Technology choices in Water Supply and Sanitation:

Report on collaborative research, learning and networking between Ethiopia, Sudan and Kenya

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Acronyms

CPC	Community Project Cycle (Kenya)
DAP	Development Activity Programme (Ethiopia)
DWC	Drinking Water Corporation (Sudan)
EU	European Union
HCS	Hararghe Catholic Services (Ethiopia)
IDP	Internally Displaced Person
IHP	International Hydrology Programme (UNESCO)
ISWM	Integrated Sustainable Waste Management
MDG	Millennium Development Goal
NGO	Non-governmental Organisation
ODI	Overseas Development Institute
PAC	Practical Action Consulting
PSNP	Productive Safety Net Programme (Ethiopia)
RiPPLE	Research-inspired Policy and Practice Learning in Ethiopia and the Nile Region
RWC	Rural Water Corporation (Sudan)
Sida	Swedish Agency for International Development Cooperation
UNESCO	UN Educational, Scientific and Cultural Organization
UNICEF	UN Children's Fund
UWC	Urban Water Corporation (Sudan)
WESS	Water and Environmental Sanitation Services (Sudan)
WFP	World Food Programme
WIC	Water Irrigation Committee (Ethiopia)
WMC	Water Management Committee
WSB	Water Services Board (Kenya)
WSP	Water Service Provider (Kenya)
WSRB	Water Services Regulatory Board (Kenya)
WSS	Water Supply and Sanitation

Executive Summary

For practitioners, technological choice plays a huge role in designing water supply and sanitation (WSS) systems. Often considered in isolation, this study looks at factors that surround technological choice. This is by no means an exhaustive list of factors, but rather an attempt to start looking more closely at what factors should be considered when making technological choices, and how.

This report presents the key findings of a study undertaken by Research-inspired Policy and Practice Learning in Ethiopia and the Nile Region (RiPPLE) and Practical Action Consulting (PAC) in Ethiopia and Sudan in 2008. A sector review from Kenya was also carried out and included in the analysis.

The main purpose of this work is fivefold: to identify, document and compare factors affecting choice of WSS technologies in Ethiopia and Kenya through collaborative research; understand the links between the process of technology choice and its wider context related to participation, planning, governance and demand; to identify and establish potential for research and communication among practitioners; to develop capacity and establish channels of communication for strengthening the Nile region RiPPLE network; and propose further actions in collaborative research and communication. This study presents key findings with a view to sharing and learning from these experiences.

The methodology and fieldwork were developed by the research team, made up of members from organisations across the countries. As such, findings are both comparative and narrative-based. Based on 11 study sites, findings highlighted lessons to be learned in planning, participation, land rights, sustainability, accessibility, financing, growth and productivity, risk and vulnerability and sanitation.

Across the board, sustainability needs to be strengthened in planning processes by considering all of the above factors. Land rights issues are prominent in Ethiopia, where land is scarce, whereas maintenance and management were greater challenges in Darfur, Sudan, where the conflict has had serious damaging impacts on systems. Clear agreements on use of land and water have often been used to resolve conflict over access to water points. Feeding natural resource management into the planning stages can help maintain water levels, increasing the amount of water available. Community-based management seems to be a popular solution but, with more complex systems, such as motorised boreholes, it is more difficult for rural communities to perform maintenance, particularly in the case of breakdowns. More complex systems, often seen as the only viable solution, tend to require more long-term and often external technical and managerial support. Overall, there is strong evidence for the need for context-specific management solutions. Fee recovery schemes vary in their success, but most of the sites visited failed to demonstrate an understanding of how to reinvest in improving their water systems.

In conclusion, technology choices are often made by engineers, based on a number of considerations, including technical, environmental, policy and financial variables. The key factors identified above tend to affect the sustainability of the system, rather than technology choice. Sustainability, which is affected by all the identified factors, needs to be better considered throughout the project cycle. Finally, management of technologies and the natural resources around them is often the largest determining factor in the longevity and benefits of a service. Carrying out collaborative research and sharing and exchanging ideas and perspectives represent a unique opportunity for learning.

1. Introduction

This research report presents the key findings of a study undertaken by the Research-inspired Policy and Practice Learning in Ethiopia and the Nile Region programme (RiPPLE) and Practical Action Consulting (PAC) in Ethiopia and Sudan in 2008. The study was a joint research, lesson learning and networking exercise, with fieldwork carried out by researchers and practitioners in Ethiopia and Sudan. A sector review from Kenya is also included. The main purpose of this research is fivefold:

1. To identify, document and compare factors affecting choice of water supply and sanitation (WSS) technologies in Ethiopia and Kenya through collaborative research.
2. To understand the links between the process of technology choice and its wider context related to, for example, income and employment of poor people, local economic growth and management at local level.
3. To identify and establish potential for research and communication in WSS at different levels, from community groups to district/regional governments, between two countries, with a view to linking with other organisations in the region, especially in Sudan, Kenya, Uganda and Ethiopia.
4. To develop capacity and establish channels of communication in shared research and learning as a basis for strengthening the Nile region RiPPLE network and to identify avenues to further strengthen the network on this subject area.
5. To propose further actions in collaborative research, networking and communication in the region and to create links with other projects being undertaken by PAC and its partners.

The report was facilitated by PAC in Sudan and Kenya, along with the RiPPLE office Ethiopia and the Overseas Development Institute (ODI) in the UK. The field visit was initially planned for Kenya, but this was shifted to Sudan because of Kenya's post-election violence. PAC identified researchers and case study sites in urban/peri-urban areas in Sudan; in Ethiopia, this was done by Harar Catholic Services (HCS). Both of these organisations are partners in the RiPPLE research programme. Before the visits, a methodology was prepared and a work plan was discussed in each of the countries. It was agreed that the research would explore the following as guiding questions:

- How are technology choices made, at which stage in implementation and by whom?
- To what extent is demand factored into choice of technology, if at all, and how far is consideration given to possible management by communities?
- How far does choice of technology reflect issues of sustainability, cost benefit and cultural and other factors?
- What does the process of technology choice tell us about links between service delivery and wider sets of social and economic considerations, including income, employment, gender, disability and productive uses?
- Where does the real scope to influence technology choice exist to achieve greater benefits for the poor?
- What is the potential for networking and researcher collaboration on WSS technologies?

RiPPLE partners in Ethiopia and Sudan formed a joint research team to develop and examine these questions, to establish an operational research methodology and to agree the working concepts and context of analysis. Experienced local PAC technical staff from Kenya conducted a review on Kenya and provided a detailed description of two cases in particular. Team selection was carried out by PAC and RiPPLE management. The team comprised up to four people from local partner organisations, two representing RiPPLE staff and two representing PAC. After the visit, each team produced site descriptions, providing background information and key processes in the selection and management of technologies. The key findings in this report are based on these site description reports.

The overall aim of the research was to develop more understanding on technology choices and opportunities for research collaboration and networking. It is important to note that the word 'technology' may have wider meaning. In this research, we started with the meaning of physical infrastructure provided or improved for WSS at the household, street or area level. However, during the research process, the teams preferred to use a wider definition, incorporating planning, design, management, operation and maintenance, as processes necessary to choosing and providing technologies. It was agreed that a definition of technology includes physical infrastructure, machinery and equipment, knowledge and skills and the capacity to organise, operate and maintain all of these.

This report also presents the methodology, as developed before the visits, and reflections on how far this was used. This is then followed by short summaries of the sites visited. Detailed site descriptions are included in the annexes. The main part of the research is the section on key findings, which includes our analysis. The report also includes some conclusions and some thoughts on the way forward from here.

Snapshots from the field study. Upper row: Ethiopia. Lower row: Sudan

2. Common practice in technology choice

Traditionally, development agencies and specialists would develop or import technologies as physical infrastructure, tools and machines from other parts of the world and apply them to the local situation, with very little, if any, modification to meet local needs and circumstances. This resulted in a number of failures as, after the initial excitement, technologies were soon abandoned. Learning from these failures, the emerging trend was to maximise participation and accept trial and error as an essential part of the process.

At the same time, there was greater recognition that hardware technology was only part of the solution, and that it had to work well in the wider physical, social and economic context. This shifted the focus of attention to more area-wide approaches and to promoting partnerships between actors. For example, participatory planning with users was considered the key to sustainability, with technology choices then made within the context of participatory appraisal and planning. Processes were developed to identify, profile and map the different actors and relationships existing within the sector. Identification of existing opportunities and barriers to working together were identified at the planning stage.

This change in terms of creating more space for users to participate, choose, own and manage led to greater use of approaches that helped in understanding the community's vision, and using this as the most important factor in the choice of technology. The role of the expert changed to that of facilitator to guide communities to search more deeply for solutions and strategies to achieve their goals.

People's ability to choose the most appropriate technology was further enhanced by the facilitator through the use of photographs and films and, if possible, by arranging exchange visits to places where a technology was actually working. In this way, users become the main decision makers in the choice of technology. Users, especially poor users, were offered more opportunities to participate in choice of technology, to decide on budgets and spending and, if possible, to manage some of the communal services to obtain more control of technology and outcomes, such as sustained income and employment from services.

In this participatory process, decision makers also learn the importance of different factors affecting choice of technology and the inter-linkages between these factors. For example, ability to operate and maintain a particular water supply technology depends on acceptability of regulatory organisations, as well as social and cultural norms. Poor people may be allowed to bypass regulations, as they cannot afford the high costs, although when development is facilitated by an external organisation, it is almost impossible to bypass government regulations and standards.

Regulations and standards are created for various reasons, for example, health, safety and comfort. Recently, a number of regulations have come into being as a result of environmental concerns. This has had important implications in terms of cost and ability of users to understand, own, operate and maintain various technologies.

Certain physical factors, such as distance, housing type and population density, also play an important role in the choice of technology. For example, in high density areas, people may not have enough space to construct a household sanitation system. Certain cultural considerations and beliefs also play a role in the choice of technology. This affects, for example, the use of water and materials for hygienic purposes and demand for water.

When it comes to the construction of physical infrastructure, it is common in many cultures for men to take a leading role in the decision-making process. This sometimes has the result of excluding women and children. As a result, certain technologies do not give full benefit to women and children.

While gender issues vary across cultures, the technology choice process must have clear guidance as to how it can be more gender sensitive. For example, in relation to sanitation, it is women and girl children who actively manage the cleaning of facilities and ensure regular use for the entire family. In addition, it is extremely important to take into consideration the specific needs of women, such as those regarding privacy, squatting position and disposal of sanitary towels, to ensure equitable use in the Nile region.

Similarly, there are special needs for elderly and disabled persons. When access to basic services is in short supply, older and disabled persons are worst affected.

3. Methodology

Before leaving for the site visits, the teams participated in a half-day workshop to understand the programme's perspective, work plan and reporting schedule. This also provided the teams with an opportunity to debate the guiding questions. The following is an edited outcome of some of those discussions.

In the process, the key RiPPLE focus areas and its approach were discussed. Subsequently, the workshop tied the methodology strongly to a project cycle of planning, implementation, operation and maintenance, impact and sustainability, as well as investigating the wider policy context. The team conducted its investigation using the following methods:

1. Project documentation: This was a review of existing documentation held by implementing agencies, such as project plans, evaluation reports and design specifications. The major limitation of relying overtly on project documents was that most documents were incomplete or unavailable. The team recognised the need for proper process documentation of project implementation for learning.
2. Observations (site visits): To supplement project documentation, and to obtain an overview of the physical structure of each site, the team was given a guided tour by representatives from the implementing agencies involved in the project cycle. These were mainly engineers who had worked or who were still working with communities, in conjunction with water management committee (WMC) members. Site visits aimed to allow the teams to understand and crosscheck historical perspectives. Photographs were taken where possible to give visual representations of what were often complex systems.
3. Focus group discussions: These were conducted with community members to give an overview of the level of community participation, management and understanding of the systems in place. Questions followed the project cycle, including planning, implementation, operation and maintenance, impact and sustainability. Sanitation was looked at briefly, but not fully incorporated into the discussions.
4. Key informant interviews: For key informants, questions focused on general policy and, where relevant, site-specific issues. It was decided that, owing to resource limitations, sanitation would be looked at separately and only when possible, making service delivery the main focus of investigation. Key informants were either government officials or implementing organisation representatives. Their role was to provide information on the bigger picture in terms of higher-level policy and approaches to project implementation.

Each team member was expected to draw up a summary of daily activities, from which site briefings would be drawn, supplemented by information extracted from project documentation. Owing to time constraints, the study was to be heavily narrative, as a precursor to further investigation.

Annex 1 contains methodology documents, including the full checklist for focus group discussions and key informant semi-structured interviews and the daily reporting templates.

4. Country and site contexts

4.1. Introduction to countries

1: Kersa and Meta woreda, East Hararghe zone, Oromia region, Ethiopia

2: Al-Fasher, North Darfur region, Darfur state, Sudan

3: Nairobi region, Kenya

Figure 4.1: Map of three countries and focus areas of studies

Before we present and discuss the key findings, it is important to understand the context of the three countries covered in this study, namely, Ethiopia, Sudan and Kenya. Located in East Africa, and being among the 10 Nile riparian countries, these three countries enable interesting comparisons in terms of geography, culture and government institutional structure in water interventions. Within each country, sites were chosen based on locations of partner organisations. In Ethiopia, these were regions where RiPPLE and HCS offices were based. In Sudan and Kenya, site locations were selected in areas where PAC was working. Figure 4.1 below shows the geographical location of the regions of the selected sites across the three countries.

4.2. Brief sector context in each country

4.2.1. Ethiopia

In Ethiopia, there is a standard procedure for project planning and implementation, based on Ethiopian government policy related to non-governmental organisation (NGO) work. The procedure relates to communities seeking assistance from local government or NGOs and/or local government providing assistance to prioritised communities. For a more detailed description of the Ethiopian governance and planning context, refer to Annex 2.

In the context of Ethiopia's federal system, the country is divided into nine regional states and two administrative towns, namely Dire Dawa Administrative Council and Addis Ababa Administrative Region. The sites visited are located in Oromia region, shown in Figure 4.1. At regional level, there are four levels of decentralised administration. Starting from the lowest tier, these are: kebele, woreda, zonal and regional. Put differently, regional states are subdivided into zones, which are then subdivided into woredas; woredas, are, in turn, subdivided into kebeles. With reference to kebeles, it is important to distinguish between peasant associations and urban dwellers' associations: the former refers to rural kebeles whereas the latter refers to urban kebeles. In combination, the kebeles are the administrative units that constitute the woreda.

There are government water offices at the woreda, zonal, regional and national level. Any intervention by NGOs needs approval from the regional, zonal and woreda levels. However, prior to any NGO intervention at regional, zonal and woreda level, it is mandatory for NGOs to register with the federal Ministry of Justice. In an attempt to harmonise donor interventions at regional and woreda levels, each NGO is assigned a geographic area in which it can operate.

The water sites visited by this study are in Kersa and Meta woreda, which lie in East Hararghe zone of Oromia regional state. These woredas were selected because they lie within the operating scope of HCS. Boxes 4.1, 4.2, 4.3, 4.4 and 4.5 provide brief descriptions of the selected sites.

Box 4.1: Kenchera – Lift and drip irrigation technology promotion

Kenchera is one of 12 villages in Lede-oda Mirrga Peasant Association of Dire Dawa Administrative Council. The village has 73 households, each household with an average family size of five members, whose livelihoods depend mainly on rain-fed mixed farming. The research looked at the drip irrigation being tested by farmers.

The water for irrigation comes from a hand-dug well, which has been reinforced to prevent collapse. This water is then pumped into a storage tank and distributed using various types of irrigation; furrow irrigation and three types of drip irrigation (pipe, tin and plastic bottle). This is the second intervention by HCS in the community. HCS is working in collaboration with Alumiya University, which conducts research on developing and improving drip irrigation technologies within the community.

The testing, carried out in full partnership with farmers, has shown the advantages and disadvantages of the different techniques. The farmers reflect on their preferred methods by describing the technologies and then listing their pros and cons. Furrow irrigation is simple but uses a large quantity of water, and leads to weed growth and soil compaction and cracking. The 'improved' drip irrigation saves water, is easy to manage and does not lead to problems with soil cracking, but evapo-transpiration is high. Traditional drip irrigation, which consists of plastic bottles buried near the root zones of plants, is also an efficient way to use water, but is harder to manage, as the bottles have to be opened and closed and refilled on a regular basis. A variant on the above, using 5 litre tins, was considered an improvement. A replication of the tin drip irrigation is being attempted on a nearby farm with an associated dug well (un-reinforced). However, the shortage of 5 litre tins has been cited as a potential limitation.

Some people here get drinking water from hand pumps or...

Well and pump that feeds tank

Regardless of the merits of the technological innovations, issues relating to land rights were identified as being of crucial importance in this area. There had previously been problems with land rights and access to land to the extent that, in the second phase of the project, particular effort had to be made to resolve these. This was achieved by putting in place a legal binding tenancy agreement between the landowner and farmers.

From hand-dug wells which are unprotected

Tank that feeds irrigation for farms

Different types of drip technology being tested out by farmers: Plastic bottles, Tin cans and 'improved' irrigation

Box 4.2: Goro Beyo – Spring-fed gravity system

Goro Beyo is a peasant association located in East Hararghe zone of Meta woreda, southwest of Dire Dawa town. Goro Beyo has a spring-fed gravity system, whereby water from the spring is channelled into a reservoir, where it is first stored and then distributed to four water points plus an irrigation pond. Prior to project implementation, the community used unprotected springs and ponds and experienced many problems with waterborne disease.

Overall, the system is managed by the community on the basis of traditional management practices embedded in modern water management structures, as suggested by implementing agents. This aims at improving transparency and accountability in the management of the spring-fed gravity water supply system.

Some of the advantages of the gravity-fed systems are that they are traditionally of low cost to run, and that they are generally better managed, maintained and operated, with a fixed tariff per household.

The system has benefited from sufficient availability of water to fill an irrigation pond, to allow for a multiuse system. Although the system has been highly useful in terms of an increase in productivity for irrigation beneficiaries, it has not had the same direct impact on non-irrigation beneficiaries. The system has also reached full capacity, with increased demand from outlying areas, and there is some interest and understanding on the part of the community with regard to expanding the system.

Again, land rights issues were identified as key, with access to a cattle trough denied by the owner of the land, as the land was being degraded by people accessing the water point. This issue was still under discussion at the time of writing.

Left: Gorobeyo is fed by a capped spring supply that helps increase the discharge of a spring

Water from the spring feeds two storage facilities. The storage pond (left) feeds irrigation channels and the storage tank (right) feeds the pump for drinking water, laundry and cattle troughs.

From left to right:
Distribution junctions are used to control where the water goes to farms, by appointed distribution managers.
Water runs freely from taps, as distribution points are not well-maintained.
A land issue with the local farmer, restricts access for villagers to the constructeed laundry facilities and cattle trough.

Box 4.3: Welteha Bilisuma – Motorised water supply

The project at Welteha Bilisuma pumps groundwater from a 66m borehole with a submersible pump and delivers it to a reservoir, from where it is gravity fed to distribution points. The scheme serves 800 households. The community was involved in the building work, such as constructing a road for vehicles (over 500 individuals). Researchers saw this as very positive, as the sense of community ownership was felt to be very important. The WMC is made up of community members (as standard practice); the two water caretakers and the two pipeline caretakers are also community members. Fee collectors are elected (all women). The management system reportedly works very well.

The community has seen an improvement in the health of humans and animals owing to a lower incidence of waterborne disease. In addition, the borehole has meant reduced time and effort among women and children in fetching water. There are plans to buy another motor with the revenue generated by the water points. This may be used to expand the system, or to replace the current one in case of failure.

Negative points identified were low level of bookkeeping skills within the WMC and a lack of focus on sanitation. Motorised systems require fuel and recent fuel price increases have led to increases in fees charged. This has had an effect on community water usage.

System is a motoried pump which feeds storage tanks, with distribution points that are fed by gravity. The functioning distribution points are the taps where water is collected for domestic use.

Women and children queue for water, which is charged per litre, For every container, the fee-collector collects money, which is then reconciled with the meter readings.

Problems with the system: When families cannot afford the water, particularly with rising fuel prices, they resort to original, unprotected water sources.
Shower facilities are in the middle of the village, and women don't feel as protected, and prefer to bathe at home.
Laundry facilities are blocked because they don not have adequate controls.

Box 4.4: Millennium Village – Gravity-fed system, sanitation interventions

The water system in Olan-Oulla was developed after previous interventions were destroyed by flooding. Before the project was set up, villagers were using water from an unprotected source. In fact, the name of the village means 'leeches', because of the presence of leeches in this water source. Unusually, it was the strongest members of the household (men) who typically had to collect the water, owing to the inaccessibility of the spring, so it is their time which has been freed.

With the reconstruction of the spring-fed system, an integrated programme approach was implemented, including water supply, sanitation promotion, watershed management and irrigation, alongside cross-sector interventions in education and health. The system had been running for about four months at the time of visit, and already impacts were being seen in areas such as sanitation (showers, latrines), with now coverage of pit latrines now reaching 50% of households. Water was also used for livestock, irrigation and house construction (which uses mud). This has the attendant effect of reducing deforestation, mainly because mud substitutes for wood in house construction.

Prior to the system installation, the leeches in the unprotected water caused several health problems.

Alongside WSS interventions, there have been simultaneous interventions in health, education and environment, as Millennium Village is a pilot for testing out cross-sectoral programme interventions. Overall, the heavy investment has had a major impact with regard to lifting people out of poverty.

The obvious question seems to be: Will these benefits be sustained once the heavy financial support is removed?

The capped spring has allowed for increased yield. Terracing in the hills is part of watershed management

The water from the spring, goes via a storage tank to distribution points and cattle troughs. Farmers can now grow produce for sale.

Alongside water and sanitation interventions, the NGO introduced brick making to reduce reliance on wood for buildings, and home management programmes including domestic facilities such as laundry and improved stoves.

Box 4.5: Ifa-Jalela and Kufanzik – Two kebeles sharing one water system

Ifa-Jalela and Kufanzik are two adjacent kebeles that share the same source, through a relay system. The water system originally served Ifa-Jalela, where the borehole is located, and was extended to serve Kufanzik. This owed to the fact that there was no technical alternative to provide Kufanzik with water. The water system also provides a point for laundry and shower facilities. Prior to the implementation of the scheme, residents accessed water from open ponds or an intermittent stream (3km from the settlement) and thus experienced high levels of waterborne disease.

The system has been plagued by technical and managerial problems, with breakages and leakage as well as tension between the two kebeles. This had led to slow filling of the reservoir and an increase in the amount of fuel needed and subsequently cost to the users. However, the community reported improvements in the health of the people and their animals. In addition, communities reported that the new system has led to reduced time expended in water collection.

Management problems were identified as the main reason for the failure of the system, with a recent audit indicating misappropriation of funds. This led to the dissolution of the WMC. At the time of writing, an interim management committee had been established, with further investigation and conflict resolution being taken on by local government. Lack of communication between kebeles and resentment at having to rely on another kebele's water supply were cited by the community as problems. This site highlighted issues surrounding ownership of and rights to water, with both communities perceiving the owner of the land to be the owner of the water.

Left: Due to the mismanagement, most taps have not seen water in months.
Below: The design engineer listens for water filling the tank in Kufanziq for the first time in months.

From Top down: Motorised pump which feeds storage tank, that is dispersed by gravity to pumps in Ifa-Jallela. The pump also feeds a second storage tank on the border with Kufanziq (right).

Villagers have to resort to original unprotected sources for water, because of poor management.

Despite lacking access to water, Kufanziq has 100% latrine coverage, but handwashing remains a challenge.

4.2.2. Sudan

Sudan is the largest country in Africa, with varied cultures and ethnicities. Darfur is one of Sudan's regions, divided into three federal states: West Darfur, South Darfur and North Darfur, which are coordinated by the Transitional Darfur Regional Authority. Owing to the Darfur conflict, the region has been in a state of humanitarian emergency since 2003. Sites visited in Sudan were located in the state of North Darfur.

In Sudan, no clearly stated government policy and operational framework guide work with NGOs in the water and sanitation sector. Most NGO activities are humanitarian in nature, working with refugees and internally displaced persons (IDPs). The Drinking Water Corporation (DWC) is an umbrella body for all water-related government initiatives, covering Water and Environmental Sanitation Services (WESS), the Urban Water Corporation (UWC) and the Rural Water Corporation (RWC). The UN Children's Fund (UNICEF) and the government of Sudan have a five-year masterplan that provides policy guidelines in water, health, education and primary health care. A more detailed description of the Sudanese planning and governance context is included in Annex 3.

The sites visited in North Darfur are located in the region in which PAC Darfur operates. Boxes 4.6, 4.7, 4.8 and 4.9 provide site descriptions for Sudan.

Box 4.6: Azagarfa – Water harvesting dam

The Azagarfa water harvesting project is located 33km north of Al-Fasher, the capital of North Darfur. A dam retains floodwater for the purposes of irrigation, but construction has not been completed owing to the conflict. As such, only five families are able to use the dam system for irrigation.

Other natural ponds are used for fetching water for domestic purposes, livestock and brick production. Boreholes and hand-dug wells for drinking water have been constructed at different times by different agencies.

An attempt to improve a natural pond to increase its capacity resulted in damage to the rainwater streams that fed the original pool. As a result, no water drained into the 'improved pool', rendering it useless.

Generally, management and fee collection of the hand-dug wells are carried out by trained villagers trained (two from each village). Fees collected are spent on maintenance and salaries, with little scope for building up savings. The ponds (hafirs) are not monitored and fees are not charged for use, partially as a result of the conflict. It has been suggested that, with a management system in place, the pond could be rehabilitated and water quality improved.

Alongside the WMC, there is also a 'popular committee', which is made up of members of the community. The role of this group is to present requests/problems from the community to the WMC and to monitor its performance. The existence of this 'popular committee' is seen as important to the success of the project, since it ensures accountability and transparency as well as better integration of village-level development programmes.

The design of the Azagarfa design worked using locally available materials and local skills. However, a combination of silting, the conflict preventing completion and restrictions on maintenance has caused the dam to fail. The nearby hafir provides water to local populations, several thousands of heads of cattle and brick construction.

Box 4.7: Fasher Hafirs – Twin ponds

Fasher Hafirs (ponds) are located 11km east of Al-Fasher town. The twin ponds are used by 60,000 people and their livestock. The main water source for this area is surface water, with groundwater sometimes available, from 11 hand-dug wells (of which eight were operational at the time of writing). Other parts of the Fasher Hafir system include a pump and storage system, which were no longer in use, owing to the conflict.

The community contributed to the construction of the water ponds with labour paid for by the government; the wells were also constructed using local labour, as part of a participatory development process.

In 2008, the community felt the need to re-establish its own WMC to mitigate ongoing damage to the water system. Initial management was taken on by the government. This was thwarted at the start of conflict, at which point access became unregulated. Generally, tariffs and user fee collection are mandatory in any water system in Sudan. The tariff for the use of these ponds is set by the Water Corporation and fees are paid in advance. The new WMC set tariffs based on Water Corporation tariffs, to cover operation and maintenance costs.

Owing to the limited access to groundwater, it is believed that water from the ponds is used for human consumption, with adverse implications for human health. There is therefore an urgent need to set up a system to treat the water. Access to water for domestic use and livestock in such close proximity could address the multiple needs of the community. However, special care would have to be taken to avoid contamination, and the ongoing conflict in the area makes improving any water source a difficult prospect.

Twin hafirs feed the nearby water yard, through wells. There used to be a storage tank, but this has gone into disuse due to the conflict. There is currently no control over access. Disused wells are guarded against people or animal falling in and the water is not treated.

Local NGO works with women groups to create nurseries, but access is thwarted by the conflict.

Comparing technology choices in cattle troughs: metal sheet troughs are easier to move around and carry, in comparison to concrete ones, which are sited.

Box 4.8: Golo dam and Shugra boreholes – Supplying the town of Al-Fasher

The town of Al-Fasher (population 300,000) is served by several water sources, of which two were studied: Golo dam, a surface water dam with three reservoirs, supplies water during the rainy season and the Shugra boreholes, a set of 20 boreholes across two villages, supply water during the dry season. Golo dam has had its capacity reduced by half owing to silting, and this is of concern in an area with a growing population. The government at this stage does not seem to have the capacity or resources to rehabilitate the reservoir.

Planning, design and construction was carried out by the DWC, with the village of Golo created to supply labour for the construction process. The residents of Golo have relatively easy access to the water, but it is untreated, so there is high incidence of waterborne disease.

The government of Sudan signed a declaration in 1990 to supply the villagers in the area with water and electricity in return for the use of the groundwater on their land. However, there seem to be some problems with delivery: pumps bought to install the network are still in storage. Again, at this site, the conflict makes work difficult – any construction projects have to be carried out after negotiation with the rebels controlling the area.

Golo dam (left) and sub-dam (middle) provide most of Al-Fasher's water. Golo's main dam runs dry towards the end of the rainy season, and there is reliance on the sub-dam, as well as the Shugra boreholes. Shugra boreholes feed storage tanks (right) in sShugra, and then the water is pumped to Al-Fasher town, whereas the water from Golo dams is pumped directly to Al-Fasher town and stored there.

Box 4.9: Al-Fasher – Privately owned borehole

This well was dug manually in 1947 for irrigation purposes, and currently has a depth of 47m (deepened from 39m). The owner now uses a motorised pump to access the water, powered by the mains supply or a diesel backup generator. The water is pumped into storage tanks where horse carts are filled by water purchasers. Contamination of water in open tanks has been identified as a potential health hazard.

Fees go towards maintenance (which was problematic in the past owing to limited availability of spare parts), fuel expenses and income for the owner's family. The rate charged for water varies over the year, with the owner able to charge higher prices in the dry season when there is greater demand.

The owner is registered with the local government but refuses to pay any tax, as he feels he is not served by the local government (for example, when he applied for help to maintain the pump he was refused).

The water is pumped up from the well, to a storage tank and then fills water tanks pulled by horses.

4.2.3. Kenya

Kenya comprises eight provinces, each of which is subdivided into districts (wilaya). Districts are then subdivided into divisions (taarafa) and further divided into locations (mtaa) and in turn, sublocations (mtaa mdogo). Nairobi, the capital, is a full administrative province. The government supervises the administration of districts and provinces.

In order to address the problems associated with access to and provision of water and sanitation services in Kenya, the government has embarked on reforms in the water sector under the framework of the Water Act 2002. The Act aims to provide harmonised and streamlined management of water resources and water supply. The Ministry of Water and Irrigation, supported by water service boards (WSBs), is spearheading the implementation process. The reforms also aim to coordinate the various actors involved in the water sector and to ensure that policy formulation, regulation and service delivery roles are clearly delineated, with each role carried out by a separate entity within a coordinated framework. The Ministry of Water and Irrigation is no longer directly involved in management of water services. Its key responsibility is to undertake policy formulation, sector strategy development, research and training, sector coordination, planning and financing. The Water Services Regulatory Board (WSRB) is responsible for the regulation of water and sewerage services, including development and maintenance of quality standards and issuance of licenses for service provision. WSBs have the legal responsibility to provide water and sewerage services within their prescribed areas of jurisdiction under license from the WSRB. Their tasks include holding or leasing and developing water assets, contracting water service providers (WSPs) (their main agents in provision of water services) and preparing plans for improvement of services, including expanding service coverage and reviewing tariffs. WSPs are the entities through which the WSBs provide water and sewerage services under appropriate agreements entered into with the approval of the WSRB. The WSPs may be community groups, NGOs or private companies, including those set up by local authorities for the specific purpose of operating water services.

In Kenya, the PAC team conducted a review of an urban sanitation programme in Kibera, Nairobi, and a rural water supply programme in Kabuku (Box 4.10). A more detailed description of Kenya and the sites studied there is included in Annex 6.

Box 4.10: Kabuku water project

Kabuku is a community-managed water supply scheme, initially completed in 1979. It ran until 1988, before the community sourced funding for rehabilitation from Sida in 1993. The Kabuku water supply project is a pumped system from a spring and serves a population of about 2500 people, through a mixture of household connections and public tap-stands.

Kabuku now provides an example of strong financial management – through metering, effective pricing and fee collection; its income is reliable. Annual income generated is about US$11,000, with US$9000 going on operation and maintenance costs and the surplus going towards extension and rehabilitation.

The Kabuku group members, registered as a society, own the water supply collectively, with rules on membership, governance, management and ownership of assets. The members elect a management committee and hold it and the staff accountable through approval of the annual budget.

Members, management committee members and staff all receive detailed and extensive training covering management; bylaws; key features of water supply; finance and accounting; budget preparation and record keeping; staff supervision; and operation and maintenance.

To improve on management and use of water, each member of the Kabuku project is given a meter that is regularly serviced; readings are taken on monthly basis. Non-members pay a set tariff for water from the public tap-stands.

From the point of view of the group members, this scheme is successful. There is cohesion within the group, they pay their bills and receive a good service. The group's financial sustainability is helped by its ability to set its own tariffs. Accurate and clear financial accounts are important to maintaining trust among members.

5. Key findings from Ethiopia and Sudan visits

5.1. Planning procedures and practices

In Ethiopia, information about community needs in water and sanitation are held at the woreda level, but the community voices its needs at kebele level, which is then channelled to the local woreda Water Office. The woreda Water Office then prioritises community needs. Further to prioritisation by both woreda and NGOs, a feasibility study is conducted. Users are supposed to participate at every level, from needs identification to planning, apart from some technical design, such as depth of boreholes, which is carried out by water engineers. This research did not assess the quality of the participation.

Local government supervises implementation, carries out training and provides follow-up support. Implementing NGOs coordinate with the community in planning and implementation, provide training for community members and government staff, arrange maintenance kits, kick-start funds and manage a phase-out strategy. National policy stipulates the need for participation but, in most cases, regional governments do not have the resources to practise this. It is also important that government mainstreams participation in its programmes and activities. In view of this, the main driver for participation seems to be NGOs, partly because national policy creates space for them to facilitate it. In the case study sites, HCS plays a central role in ensuring participation in community water management processes at woreda level. The woreda system may not have the resources and motivation to mainstream participation: such support is provided by HCS.

In Ethiopia, much of the decision-making happens at woreda or regional-level offices, in conjunction with implementing NGOs.

In the case of the Golo dam and Shugra boreholes near Al-Fasher in Sudan, the planning, design and construction process was carried out entirely by the DWC with the aim of making water available to Al-Fasher town. Local people were employed as labourers, and some are still employed by the DWC. The village of Golo was created to provide a source of labour for the dam, and has since grown to around 1500 people. In Golo, discussions with the community reflected little involvement in the planning, design and maintenance of the system, as water supply is managed by the DWC. A significant proportion of workers at the Golo pumping station are from the local village. The village itself has easy access to the water point. A trip to the water points is on average 15 minutes one way, with the longest journey taking 30 minutes.

The women interviewed reflected that there were hardly any queues, and fetching water was a relatively smooth process, unless there was a problem at the pumping station. Water is used solely for drinking and watering livestock, with some cultivation on the periphery of the reservoirs, fed by the overspill from the reservoirs and pipes. However, because water from Golo is untreated, there is high incidence of waterborne disease.

It is clear that people are satisfied with the availability of water and the technology used at the pumping station, particularly as it continues to provide employment for some of the local villagers. The technical design by DWC did not see consultation with the community, nor did it give community members a range of options, but this does not create any problems as long as the water supply is reliable. It is not certain from the field notes whether users are aware of water quality and links between this and incidence of certain diseases. They may need better knowledge to measure water quality and to report on this to the responsible office. In the case of sanitation, planning with the people and ownership is also important: as we learned from Kibera, Kenya, demand and sustained use of sanitation facilities can be challenging.

In Sudan's Fasher ponds, the system was planned and constructed by the government using heavy duty machines. During the construction process, the community contributed local labour paid for by the government. The supplementary hand-pumps (11, of which eight are functioning) in the area, were constructed by WESS and PAC, an NGO, both of which are active in the area. In implementing the hand-pumps, both the agencies have followed a community-based approach, allowing the community to contribute local labour and resources.

In the case of Kabuku, Kenya, the water supply has been serving the community for 28 years and the technologies were planned and are owned and operated by the community. The Fasher and Kabuku examples reveal that the process of technology management after construction is extremely important to ensure long-term and sustained use. Learning from the Fasher ponds suggests that being able to access water for domestic use and livestock can address communities' multiple use needs. However, those designing systems need to take special precautions against cross-contamination.

RiPPLE has identified a need to look at mechanisms for increasing transparency, accountability and effectiveness. This must be seen not only at government level, but also at levels where other organisations interact. In the case of Ifa Jalela and Kufanzik, the project faced a pre-existing situation of poor management and corruption. In Ifa Jalela, a lack of training, unclear systems and a lack of accountability by the WMC led to corruption. The government identified these weaknesses and responded by dissolving the committee, putting in place a temporary manager.

In Kufanzik, even local users suggested employing a government official to manage the system, to be paid out of a cost recovery scheme, as it was felt that the scheme was too large to manage without outside assistance. One of the key research questions emerging on this regards the role of government in improving accountability and effectiveness of community-managed systems.

Conflict can easily take place among community representative groups, community members and government structures. Large-size schemes may need government systems to ensure accountability, but in many low-income countries governments are considered corrupt by the community and people do not like to deal with government agents. In this debate, the role of a 'whistle blower' and a neutral, trustworthy regulator is important. In rural areas, the only recognised organisations available are local government structures.

Indigenous community processes could play an important role in promoting accountability. For example, in Welteha Bilisuma and Goro Beyo, the WMC blueprint utilised by HCS was adapted by the community to include local institutional elements for increased transparency, accountability and effectiveness. This is particularly true for the Goro Beyo irrigation team. The size of the committee was also altered: the norm is to have a seven-person committee for any size of project.

Experience among study participants highlighted the need to take on flexible management systems; for instance, big water systems may need more than seven committee members. Further, schemes that use complex technology and/or cover more than one community may need external support from NGOs, government or the private sector to complement community-based management approaches. In Sudan, experience showed that communities found it more difficult to manage larger systems without government management support. In Ethiopia, the best-managed systems were modified by the community to enable better management.

With reference to technology choice, certain technologies, such as water meters, could provide better potential for accountability. The use of water meters in rural Kabuku helps in charging fees and creates relatively better systems of transparency.

The key indicator for transparency, accountability and effectiveness is the reliable operation and maintenance of systems. In the cross-border scheme of Ifa Jalela/Kufanzik, where the technology used depended on cooperation between both areas, an overarching board to manage the relationship was put in place, but this failed because it lacked authority.

A factor of safety against floods is built into all schemes, but in the case of Olan-Oulla/Millennium Village, the original scheme, which could withstand regular annual floods, was destroyed by a 'freak' flood, and villagers had to revert to their old water-collecting practices for two years. The new scheme took this into account and was designed to resist flood damage to a greater extent.

In Kenchera and Goro Beyo, where some system components are on private land, further legally binding agreements are required with the landowner. On the other hand, the owner may be adequately compensated with another piece of land or other forms of compensation. Land ownership issues tend to be linked with traffic or productivity. For example, in Goro Beyo, the land owner restricted access to a cattle trough because of the livestock and human traffic across his land. In other areas, locating storage tanks on private land, which attract less traffic, was often freely allowed without any form of compensation. In Kenchera, land ownership issues from the first phase were based on the perceived ownership of produce from the land by the landowner's family, despite informal tenancy agreements. Legally binding agreements with tenants in the second phase provided some form of security for tenants. Private ownership of assets was recognised and integrated at project planning and design stages. Some assets are of relatively small size, such as a boreholes or piping, but anecdotal evidence suggests that private ownership adds incentives and leads to better operation and maintenance, by linking assets directly to an individual's livelihoods or income.

In Azagarfa, North Darfur, lack of a management committee, tariff setting and fee collection at the hafir has significantly affected the sustainable use as well as quality of the available water. Introducing a management system could enable the provision of funding for rehabilitation and even the treatment of the surface water. Formation of a management committee with people who are interested in working together to improve access to water and sanitation could be the answer.

Overall, the motivation and resources to sustain participation and to promote community ownership in technology choice is still weak at local government level. There is a shortage of resources to improve the process and, often, user participation is least prioritised. HCS has successfully filled those gaps and demonstrated approaches which reflect that such support may be needed for a much longer period than just the planning, design and initial few years of operation.

With large-scale schemes, such as motorised boreholes, participation is often heavily dependent on some form of technical knowledge. As such, community participation is limited to planning the positioning of system components and operation and maintenance management. It is often difficult to provide the community with an in-depth understanding of a system with which to make informed technology choices. As a result, support for large-scale systems needs to carry on beyond implementation and phasing out.

5.2. Stakeholder roles

Role of different actors was identified as being an area in which RiPPLE could identify useful learning points. This research focused on different roles in technology choice. The generic project approach in Annex 2 explains the roles of the various groups in planning a project in Ethiopia. Project requests come from the community; the community also participates in site selection and provides labour for construction and, in some cases, land. Community committees participate in implementation and management after a scheme has been planned. Local government supervises implementation, performs training and provides follow-up support. Implementing NGOs facilitate the community role in planning and implementation, provide training and maintenance kits, kick-start funds and manage the phase-out strategy. What we do not know is the extent to which we can standardise these inputs through government processes within other countries.

In Ethiopia, the key barriers found preventing different groups from taking an active role in local water governance were as follows:

- A standard application of a seven-member WMC blueprint was applied regardless of the complexity of the system, with villages were allowed to elect committee members.
- With regard to the WMC, there is a lack of refresher training, maintenance kits and literacy in management hampers long-term maintenance and sustainability.
- Local government is meant to provide ongoing support but lacks capacity in logistics and financial and human capital to provide proper support.
- Although there WMCs have an equal opportunity policy, this is not reflected consistently in practice. Most WMCs are overwhelmingly male and females tend to be fee collectors outside of the WMC. We do not know how these committees are represented by different tribes and what capacity and skills already exist in the community to engage with government systems.

In Sudan, DWC policy is for communities to be responsible for the management of small systems, i.e. hand-pumps, whereas larger systems, such as water yards and hafir, are under the jurisdiction of the DWC. However, in some areas, the conflict has prevented the DWC from being able to manage larger systems. In Fasher, the community took over the management of the hafir when its sustainability was threatened. Generally, women are not prominent in the WMCs of these systems.

In Kenya, members of the Kabuku group made a monetary input at the start of the project and manage the system. Members are registered as a society with its own bylaws and receive training in all managerial aspects.

Having a management system that aims to address the spectrum of community needs, especially women, is essential.

In short, actions and capacity of stakeholders are a key determinant of how sustainable a system is. Generally, in terms of water management, committee structures should be more context specific and tie in, as much as possible, with existing managerial institutions, or be flexible enough to be adapted by communities. In other cases, external stakeholders, outside of beneficiaries, are better suited to managing systems and keeping the system accountable and transparent.

5.3. Land ownership

As expected, land ownership was another issue arising as a point of contention in many cases. In Ethiopia, where land is a scarce resource in comparison with Sudan, conflicts had arisen over land ownership in most of the sites visited, particularly in the Ifa Jalela/Kufanzik case, where the water accessed by both communities is on land belonging to Ifa Jalela. As the water source and collecting chambers for both kebeles are on Ifa Jalela's land, the water is referred to as 'Ifa Jalela water'; as a result of this perceived ownership, bribes (or additional payments/non-agreed payments) are demanded from Kufanzik residents who want to access the water. Pipes have been sabotaged so that extra fuel money can be demanded and so that lack of water being delivered to Kufanzik can be blamed on this rather than on managerial failure. To counter these problems, Kufanzik residents in particular suggested that a local government official manages the scheme, since it is too large to be managed by the community.

Conflict can wreck havoc on access to water, especially in areas that suffer from land scarcity.

At the Kenchera site, the extended family of the farmer on whose land the water source and cultivable land are situated felt unhappy with the farmer group benefiting from the land. Tensions had led to the use of the land for cultivation being suspended for five years. In this new phase, a group of farmers approached the landowner with support from HCS and attempted to overcome the problem by signing a partnership tenancy agreement recognised by the kebele administration. The involved parties were the landowner and the villagers who will use the water supply for irrigation. This agreement entitles members to use the land for five years, with a certain annual payment for this right. The group has also agreed to allocate a certain portion of the land to the landowner for cultivation. The enhanced capacity of the community enabled resolution of the difficult issues and integration of private ownership within the system.

A comparison of the Millennium and Goro Beyo schemes shows that location and type of access to water impact whether or not land ownership becomes an issue. Both these villages have similar technologies – a spring-fed system with a storage tank and distribution points. In Goro Beyo, where access to a cattle trough has been blocked, water distribution points are located on private land, entailing a great deal of human and cattle traffic. The landowner found that his cultivable land was being damaged particularly by cattle, which affected his livelihood, and he was not adequately compensated. The storage tank in Goro Beyo was also located in the middle of private-owned farmland, but attracted minimal traffic, so the landowner was seemingly unaffected (and indeed benefited from overspill). In Millennium Village, water distribution points were on communal land and access was by means of communal pathways, therefore traffic did not pass over private land. The Millennium scheme also had storage tanks sited on private land, with no problems with the landowner.

In Shugra in Sudan, the government signed an agreement in 1990 to give villagers free water and electricity in return for the use of the water situated on their land.

Some important research questions need to be explored here with regard to assets and conflict, regulations on ownership of water resources and government processes to deal with such situations. An understanding of the resources (land or water) and their perceived ownership is crucial to technology choice and situation of system components. Such an understanding could prevent future conflict and help put in place processes for their sustained and long-term use. Designing systems that ensure that paths of access to water points are on communal land might be one way of reducing conflict within and between communities.

5.4. System sustainability

The long-term sustainability of WSS technologies depends on several factors, including the robustness of the technology, its proper maintenance, community capacity, fee recovery, resolution of conflict and management issues. Operational sustainability also depends on the ability of the community or local government to mobilise resources in case of a large repair need. The site descriptions collected by the visiting teams looked mainly into technical aspects.

As mentioned previously, water supply schemes are designed to resist normal flooding, although in some cases there are risks of major freak floods that can destroy the system. In other schemes, such as the improved natural pool in Azagarfa, an existing water source may become damaged if poorly designed and/or implemented. A design that avoids such risks increases the cost of the infrastructure. To deal with such difficult decisions in the choice of technology, good interaction is needed among designers, users and local government. What need to be avoided are situations such as that at Millennium Village, where the scheme was destroyed by a flood and nothing was put in place for two years, leaving villagers to revert to unsafe practices. An important research question arises in such cases: what to do with the previous infrastructure? There are indications that users would like to keep such infrastructure as a back-up. In Kibera, Kenya, old sanitation blocks continued to be used by women to fill their hygiene and sanitation needs. Eventually, the new system at Millennium Village was partially constructed with recovered pipes.

Designing systems that can be easily maintained is a challenge for rural communities who have limited access to spare parts.

This also highlights the importance of a community having an understanding of the technology so that members are then capable of rehabilitating the system with minimal support. In Welteha Bilisuma, the community took the initiative to get components of their system maintained, utilising their savings and training. In contrast, Millennium Village had the savings to fix the spring system but felt unable to take the initiative to undertake the rehabilitation, waiting instead for external support and mobilisation. In Kabuku, phase two of the self-help water project ensured complete installation so that the community could manage and rehabilitate the system when necessary. Ensuring a community understands a technology and has access to adequate support can help improve its chances of maintaining a water system.

Maintenance concerns are also important for long-term sustainability. For all motorised sites, spare parts are a problem. For example, in Welteha Bilisuma, some of the necessary spare parts are available only in Addis Ababa. Fuel can be a problem, bearing in mind the rising prices. The capital and operational costs of a system are also important for wider uptake and replication. We believe that both training and improving access to spare parts are vital. The technologies selected must use local spare parts and should not depend on imported parts or skills; otherwise, after a breakdown, users need to wait for a long time or repair may not be possible at all. This is a challenge for large and complex schemes in particular, as these require a high level of technical knowledge in the case of major rehabilitation, e.g. Golo dam or Ifa-Jalela/Kufanzik.

Among the major barriers hindering sustained use of technologies is conflict. It is common in community-managed schemes for community groups to be unable to overcome internal differences, which can lead to delays in maintenance, poor operation and ultimate abandonment of the whole scheme. In some cases, conflict is external and it is beyond community capacity to do anything about it. The problem of maintenance is aggravated in Sudan by the ongoing strife: the area outside Al-Fasher town is under the control of rebel factions and, as such, maintenance and rehabilitation have to be carried out through negotiation with rebel groups. Design persons need to be aware of all these risks, so that technologies can be made more resistant.

Agreement on the use of the land is another important consideration in the choice of technology and the management processes surrounding it, particularly with regard to cultivable land near irrigation schemes. It has been suggested that, in the case of Kenchera, the fairly short-term (five-year) nature of tenure with the landowner is a disincentive to joining the scheme. If shorter-term land tenure agreements become the norm, this will stop the private sector becoming more involved on a long-term basis and deter other groups (farmer groups, householders, etc.) that may need more long-term security from joining. On the other hand, short-term tenure offers the chance to look into alternatives if performance is not satisfactory.

Regular maintenance is important to sustain use. Despite promises by local government, and policies that ensure handover from implementing agency to local government, they may not have enough capacity to maintain it. The capacity of Golo dam in Sudan has been reduced by approximately half on its design because of silting. As such, its sustainability is under threat. Engineers interviewed stated that rehabilitation would make a significant impact in terms of providing for the water needs of the growing population of the town of Al-Fasher. They went on to identify as a constraint limited government capacity to carry out proper maintenance and rehabilitation (particularly in light of the ongoing conflict), even when resources are available.

5.5. Universal access to water

Universal access to water has been identified by RiPPLE as an important research area. This depends on a number of factors, some of which have already been discussed, such as problems and tensions surrounding land access (either community members accessing water on land belonging to an individual or one community accessing water on land owned by another community). In the sites studied, several ways of dealing with land issues have been suggested to mitigate problems. There may also be scope for further work on developing a clearer framework for access to land in such cases.

Mere provision of infrastructure services is not enough. One important issue picked up during the visit and discussions was the risk of inequality of access within the same community. Once access is provided, there is a need to look into impacts and economic outcomes. For example, if a certain number of residents can access a scheme and not others, inequalities may be created or existing ones increased.

In the case of Goro Beyo, members of the cooperative who access the irrigation system are able to earn up to Birr 7500 annually, whereas those who do not earn on average Birr 1500.

Equitable growth is always challenging in the short term and it is common for those with more resources and power to benefit first and most. Equitable economic outcomes from access to water are only possible if capacities are built across community groups to benefit economically from access to and use of water, whether directly or indirectly. This should be considered within the larger effort to determine how technologies can benefit all.

In Gorobeyo, villagers with access to irrigated land, have seen their incomes increase by more than 300%.

At the Kenchera site, where water is scarce, simple technologies have been demonstrated to reduce water use and improve its efficiency. Different technology choices are being tested by farmers, with significant uptake by other farmers in the area even before the testing phase is complete. This is because farmers understand the technology and because it uses highly accessible and available materials. This type of self-replication shows the strong potential of technology to contribute towards universal access.

5.6. Financing and user charges

The choice of technology, its capital cost and the need for operation and maintenance are directly linked with the financing. Understanding the financial needs on the ground is necessary to be able to incorporate such learning into policy. Where available, the teams looked into the capital cost of technologies, community contributions and user charges.

5.6.1. Capital costs and community contributions

In the Ethiopian context, projects are generally funded in the same way, according to the procedures set out in Annex 1. HCS secures funding from different programmes (e.g. the US Office of Foreign Disaster Assistance – OFDA, European Union – EU) and then grants this to selected sites based on government and HCS prioritisation and selection criteria. However, there are instances where the local community has also contributed to the initial costs of a system, for example in Goro Beyo, where community social services provided a Birr 1000 loan to start up an irrigation committee. Communities also contribute their labour in building schemes as their form of matched funding. The community contribution is an essential component to demonstrate community trust in a particular water system. It creates a sense of ownership and provides an important impetus to maintain the technology. However, often this is not considered important, as communities are poor and local governments expect to maintain systems for them rather than handover all responsibility. These linkages are extremely important research areas for further work in RiPPLE.

5.6.2. Cost recovery

Conventional technology assessments ensure that technologies deliver what they are expected to deliver. However, a broad assessment also takes into consideration issues such as how a community expands its economic opportunities with the use of a technology. In Kenchera, after an initial well improvement project increased farmers' productivity and therefore income, users could afford to pay for further improvements (a pump). This type of 'incremental' development could be considered for other areas, where using savings or own initiative to collect money and reinvest may not have been considered.

There were cost recovery mechanisms in place in all schemes studied in Ethiopia, as part of HCS policy. There are two main modes of user payment: a flat rate irrespective of usage or a fee each time water is collected, based on the running costs of the system. Motorised systems have much higher running costs, so are better suited to a fee charged at point of collection. In Ethiopia, where motorised systems are more prevalent, it was seen to be more manageable for users to pay daily for the amount they need, particularly as they lack meters to measure individual consumption. In these cases, if the price goes up, people reduce their consumption, using water only for drinking and cooking and returning to original unprotected sources for surplus needs. This could lead to a drop in overall revenue to keep the system financially viable, as well as leading to possible health risks for the community through use of unprotected water. Revenue collected on an ongoing basis covers maintenance, guards and caretakers and fuel costs, where applicable. Charges for water need to be in line with income and seasonal patterns. They also need to take into account the multiple livelihoods and seasonal migration patterns of a community.

In Ifa Jalela/Kufanzik, the WMC became corrupt and was eventually dissolved by local government (as mentioned earlier). This issue could have been avoided if the amount of income generated was clearly known about. In Welteha Bilisuma, the treasurer could neither read nor write, so accountability was poor: he was not aware of how much money he had. The amount of money in the bank reflected discrepancies with the figures provided by the community. Generally, managing a motorised system is more difficult and needs more support, not only because of the complexity of the system but also because of the high running costs, the potential for less financial transparency and accountability and the dependence on fuel.

In gravity-fed systems, water is generally more abundant and running and maintenance costs are minimal, so a flat rate can be implemented. It was observed that, at sites where a flat rate was payable irrespective of usage, there was more transparency and accountability, since each household paid the same amount and the number of households was known (so the level of income was known and the system was less open to fraud). Members of farmers' cooperatives who used gravity-fed systems also tended to pay a certain rate on an annual basis, irrespective of usage (e.g. in Goro Beyo scheme). Whilst not all members of the community have the same ability to pay, varying tariffs can help people better afford water. Ideally, a range of technologies must support more flexible systems of payment, but this is not always possible because of management difficulties.

Tariff and user fee collection is mandatory in any water system in Al-Fasher state and Sudan in general. For government-constructed water systems larger than hand-pumps, tariffs are always set by government, but tariffs on locally constructed water points such as hand-pumps are decided on by local communities. At the moment, the tariff for pond use is based on a tariff set by the DWC and fees are paid in advance. A ticket/pass is provided for households using the water service. Livestock owners are expected to register the number of livestock they own. The tariff rate for domestic use, for example, is SDG 0.5S whereas for livestock it varies according to size, i.e. SDG 0.3, 0.2 and 1.5 per head per year for sheep, goats and camels, respectively.

In villages around Shugra in Sudan, water points are managed not by committees but by an individual from the community. Individuals are invited on an annual basis to tender, and the winning bidder administers the water point and retains some income. By attaching a meter to the water yard, having one individual held accountable makes it possible to increase transparency and accountability.

The Al-Fasher privately owned borehole provides some useful insights into the processes of the private sector and governance. In this case, maintenance is conducted by the owner and his sons or, if an issue is beyond his capacity, the owner pays for maintenance services from the DWC. The operational costs go towards fuel expenses, maintenance and a supplementary income for the family. Users currently pay SDG 1 per horse cart (about 400 litres) during summer months, when there is less demand, owing to rains and recharged natural pools. During the drier months, just before the rainy season, when there are limited alternative water sources, the owner is able to charge SDG 3 per horse cart (April – 15 June). In addition, the owner is part of an organisation of private well owners, who agree on a set tariff between themselves, depending on the power supply. The income from the well is shared among the extended family, whereas income from his adjoining farm (about SDG 200 a week during harvest season) is just for the owner. The owner has used some of the water from the well to irrigate his land, but only a small area. Most of his cultivable land sits in an area fed by rains and does not need irrigation. The owner is registered with the local government but refuses to pay taxes because feels he does not receive any government support.

In Kabuku, the community-managed network has tariffs set by the community members. Some of the water is distributed through a home network and the rest through public tap-stands. Monthly billing, a progressive tariff and strict enforcement of payment rules have enabled the scheme to maintain high average collection rates over many years. This financial discipline, together with each group's authority to set its own tariffs and to set and approve annual budgets, ensures that income collected is enough to cover all operating and maintenance costs. Having a set number of members, rather covering than the entire community, allows for easier management as well, but this may create barriers to entry.

Metering is key in aiding cost recovery and financial sustainability in Kabuku.

In all, the field visits presented a range of fee recovery options, with variations depending on type of technology, system ownership (public/private/community) and impact on transparency and accountability as well as maintenance and rehabilitation.

5.7. Growth and productivity

Unsurprisingly, access to water means that productivity improves; this is important for all the sites. Impact on growth and productivity is heavily dependent on availability – amount of water available for multiple use (drinking, livestock, irrigation, etc.) – and accessibility (for example, farmers within the cooperative and those not). In sites where there is no irrigation, such as Welteha Bilisuma, productivity has also shown improvements owing to healthier livestock and time saving. Employment has increased, for example in Goro Beyo, where there is an irrigation scheme. There is now more year-round self-employment in farming activities. Members of the farmer cooperative in Goro Beyo have access to markets for their produce, hence the increased income, and are now looking to obtain assistance in order to remove the middlemen and access the market directly themselves. In Kenchera and Millennium Village, farmers can now earn an additional income from selling surplus vegetables. Kenchera has links with a women's processing project in Dire Dawa, to which it is planning to sell first harvests to generate capital quickly.

There is also indirect employment in non-farm-related activities, for example mud brick construction. In Sudan, mud brick construction and livestock are the main sources of income, particularly for users with access to hafirs. Being able to partake in mud brick construction has provided another source of income in Millennium Village in Ethiopia also. Access to water ensures that these incomes can be derived from non-farm-related activities. In Fasher in Sudan, nurseries can generate an income for women farmer associations to add onto the income earned from livestock.

Introducing more environmentally-friendly ways to make bricks is one of the lessons that can be learnt between villages in the region.

Overall, better access to safe water has saved time in the sites, and communities recognise improvements to their health and have seen an increase in income from both farm-related and non-farm-related activities.

5.8. Risk and vulnerability

Provision of water services was found to decrease vulnerability to shocks in various ways. In Kenchera, land tenure systems have allowed farmers to grow vegetables and create incomes where this was previously not possible. As we saw in the previous subsection, growth in farm-related and non-farm-related income generation can allow households to protect themselves from vulnerability. In Goro Beyo, grain was being saved and then sold at a higher price during times of scarcity to make a profit. In Millennium Village, more people have been building mud brick houses, thus investing in an asset that will give them greater security in times of hardship. In irrigation schemes such as Goro Beyo, there has been a direct increase in food security as the productivity of the land has been raised. Nevertheless, achieving sustainable livelihoods is a bigger issue than that suggested by these positive signs and water can contribute only to certain dimensions of this.

The increased availability of labour was noted in several cases. In most cases, women previously had the responsibility of collecting water but the scheme allowed them more time for other activities. In one case (Millennium Village), the water was previously collected by the strongest members of the household (men) since the source was very inaccessible and dangerous to reach. In this case, the labour of this group was freed up to allow men to participate in other income-generating activities, such as farming. In many cases, it was reported that children had more time to attend school.

Skills have also been developed in the communities. For example, in Millennium Village, residents can now maintain the system themselves. All sites have trained caretakers, who should be able to carry out minor maintenance, such as replacing taps. Motorised pumps have separately trained caretakers, for fuel loading and pressure checking.

The issue of asset inequality was brought up in the site report of Goro Beyo: increases in income inequality between beneficiaries of the irrigation scheme and others in the village could lead to conflict.

5.9. Sanitation

In Ethiopia, HCS interventions are accompanied by hygiene awareness programmes to improve sanitation alongside water schemes. As such, improvements in sanitation were reported in many sites in Ethiopia as a result of integrated programmes run by HCS. At Kufanzik, there is now 100% latrine coverage at household level, despite limited access to water. At Goro Beyo, there was improved latrine coverage, with water at the entrances of latrines to be used for hand washing. And at Millennium Village, the community has built latrine pits, with maintenance the responsibility of the females and construction the responsibility of the males. All of these improvements should lead to public health benefits and therefore improvements in quality of life. At Golo in Sudan, there was a keen interest in developing latrines and sanitation systems, as seen in camps for IDPs. Generally, in Sudan, Islamic religious practices consider hand washing an important component of ablution.

Whilst, sanitation at a household level was visible in most places we visited, there was little investigation into hygiene or maintenance of such facilities.

In this study, however, there was, yet again, evidence of a lack of attention and focus on sanitation, with a focus on water taking precedence. This reflects to some extent the attitudes of implementing agencies as there is not enough recognition of the benefits of good sanitation practices and, as such, sanitation is merely an afterthought.

6. Conclusions and the way forward

6.1. Phases of technological choice

Based on the learning and research exchange on technology choices in Ethiopia, Sudan and Kenya, this section summarises overall learning and proposes way forwards. A number of specific points and areas for further exploration were also included in the previous sections.

The process of technology choice can be broadly divided into three phases:

The **first phase** is the process of exploration and planning before the actual physical design and construction. This needs to be informed by a range of technical details and a thorough understanding of the social processes in place. Communities could take a leading role in some of the key decisions, such as location of the schemes, land ownership, operation and management of assets, charges and systems of conflict resolution. The community also needs to be informed of future requirements which they may not know about, such as need for spare parts, fuel consumption, protection against floods, etc. Ideally, governments should coordinate this process, working with an informed community but, in the absence of resources, capacity and sometimes commitment, NGOs often take this role. Careful assumptions need to be made about the capacity of local government and communities to operate and maintain the systems beyond the period of external project support. Interviews with staff at the Water Bureau in Ethiopia and the DWC in Sudan showed that, although policy is in place, there are limitations in terms of government capacity and resources. In Sudan, this has been exacerbated by the conflict. These processes are mentioned in the annexes covering the generic project description and site reports, but the quality of the process could not be assessed and commented on. Although this is one of the important phases with regard to technology choice, detailed investigation could not be carried out, as research would ideally occur during the planning process rather than post-installation. As most of the projects visited were already functioning, the visiting group could look into its current operation only and spoke only to those responsible for the schemes now.

Once the participatory plans are ready, the **second phase** is the actual technical design and construction of the scheme. Traditionally, engineers are responsible for this phase and they are trained to prepare designs and estimates, select contractors and make payments. They are responsible for the quality of construction and they validate the design for safety against any possible physical failure. Safe and quality designs need financing and sufficient resources to ensure that sound technological solutions can be implemented and maintained. In community-managed systems, there is a need to work in consultation with the community, to build local operators' capacity and to use and train local labourers or small contractors from the local area. Resources are often in short supply and needs are huge. Often, strict national/regional standards and regulations make the choice of technology fairly restricted, especially when it comes to reducing the cost and creating space for users to participate and benefit from services. Freedom of innovation becomes narrower as a result of licensed engineers signing off the design against any failure. In most of the schemes visited, the design was carried out by local government engineers and local contractors were hired, although community labourers were used in some cases. An important area for understanding and further investigation is the engineering design process and the ability to link the design with plans and operation and maintenance afterwards.

The **third phase** is the actual use of the technology and making sure that it sustains the operation, makes an impact and delivers outcomes. The success of this phase depends on the quality of the information and processes in Phases 1 and 2. Most of the failures in externally supported projects lie in this phase, when funding is over and there are not enough resources to reassess and understand the issues. As a result, local governments and community leaders start looking for new projects. Many assumptions about the capacity of the community, partnerships, user payments and government ability to serve the community may prove wrong at this stage. Consequently, despite the very positive intentions of NGOs, communities, government and donors, technologies fail to deliver the intended outcomes. This situation needs to change: a great deal of action research and learning needs to be carried out on this third phase. This was also one of the key recommendations arising from the Kampala Colloquium. A range of specific findings related to RiPPLE themes are discussed in the previous sections also.

In this small piece of research on technology choice, interaction with practitioners was very beneficial. However, the research process was potentially restricted by the choices of organisations to provide access to their own relatively 'successful' projects. In addition, projects in Ethiopia work under a framework set up by the government, which restricts NGO intervention to one organisation and, in some cases, limits innovation in technology choice and processes, despite very intelligent use of the available space by HCS. In Sudan, logistics restricted the range of organisations and the depth of investigation possible. In future, PAC is keen to look more into the capabilities of the community to participate in the process, to understand the constraints for the government and NGO engineers in using low-cost and innovative systems and to bring the dynamic processes of learning and research to the grassroots level. The Kenchera example of testing drip irrigation technology with farmers is an example of rapid and useful technologies that are easy to use and easily replicated and that increase the skills of the beneficiaries. At the same time, larger and more complex systems are needed for places where water is limited and access is difficult (for example in Kufanzik). Developing technology to improve the efficiency of water, as well as implementing natural resource management programmes integrated into water schemes, can improve the sustainability of water supplies. With growing concern over the impact of climate change on this limited precious resource, there is a need to share learning on using and adapting technology in a sustainable manner. Our offices in Sudan and Kenya will hopefully make such research and networking possible to make a wider impact in the Nile region.

6.2. Ways forward

There were two key advantages in carrying out this study. First, the research brought a multidisciplinary perspective to the understanding of social, economic and technical aspects of WSS. Second, the study gave primacy to both local issues at site level, which were vital to understanding the complexities of the various situations, as well as the wider policy issues. This approach underlined key lessons learned and highlighted room for improvement in every site, even those deemed 'successful'. Participants also learned from participation and sought to put behavioural changes into practice.

The real work on technology choice lies in approaching development as a dynamic and hard-to-control process as opposed to a linear process, constrained to sequential phases, with expected outcomes based on an approved strategy or business plan.

Technology choice needs to come to be understood as a complex interaction of technical and social processes, and policy on implementation should reflect this at every stage. All the players in this process are important, but the key decisions are often made by government officers/engineers, community leaders and NGO staff. These groups need information at the relevant time and in a format that they can understand and use. RiPPLE's flexible approach to learning alliances and networks could be important in this. Relatively more learning opportunities are available now because of the internet and other means of communication. However, there are still major barriers to overcome before this knowledge can be used for the benefit of poor people:

1. The support process to ensure that knowledge is available at the time of need and in the right format for the people who need it most is still missing.
2. The cost of delivering this knowledge is still high, mainly because there is a large mismatch between need and availability, even if knowledge centres are hosted nationally.
3. Policy on technology choice should aim to be as flexible as possible, because of the complexity surrounding technical and social processes.

Future research on technology choices must look in more depth into these processes and relatively less into physical design. It must focus more on simple outputs, with a great deal of collaboration with practitioners and local communities. This can be done over a long period of time, to lead to mutual exchange of information and experience. This will give equal importance to talking and discussion at local level, moving away from the current emphasis given to research and high-profile publications. Quality needs to be measured in terms of the process, not just the product.

Numerous discussions with a range of stakeholders in the field were conducted as this piece of collaborative study was conducted.