures stem from a mix of poor siting, inadequate design, and, most critically, a lack of regular maintenance and oversight. One of the most acute challenges is the shortage of skilled personnel and trained operators. Individuals tasked with managing infrastructure, whether from local government offices, NGOs, or the community, often have no formal training in operation or upkeep. As a result, structures fall into disrepair from mismanagement, unnoticed issues like siltation, or poorly timed interventions.
Interviewees repeatedly emphasized the absence of clearly defined maintenance responsibilities. In many cases, it is unclear whether maintenance falls under national authorities, state agencies, local governments, or the community. Even when nominally assigned, these roles are rarely accompanied by adequate training, tools, or budgets. The lack of as-built documentation and long-term operational plans further complicates the situation, making it difficult to track design standards or plan maintenance schedules.

Political instability has only deepened these structural weaknesses. Ministries and implementing agencies frequently undergo leadership changes, mandate shifts, and funding disruptions. Promising units and initiatives are often merged, downsized, or dissolved entirely, resulting in a lack of continuity and institutional memory.
Contractors present another constraint: while small-scale structures like haffirs or basic boreholes can be built with local expertise, there is limited private sector capacity for more complex or innovative solutions. State-level experience with underground storage and newer technologies remains limited.
Addressing these challenges requires a renewed focus on capacity-building and institutional clarity. Skilled maintenance personnel must be trained and retained, especially at the state and locality levels. Clear operational roles need to be defined and accompanied by budget allocations and performance monitoring. At the same time, governance systems must be stabilized and insulated—where possible—from political disruptions that undermine long-term planning.
Without these structural reforms, even the most technically sound interventions risk falling into disrepair. Maintenance is not just a technical requirement—it is a systemic issue that must be addressed through planning, training, and institutional commitment.

3.2.4. Local Adaptation, Participation, and Ownership

While technical soundness is important, the sustainability of water harvesting projects in Sudan hinges on local engagement. Interviewees consistently stressed that when communities are not involved in planning, implementation, or operation, infrastructure tends to fail—either from neglect, misuse, or rejection.
Participation strategies must be highly context-specific. In some regions, traditional norms restrict women's involvement; in others, community-based governance systems already exist and can be built upon. Power dynamics also vary significantly: in Gadarif, where farmers typically hold authority, approaches must differ from Kordofan or Kassala, where pastoralist groups are dominant. As one interviewee put it, "a hafir in Kordofan is not the same as a hafir in Gadarif", not because of the design, but because of who uses it, who manages it, and who benefits.
Ownership plays a foundational role in whether infrastructure is sustained over time. In many communities, water sources like hafirs generate income, through access fees or livestock use—but those funds are rarely reinvested in maintenance. Instead, they are redirected to other community priorities, such as schools or events, partly due to a lack of financial planning, and partly due to mistrust in government systems. Formal ownership remains with the state, while communities operate informally, resulting in unclear responsibilities and little long-term commitment.
Building true ownership takes time. Structured community mobilization—spanning six to nine months, is often needed before infrastructure development begins. This process should bring together diverse groups across ethnicity, livelihood, and geography, and must be guided by facilitators who understand both technical and social dynamics. As interviewees stressed, it is not enough to present designs; the real work lies in understanding what the community values, how water is governed, and what trade-offs are acceptable.
Many practitioners noted that while Sudan has technically capable engineers, few possess the facilitation skills necessary to lead community engagement. The combination of technical and social capacity remains rare, and urgently needed.
Pilot projects can play a pivotal role in building this bridge. When implemented through a participatory process, even small pilots can demonstrate feasibility, create trust, and encourage replication. However, replication must also be adapted: what works in one community may not apply in another unless governance and use patterns are taken into account.
Failures often stem not from poor design, but from lack of awareness. When users don't see the relevance of infrastructure, or don't feel ownership over it, they are less likely to maintain it. Moreover, many users lack the technical skills to identify early warning signs—such as sedimentation or damage, and don't know when or how to intervene. Building awareness must therefore go hand-in-hand with practical, site-level training.

Ultimately, sustainable water harvesting is not just about hydrology and engineering, it is about relationships, trust, and the ability of communities to shape and sustain solutions that work for them.

3.2.5. The Case for a Revitalized Knowledge Platform

A major barrier to scaling water harvesting in Sudan is the lack of structured, accessible knowledge exchange. Interviewees across all sectors stressed the need for a centralized, user-friendly platform that consolidates technical manuals, pilot experiences, environmental data, and contextual insights. Such a platform would serve multiple purposes. It could reduce duplication in planning and research—many stakeholders cited cases where the same kinds of assessments were repeated in different regions simply because previous results weren't available or accessible. It would also enable learning from both successful and failed implementations, ensuring that hard-won lessons are not lost but used to guide future work.

However, interviewees emphasized that platforms and tools must be understood as support mechanisms, not prescriptive solutions. The *Water Harvesting Explorer* (currently not available for Sudan) is a good example of such a tool: it offers a useful starting point by mapping the technical and environmental suitability of various water harvesting techniques based on remote data. Yet while this information is valuable, it must be further refined through local engagement. Geophysical suitability alone does not determine project success, social, political, and cultural factors are just as important. Platforms like the Water harvesting Explorer are best used to frame and inform participatory discussions, helping stakeholders understand the range of viable options. They should guide exploration, not dictate implementation.

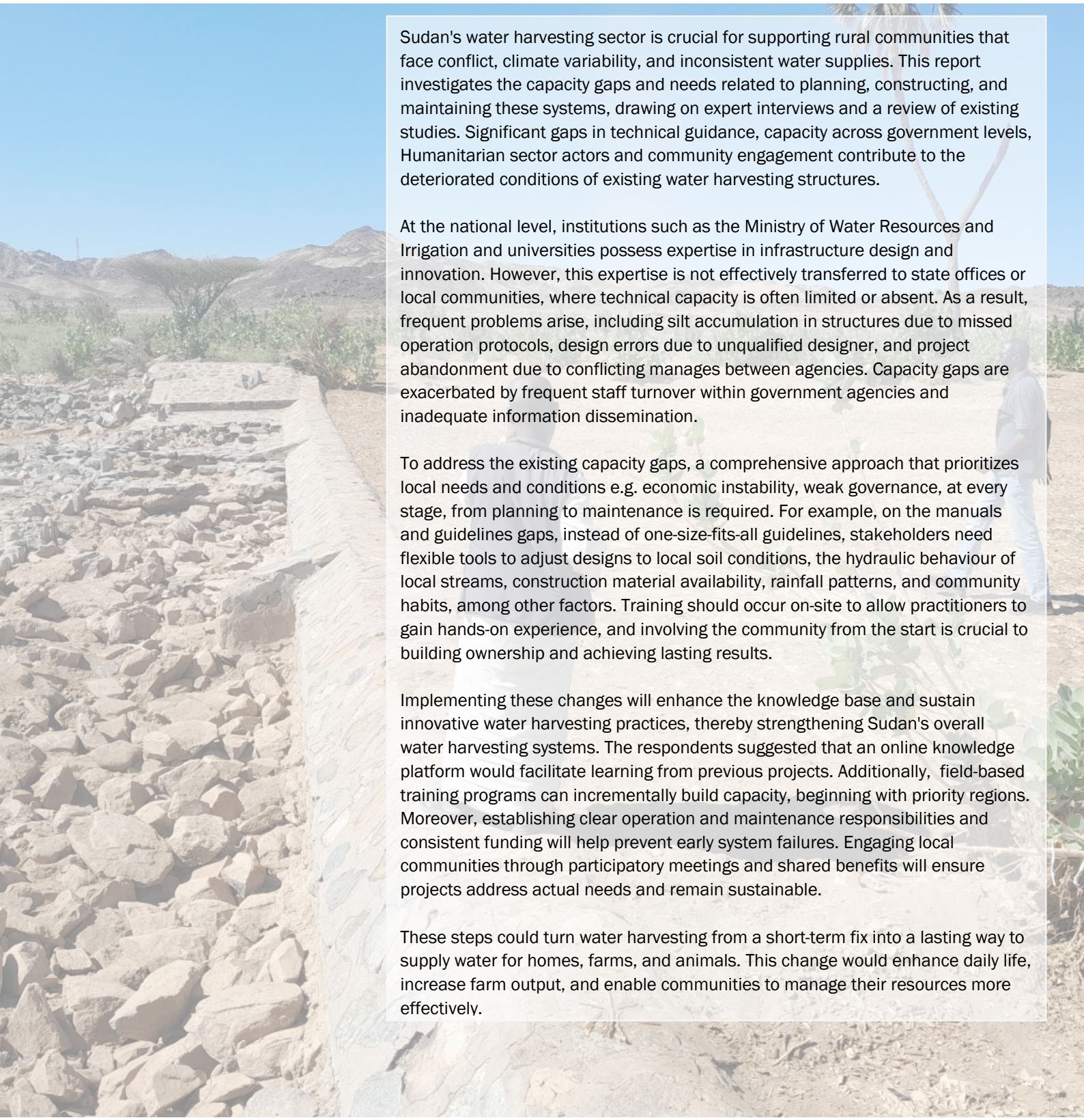
To be truly effective, the platform must go beyond traditional documentation. It should include not only formal guidelines and engineering designs, but also practical insights from implementation: how sedimentation was managed in a specific location, how a community responded to a fee system, or how a participatory process helped resolve land-use conflicts. This kind of experiential knowledge is often stored informally in institutional memory or personal expertise and is especially at risk of being lost in the current context of political and institutional instability.

Interviewees also highlighted regional disparities in knowledge-sharing. In Kassala, there is an established IWRM platform that facilitates exchange among technicians and institutions. In contrast, in Gadarif, such systems are lacking. Although some actors share findings with government staff or technicians on an ad-hoc basis, there is no coordinated approach. A national platform could help address these gaps by linking existing efforts, promoting peer learning across states, and embedding a culture of documentation and exchange.

To succeed, the platform must be hosted by a credible national institution with connections to universities, ministries, and NGOs. It must be mobile-friendly, regularly updated, and designed for real-world usability. Content should be multilingual and varied in format—from PDF manuals and GIS maps to instructional videos and moderated discussion forums. Platforms must also reflect different user types: from federal planners to local engineers and community members.

Crucially, sustainability must be built into its design. This means embedding it within institutional mandates, securing funding beyond short-term donor cycles, and ensuring it is co-owned by its users. Sudan already holds a wealth of knowledge, technical, practical, and social. What is missing is the infrastructure to bring that knowledge together, adapt it, and make it available to those who need it most.

4. Conclusion



Sudan's water harvesting sector is crucial for supporting rural communities that face conflict, climate variability, and inconsistent water supplies. This report investigates the capacity gaps and needs related to planning, constructing, and maintaining these systems, drawing on expert interviews and a review of existing studies. Significant gaps in technical guidance, capacity across government levels, Humanitarian sector actors and community engagement contribute to the deteriorated conditions of existing water harvesting structures.

At the national level, institutions such as the Ministry of Water Resources and Irrigation and universities possess expertise in infrastructure design and innovation. However, this expertise is not effectively transferred to state offices or local communities, where technical capacity is often limited or absent. As a result, frequent problems arise, including silt accumulation in structures due to missed operation protocols, design errors due to unqualified designer, and project abandonment due to conflicting manages between agencies. Capacity gaps are exacerbated by frequent staff turnover within government agencies and inadequate information dissemination.

To address the existing capacity gaps, a comprehensive approach that prioritizes local needs and conditions e.g. economic instability, weak governance, at every stage, from planning to maintenance is required. For example, on the manuals and guidelines gaps, instead of one-size-fits-all guidelines, stakeholders need flexible tools to adjust designs to local soil conditions, the hydraulic behaviour of local streams, construction material availability, rainfall patterns, and community habits, among other factors. Training should occur on-site to allow practitioners to gain hands-on experience, and involving the community from the start is crucial to building ownership and achieving lasting results.

Implementing these changes will enhance the knowledge base and sustain innovative water harvesting practices, thereby strengthening Sudan's overall water harvesting systems. The respondents suggested that an online knowledge platform would facilitate learning from previous projects. Additionally, field-based training programs can incrementally build capacity, beginning with priority regions. Moreover, establishing clear operation and maintenance responsibilities and consistent funding will help prevent early system failures. Engaging local communities through participatory meetings and shared benefits will ensure projects address actual needs and remain sustainable.

These steps could turn water harvesting from a short-term fix into a lasting way to supply water for homes, farms, and animals. This change would enhance daily life, increase farm output, and enable communities to manage their resources more effectively.

5. Recommendations

Major gaps in skills and capacity in organization working in water harvesting at both state and community levels, were identified. To address this, a practical and flexible approach that builds up local organizations and community participation. Challenges like climate change, conflict, and limited funding highlight the need to focus on simple, affordable tools and make use of local knowledge from, federal government agencies, universities and NGOs. The following set of actions are recommended to sustainably build Knowledge and capacity across WH organizations and practitioners:

Strengthen Knowledge Sharing for Adaptive Decision-Making

1. A shared digital platform can help spread practical knowledge. It should work well on mobile phones even in areas with limited internet access and offer tools that fit each region, like checklists for matching water structures to local soils and rainfall. The platform can let users share field notes, to allow for cumulative knowledge sharing despite staff turnover. This makes information easier to find, avoids repeating work, and helps practitioner in remote areas to tailored infrastructure to their needs autonomously .

2. Create simple toolkits with clear steps for choosing sites and making design changes. These guides should cover different conditions, like sandy or clay soils, and include plans for emergencies such as damaged spillways. They should also suggest low-cost solutions, like using local materials. Sharing these toolkits through NGOs and state workshops will help local engineers learn from federal experts and use this knowledge in their work.

Boost Hands-On Skills for Frontline Resilience

3. Offer hands-on training at project sites with short, focused sessions for state engineers, NGO staff, and community caretakers. Cover basics like hydrology, how to maintain subsurface dams, and how to spot silt build-up early. Working with agencies e.g. the Dam Safety Unit can provide real-world mentoring for quick responses to repetitive operational problems. Training local community, especially youth and trusted community members, will help sustain knowledge in the community regardless of government support.

4. Set up an accreditation program for local contractors and consulting firms. The program should focus on practical, low-cost methods, like the plastic bag subsurface dams, deep chiselling. This will build private sector skills, create local jobs, and make oversight clearer by setting out who does what.

5. Support the federal ministry and the state level agencies e.g. SWC, GWWD, to update specific manuals for the development of different water harvesting technologies. The manuals should take reference from the latest technologies advances ant the lesson learned from neighbouring countries active in water harvesting. The manuals should also make use of successful stories from locally adopted technologies specially through Zero thirst program, Wado Elku program and Aqu4Sudan program.

Focusing on practical and collaborative tools can help Sudan bring together scattered expertise into one system. This approach will make water harvesting projects stronger against climate shocks, help recovery after conflict, make governance clearer, and keep infrastructure running well within available resources.