International Water and Sanitation Centre

Water supply from sand rivers for multiple uses

Case studies of multiple use of water in Ethiopia (MUStRAIN case 1)

As part of the MUStRAIN project in Ethiopia, various approaches to water harvesting, multiple use of water and ecological sanitation have been studied. This case study presents experiences of the MUStRAIN project with the implementation of dams on sand rivers in Ethiopia.

Dams in sand rivers in Ethiopia at a glance

Main features: Sub-surface and sand dams both are designed to increase the storage of water in sand river aquifers. The volumes of water stored by such dams is commonly in the range 1,000 to 5,000 m^3 per rainy season without considering the additional possible storage of water in river banks. The water retained by sand dams and sub-surface dams can be exploited by wells in the river bed or on the river banks, or alternatively through canals to supply downstream irrigation areas.
Sub-surface dams aim to retain the underground base-flow along sand rivers behind an impermeable below-ground structure constructed in the sandy bed. The construction material may include clay, masonry or plastic-sheets.
Sand dams have a similar function but are constructed above-ground on sand rivers at points where there are stable banks. The usually masonry sand dam will fill with new sandy sediment, creating a new or deeper sand aquifer. The structures can be raised each year, capturing more sand and increasing the storage capacity.

Implementation: Sub-surface and sand dams have so far been constructed at small scale in Ethiopia. This case study describes a recent pilot, implemented by the MUStRAIN project in Eastern Hararghe and seeks to draw general lessons from this experience.

Options for multiple use of water: Water harvesting along sand rivers is one of few water supply options in dry, lowland environments where groundwater is not accessible. Groundwater storage reduces evaporation as well as pollution. Hence water volumes and quality may be sufficient for communal schemes catering to multiple uses, including domestic use, livestock and sometimes small-scale irrigation.

Challenges for uptake: Experience from other countries suggests that it is possible to build dams in sand rivers and supporting structures at low cost. Each region has its own particular geo-hydrological particularities to which sand dams need to be adapted. Construction can be challenging and dams that are not properly built, may leak. Because of their location in flood-prone areas, the supporting structures, and sometimes the dam itself, need regular maintenance. This requires communities to build sustainable financing models that cover replacement costs, or to receive continued external assistance. The specialist skills needed to site, design and supervise construction of novel structures are a further challenge.

Introduction

In dry areas with low and unreliable rainfall, water security and productivity are both low, contributing to high poverty levels. In lowland areas, groundwater may be the main water resource but can be deep and costly to extract. In Eastern Hararghe, these conditions are combined with small land holdings that are usually rainfed. Degraded rangelands can no longer support large herds of livestock upon which the previously pastoralist inhabitants depended.

Ephemeral sand rivers (wadis) that cross the area constitute a potential water resource that has arguably been overlooked for a long time. The sandy rivers beds contain aquifers of water that can be exploited. Local communities know this as even in the dry season, people collect water from holes in the river bed. Often this is a traditional water source that people revert to when hand pumps or other water supply systems have broken down.

Dams in sand rivers, both sand dams and sub-surface dams, can play an important role in capturing and storing surface runoff and the underground water. Such retaining structures make it possible to harvest water from an aquifer in the sandy river bed behind the structure. Sub-surface dams involve excavation to construct most of the dam below the surface of the river bed. Sand dams are similar but rely on a structure that retains an increasing volume of sand (and water) over time.

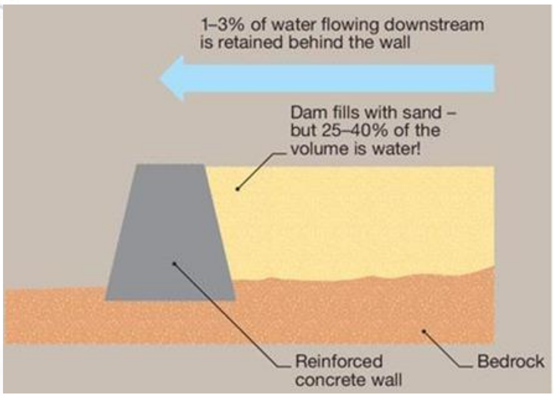

Figure 1. Diagram of a sand dam.[1]

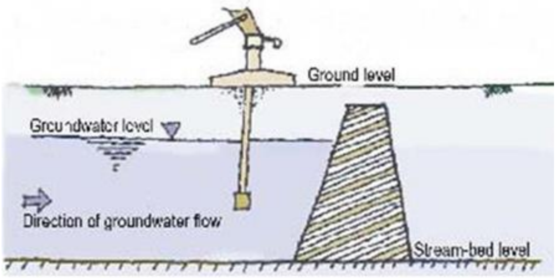

Figure 2. Schematic of a sub-surface dam.[2]

The underground reservoirs, created by these dams, have the advantage of reduced evaporation and pollution as compared to open surface reservoirs. Because of the restricted access to people and animals, contamination of the water is less. Filtration through the sandy river bed further enhances water quality. Together, this makes higher volumes of better quality water available for multiple uses[3]. An additional health benefit is that less suitable breeding sites are created for vectors of disease, such as malaria mosquitoes or snail hosts of schistosomiasis.

Implementation

Sand river dams were tested 20-30 years ago by the Hararghe Catholic Secretariat (HCS) and other organizations in Eastern Hararghe. The objectives at the time were mainly related to watershed development and erosion control, rather than water supply. The success of these interventions was limited and replication low.

Currently several NGOs are currently involved in building dams in Ethiopian sand rivers, such as Action for Development (AfD)[4], the Italian Comitato Internazionale per lo Sviluppo dei Popoli (CISP) and the local South Ethiopia Peoples' Development Association (SEPDA)[5]. Unfortunately no long-term systematic evaluation of these experiences has been possible so far.

Under the MUStRAIN project, demonstrations set out to test whether these dam structures and schemes, when developed with higher levels of community participation and destined at both domestic and productive water needs, could be an effective solution to the challenge of improving access to water and livelihoods in the region.

Sub-surface and sand dams in Dire Dawa

Dire Dawa Administrative Council is located 515 km east of Addis Ababa and about 350 km west of Djibouti, in Eastern Hararghe, Oromia region. It has a total population of 290,000 inhabitants spread over one town and several small communities. Annual rainfall in the area is around 500 mm with high variability between months and years and a potential evapotranspiration of 2630 mm.

In 2011[a] the MUStRAIN project initiated a pilot of 6 dams in sand rivers in the Dire Dawa area. The pilots were implemented by HCS, with support from various MUStRAIN partners: RiPPLE for management of activities within Ethiopia, the RAIN foundation (RAIN) for technical support and supervision[6], and IRC for overall project management.

At inception, the proposed approach was to work in two phases: 3 demonstration dams in phase one with intensive technical support from the MUStRAIN partners, and 3 further dams led by HCS with reduced support from the MUStRAIN partners. The budget for each dam was € 16,000, excluding additional support from the project, hence € 96,000 in total.

Planning and design

Finding the appropriate sites for sand dam and sub-surface dam construction can be difficult and requires specific expertise and skills. For the pilot schemes, siting was done by RiPPLE staff working with HCS, and with further support from RAIN staff. Potential sites were identified on maps, and 12 of these were visited in 11 wards. In the field, information was collected on various selection criteria, such as: gentle slope of the river bed, stable river banks, grain size of sand in the river bed, presence of traditional scoop wells in the river bed, presence or lack of alternative water sources, available command area for irrigation, location of settlements, number of potential beneficiaries, and the projected water demand. Based on the information gathered on-site, one river stream was selected in the ward of Lege Oda Mirga. It was deemed possible to develop 3 schemes in this area.

HCS proposed to construct two sand dams and one sub-surface dam schemes in the first phase of the MUStRAIN Project. The dams were proposed to be sited within 1.5 km of the villages of Gende Roba, with 728 inhabitants, Eresa, with 311, and Kenchera, with 569 inhabitants. All inhabitants were supposed to benefit from the dams, in any case for domestic water use. This 1.5 km

[a] All dates are noted using the international (Gregorian) calendar.

action radius is the standard for rural water access set by the Ethiopian government.

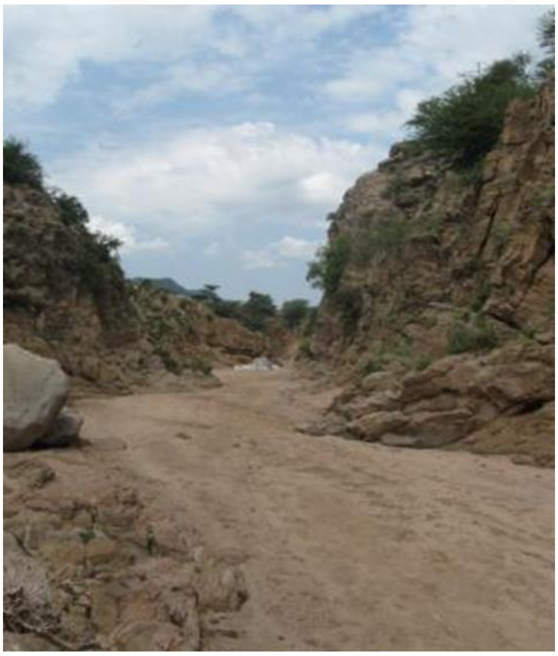

Figure 3. Proposed site for the Eresa sand dam downstream from Gende Roba.

The target community for each of the demonstration sites was involved in various project stages. Several community meetings were held to discuss the proposed pilots and the roles and responsibilities of the different stakeholders. The community roles were set out in an agreement signed between RiPPLE and the Dire Dawa administration as follows:

- Baseline - survey to describe water needs and uses by the communities;
- Design phase - explanation of how the project would address the community's needs by describing their involvement during site selection;
- Project implementation - community members to contribute in kind by providing labour and local construction materials such as sand and water;
- Setting up a water management committee (WASHCO) to increase the life-cycle of the schemes, to build the capacity of the users and to formalise the water management committee by means of formal by-laws.

For the three dams, the following key design parameters were included:

- *Gende Roba* - sand dam of 11 metres wide masonry and estimated capacity of 4500 m^3 (two rainy seasons). Water supply points for domestic use and livestock some 200 m downstream of the dam.
- *Eresa* - sand dam of 18 metre wide masonry, approximately 600 m downstream of Gende Roba. Estimated capacity of 11,500 m^3 (two rainy seasons). Gravity-fed irrigation supply to four farms (~2 ha in total), as well as domestic and livestock water supply points.
- *Kenchera* - sub-surface dam of 178 m long with estimated capacity of 51,000 m^3 (two rainy seasons). Related infrastructure includes an infiltration gallery, two intake wells with diesel pumps, two reservoirs, irrigation canals (700 m long and with 14 outlets) and domestic and livestock water points. An estimated 5 ha irrigated area was proposed.

Construction

Construction of the two sand dams was sub-contracted to construction firms, whereas the work at the sub-surface dam was carried out by the community, coordinated by HCS. The construction work was planned to be finished in March 2012 at the three demonstration sites. At the time of writing of this case study (end of 2013), construction at Kenchera and Gende Roba had almost been completed. Resources were concentrated at these sites and little progress had been made at Eresa. Construction was delayed because of various reasons. Site conditions were somewhat different than originally assessed at Kenchera, where the sub-surface dam had to be made much bigger than originally intended. Depth to the bedrock on which the dam wall would rest, was found to be 5 m instead of the expected 3 m. This changed the dam design, requiring a considerably higher wall, and a change in excavation method from manual labour to mechanical. The embankments which were expected to hold the wing walls, turned out to consist of a clay-sand mixture. This meant the wall had to be doubled in length in an effort to reach the next embankment across the dry riverbed.

Figure 4. Excavated trench for sub-surface dam wall at Kenchera.

An unexpected flood during the period of construction flooded the initial excavations at the three sites. When work restarted, an additional diversion structure had to be included to protect the works. This all led to construction delays and increased costs, despite the high levels of support.

Another major set-back was a tragic accident at the Kenchera site. As a result of changes in supervision, designs were not followed and precautions during construction proved inadequate. During excavation works of a trench for the infiltration gallery, part of the sub-surface dam collapsed into the trench, leading to several labourers wounded and even casualties. This bad experience emphasizes the crucial role of adequate, in terms of skills and experience, capacity in providing support and supervision to such relatively new and complicated construction processes.

Figure 5. Partially completed sand dam at Gende Roba (August 2012**).**

Besides considerable changes to the budget, all these challenges contributed to significant delays in the implementation process. As a result, limited time was left for training of users and start-up of productive activities under the MUStRAIN project (ended December 2013).

Costs and benefits

The capital expenditure on the sand dam in Gende Roba was in accordance with the original budget of € 16,000. However, the capital expenditure on the Kenchera sub-surface dam has been far higher than expected due to its large size and other reasons, such as switching from clay to cement for the dam wall. The costs of clay went up and cement prices came down as a cement factory was established near the site. The flood damage and other delays also increased expenditure. Total expenditure for the sub-surface dam at Kenchera is now estimated to be 3 to 4 times higher than initially foreseen. Both HCS and RAIN are mobilizing additional financial resources beyond the project budget to cover costs.

Operation and maintenance costs could be relatively low for the underground dams and associated schemes. However, because of the risks of floods at these sites, frequent rehabilitation of related infrastructure (such as abstraction points, canals, cattle troughs) may be necessary, with high capital maintenance expenditure. Hence significant follow-up direct support and funding from a committed external agency, in this case HCS, is required for repairs and new technologies.

While there are some older dams in the country and various NGOs are constructing new ones, no systematic evaluations of these structures, their use, cost, benefits and impacts have been done. Anticipated benefits include increased access to good quality water for multiple uses, but this has not been evaluated yet in the pilot sites. In Kenya, income increase of up to 60% was associated with sand dam construction[7].

Challenges for up-scaling

Dams in sand rivers and associated schemes are time and capital intensive, requiring high levels of human resource capacity for planning, design, implementation and subsequent support. The complexity of delivering such schemes in remote locations, combined with a need for high level of skills and expertise are significant challenges in taking these interventions to scale in Ethiopia. Hence, there are challenges in ensuring financial and institutional sustainability. While sub-surface and sand dams themselves are hardly vulnerable to flood damage, the associated infrastructure (e.g. abstraction points) may be and construction requires technical knowledge. There is thus need for institutional structures to ensure financing of all life-cycle costs.

The benefits of productive uses may not be widely shared as these depend on land and livestock ownership. The number of beneficiaries of small-scale irrigation projected at the two demonstration sites was very small as not all land holdings were suitable for irrigation from the dam. Hence the revenues generated from productive uses of water may not be sufficient to ensure frequent reinvestment in major maintenance of the dam, though experiences in Kenya are different[7].

The hydrological and environmental impacts of dams in sand rivers have rarely been quantified (except a few modelling studies on total flows[8,9]). The construction of sand dams and sub-surface dams, particularly in cascades, could potentially interfere with low flows in fragile environments. More research is needed on this issue, as on matters of water quality. While water is being filtered by the sand in the river bed, the water from the domestic supply points may not be of drinking water quality. Additional support for home water treatment and safe storage may be required.

There is very little policy support for multiple use schemes in general and specifically for sand-dam and sub-surface dams. Multiple use water schemes tend to fall between mandates in water supply and small-scale irrigation which are under different line ministries at federal level. The Dutch-funded Ethiopian WASH Alliance has supported replication of the sand river dams, involving the same partners (RAIN, RiPPLE, HCS). However, there is no evidence yet of any uptake of this particular mix of water harvesting technologies and multiple use approaches by the government.

Conclusion

The MUStRAIN project identified untapped potential for further development of these 'sand' river resources to supply communal schemes with sufficient water for domestic and productive uses. Unfortunately, the combination of dams in sand rivers with a multiple use of water approach could not be validated in this pilot. Still, various lessons can be formulated based on the MUStRAIN experiences, that may serve as recommendations for those who are interested in implementing dams in sand rivers.

- The planning, design and construction of dams in flood-prone sand rivers can be a complicated process, particularly when combined with water supply technologies for multiple uses.
- Proper planning is vital, taking into account seasonal fluctuations in rainfall and flood risks, to ensure safety during construction. Construction during the dry season, with some flexibility in planning, can prevent or account for delays and avoid damage to exposed structures. Allowances need to be made in the budget for contingencies caused by delays or changes in market prices for construction material.
- Participation requires considerable care and investment (time, human resources) to have the desired impact.

Coordination and collaboration is necessary. Implementers (including NGOs) need to have the required skills to plan, design and implement complicated multipurpose schemes based on sand dams and sub-surface dams. In Ethiopia, there might be a niche for very specialist NGOs or companies to provide the specific skills needed to implement these interventions.

The MUStRAIN project

The goal of the MUStRAIN project is "to address the critical water problems in water scarce rural areas of Ethiopia by collaboration, implementation of innovative and alternative solutions and exchange of knowledge and mutual learning". Scalable approaches to water harvesting (RWH) and shallow groundwater development (Self-supply) for multiple use services (MUS) has been the focus.

MUStRAIN brings together the strengths and builds partnerships of a consortium of Dutch-based organisations (IRC International Water and Sanitation Centre, RAIN Foundation, Quest and Water Health) and Ethiopian partners and experts with complementary interests in the sustainable development of approaches to MUS. MUStRAIN is led by IRC and funded by the Partners for Water (PvW) programme.

MUStRAIN aims to promote uptake of Multiple Use Services in different contexts within Ethiopia, by documenting replicable water access/MUS models. In eight case studies cost-benefit relations are analysed, as well as opportunities and challenges for implementation.

The MUStRAIN case studies are:

1. MUS from sand rivers
2. MUS and Self Supply
3. Mechanized pumping and MUS
4. Ecological sanitation for MUS
5. Greywater reuse for MUS
6. MUS and livestock
7. MUS and the Community Managed Project (CMP) approach
8. MUS and manual drilling

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The IRC International Water and Sanitation Centre is a knowledge-focused NGO working with a worldwide network of partner organisations to achieve universal access to equitable and sustainable water, sanitation and hygiene (WASH) services. IRC's roots are in advocacy, knowledge management and capacity building. IRC was set up in 1968 by the Dutch government on request of the World Health Organization as a WHO Collaborating Centre. Currently, IRC is established as an autonomous, independent, not-for-profit NGO with its Headquarters in The Netherlands, and local representation in the countries where IRC implements programmes. IRC has profiled itself over the years with innovation and action research to achieve equitable and sustainable WASH services.

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