Promoting the use of shallow groundwater for small-scale irrigation

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Background

AFRHINET was a three-year project which focused on fostering the knowledge and use of rainwater harvesting technologies for off-season small-scale irrigation in rural arid and semi-arid areas of sub-Saharan Africa. As part of this project, best practices on collecting and storing rainwater for off-season small-scale irrigation have been documented and evaluated.

This case study discusses the use of shallow groundwater for off-season small-scale irrigation. The overall goal of this case study is to contribute to the replication and scaling up of this type of technologies and practices in arid and semi-arid areas. The technical sheet has been developed in cooperation with the Roads for Water Learning Alliance (http://roadsforwater.org/) and the Flood-Based Livelihoods Network Foundation (http://spate-irrigation.org/).

The technology

This note describes how the systematic recharge of shallow groundwater recharge combined with appropriate water lifting can form the basis for productive small-scale irrigation in many of the dry areas of sub-Saharan Africa. Capturing rain-fall run-off and local floods and using it to recharge shallow aquifers can create water buffers that can provide water to tidy over dry spell, dry seasons and sometimes even relatively dry years. In general storing run-off and floodwater in shallow aquifers through a range of recharge techniques create far larger reserves than can be achieved with surface reservoirs.

Figure 1: Very shallow groundwater in Degem, Ethiopia. Photo: MetaMeta.

1. Promoting recharge and retention of shallow groundwater

In comparison to Asia the use of shallow groundwater is underutilized in Africa. Whereas there are an estimated 20 million farmer irrigation pump sets in India for instance, there are only fraction of this in Africa. Many areas have natural stocks of shallow groundwater but very often these are not intensely used. The exception are a number of high usage pockets often close to main urban centres. Shallow groundwater can also be replenished by a range of techniques. In fact in some areas with very intense watershed programs groundwater resources have been created that were not there before.

Though shallow groundwater use is on the increase, the systematic use of it is a frontier waiting to be explored. There is a rich range of techniques that help can recharge and retain groundwater, ensuring water is added to the buffer but also retained in it –making sure that water remains in the area. These techniques often combine with soil conservation techniques that serve to preserve a watershed from erosion. Different techniques serve different purposes and different condition –topography, rainfall, dominant land use determine what recharge techniques are appropriate where. It is important to know what to do where – how to manage sedimentation processes; where water can be stored and retained, where it infiltrates into the aquifer systems and what land cover and land management support this; how shallow groundwater travels, how it links to soil moisture; how micro-climate is influenced. Equally important is protecting the quality of ecosystems and maintaining water quality. In Table 1 an overview has been made –identifying techniques most appropriate in recharging and retaining groundwater and protecting land from erosion. The suitability of the techniques for different altitudes is given and how much the techniques is relevant for the recharge of groundwater, the retention and the reuse.

It is also important to do things at scale – when there is a large density of recharge measures the effect on groundwater is in the entire area is noticeable especially where we dissected valley with small local aquifer systems. This can create a landscape transformation – In East Africa there are by now a number of examples of areas where there was a turn-around transformation of areas, such as Machakos in Kenya and Tigray in Ethiopia. What is important is the entire transformation of landscapes: not piecemeal interventions that do not add up. If landscapes are transformed at scale, many processes change with it: the hydrology, the sedimentation processes, the micro-climates, the soil chemistry and nutrient cycle and the regeneration of vegetation cover. Also by working at scale side-effects - either locally or downstream - can be better taken managed. Most importantly with scale comes the transformation of lives and economies.

Figure 2: Groundwater recharge at scale: making half-moons to harvest road water in Ethiopia. Photo: MetaMeta.

The selection of techniques of course is very much based on the priority of those that live in the area, men and women, and local organizations – formal and informal. The overview describes of each technique whether the concerned techniques has an important impact on reducing erosion and maintaining soil fertility; on the recharge, retention and reuse of water – essentially to create healthy buffers; on micro-climate (including soil temperature) and on water quality.

Table 1: Techniques most appropriate in recharging and retaining groundwater and protecting land from erosion. Source: Knoop et al. (2012). Securing Water and Land in the Tana Basin: A resource book for water managers and practitioners. Wageningen, The Netherlands: 3R Water Secretariat.

Technique	Geographic Suitability			Function					
	Upper	Middle	Lower	Soil conservation	Recharge	Retention	Reuse	Micro-climate	Water quality
Grass strips	●			●		●			●
Gully plugging	●			●	●	●			
Bench terraces	●			●		●			
Stone bunds	●	●		●	●	●			
Planting pits		●	●	●	●	●			
Half moons		●		●		●			
Mulching	●	●	●			●		●	
Plastic mulching		●	●			●		●	
Farm forestry	●			●				●	
Composting						●		●	
Double dig beds						●		●	
Bio-char						●			
Boundary planting	●	●		●				●	
River bank plantation	●	●	●	●	●			●	●
Trapezoidal bunds		●	●		●	●			
Tied ridges	●			●		●			
Contour bunds	●	●		●	●	●			
Contour trenches	●	●		●	●				
Recharge pits/ tube recharge	●	●			●				
Hill ponds	●					●	●		
Surface ponds	●	●	●			●	●		
Rock outcrops		●				●	●		
Sand dams		●	●		●	●	●		
Roof top harvesting		●	●				●		
Subsurface dams	●	●	●		●	●	●		
Water from roads		●	●		●	●	●		
Protected wetlands	●	●	●	●	●	●		●	●
Controlled sand and gravel mining		●	●	●	●				
Spate irrigation		●			●		●		
Flood water spreading		●			●		●		
Flood recession farming			●		●		●		
Sand dune infiltration			●		●		●		
Making use of burrowing animals		●	●		●				
Holistic planned grazing		●			●			●	
Spring protection	●	●	●				●		●
Protection recharge zones	●	●	●		●		●		●

2. Developing shallow wells

To develop stronger water buffers through the different recharge and retention techniques descried above has large effects on local water availability, as follows:

- It generally increases soil moisture in the area –making rainfed farming more reliable and reducing the need for irrigation. It makes supplementary irrigation more attractive (Box 1).
- If there is more water in the shallow aquifer systems the base flow of rivers will increase and spring may develop that were not there before or that had dried up
- With higher and more reliable shallow groundwater it becomes easier to develop shallow wells.

Box 1: Off season versus supplementary irrigation

There are basically two main irrigation strategies. The first is to supplement with often life-saving supplies the cultivation of crops that are grown with the local rainfall or floods. The other strategy is to be able to irrigate high-value crops during dry periods. The advantage of the first strategy is that provides a high return as it prevents crop failure. The advantage of the second strategy is that makes crops available in the lean season –contributing to year-round food security and sometimes fetching extra-ordinary market prices.

In this section we look particular at the development of shallow wells. We look particular at the different types of wells and the methods of developing them. Depending on local terrain conditions but also on tradition and availability of workmanship, there a number of options for shallow well systems. The main categories are: open dugwells, either large or small diameter and shallow tubewells. Table 2 compares different types of shallow wells.

The most common shallow system in use in most parts of Africa are open hand dugwells. These are hand dug open pits that reach the shallow groundtable and penetrate in it. Depending on the soil where they are developed they may be reinforced by stone pitching or concrete rings or sometimes with woven brushwood.

This is even true for areas where shallow tubewells would be more appropriate – such as in flood plains or alluvial areas. In these areas shallow tubewells are preferable to dugwells as they are more durable, less costly and penetrate the water bearing strata deeper.

Hand dug wells are generally made by human labour working down to depths of 45m, mostly between 10 and 30m. The diameter and shape of the wells vary depending on the available materials, equipment, expected soil formations and ground conditions, familiarity of communities with specific sinking techniques and cost. Particularly for large diameter wells it is useful to develop steps into the well or a shaft – this well help access in case of emergency but will also make it possible to place a centrifugal well at larger depth, overcoming the difficulty of pumping of water levels that are beyond the typical suction depth (7 m) of centrifugal pump.

Whereas dugwells are common and are constructed in many different ways, manually drilled shallow tubewells are still less common in most part of Africa. In Asia however where geology permits and where is a choice between making a shallow well and dugwell shallow wells are always preferred. There are a number of low cost and simple technology methods available for drilling shallow tube wells using only human labour. Such drilling methods include hand augering, percussion, sludging, wash boring (or jetting). An overview of these methods -common in Asia– but not yet mainstreamed in Africa, is given in Table 3.

In general shallow tubewells are preferable to small diameter dug wells, that are in turn preferable to large diameter hand dugwells, but local condition should allow the particular groundwater technology to be feasible.

Table 2: Comparing different shallow well systems.

Type of well	Advantages	Disadvantages
Large diameter hand dug well	Location and size favours storage of floods. Farmers can go into the well when water level lowers to increase its depth (especially when equipped with steps). Small surface pumps can be easily installed.	Loss of significant cultivation land Expensive and time consuming. Creates unsafe conditions for humans and animals (when not protected). Digging deeper unsafe due to high possibility of collapse.
Small diameter circular hand dug wells	Cheaper compared to large diameter wells. Easier to provide protection than large diameter wells. Easily adaptable to simple water-lifting techniques when pumps not available.	Expensive compared to hand drilled wells. More difficult and expensive to provide protection than manually drilled wells.
Shallow tube wells	Equipment can be made from locally available low-cost materials Simple to use, minor training. Faster and cheaper than hand dug wells. Don't pose risk to people/animals Safe for drinking purpose when fully protected.	Suitable for unconsolidated materials – not for rocky terrain. Not possible to accommodate commonly available motor pumps in case water table lowers below the suction head of pump.

Table 3: Different manual well drilling techniques. Source: Abric et al. (2011). Lessons Learned In The Development Of Smallholder Private Irrigation For High- Value Crops In West Africa . Washington: World Bank.

Methods	Techniques	Average Depth (Meters)	Geology	Advantages	Drawbacks	Execution Time (Days)
Manual auger	Manual auger	10- 15	Sand, silt, clay (soft soils), gravel < 4mm	Easy to use	Temporary casing difficult to remove when there is a thick layer of clay	1
Sludging	Madrill, rotary, emas, rota-sludge	20-35	Sand, silt, clay (soft soils), soft consolidated formation (alterites)	Easy to use	Significant water consumption in permeable soils	2-4
Washbore	Jetting, washbore	6 - 15	Sand and silt	Fast	Needs a significant volume of water over a short period of time	<1
Percussion	Percussion stone hammer	15-25	Consolidated formation (laterite, rock)	Adapted to hard formation	High cost of equipment and not always available in time	7-10
Motorized auger	Motorized rotary, PAT-Drill 201	35-45	Any type of rock free consolidated formation	Fast in hard soil	Significant consumption of water, equipment +, implementation cost very high	1-5

The simple sludge drilling method is often the most easy to use and provided the soil are soft and sandy they can be used to drill to a depth of 30m through unconsolidated alluvial deposit. In this simple technology, human powered up and down motion of a drill pipe is used to penetrate the soft soil formation. It takes a small crew one to two days to complete the well – unless large boulders are encountered. The drill pipes can be made either from metal (GSI pipe) or bamboo (used in several Asian countries). Metal teeth connected at the bottom of the pipe ensures easy cutting. Water circulation is used to bring cuttings up to the surface whereby a one-way valve closed by hand at the top of the pipe -creating a suction head.

Figure 3: Developing new well by manual augering in Uganda. Photo: MetaMeta.

3. Selecting Water Lifting Technologies

To lift water from the well several technologies are currently in use. These can be categorized into manual and motorised pumps. The common manually operated pumps are bucket lift, treadle pumps, and rope pumps. Because of their small outputs, they are primarily intended for use on family wells. Bucket lift can be used for household water supply purposes and minor livestock watering purposes are not suitable because their operation is exhaustive, consumes more time and labour due to the large amount of water required for irrigation.

Rope pumps constitute a simple and affordable technologies that can meet the needs of household water supply and small plot irrigation. They are based on the principle of a chain with small cups that all lift water from the well but that tip it over once they are moved upwards. Rope pumps and lift water from a depth of up to 35m for drinking and minor hose hold use purposes. They can lift water for irrigation from a depth of up to 15m with average flow rate of 0.25 l/s and irrigation area of 0.1ha. Treadle pumps have a better discharge but a more limited range for lifting. It is difficult to use treadle pump beyond 7 m. They have an average flow rate of 1l/s and can irrigate up to 0.5ha with 4hrs of pumping a day. The limitations with manual pumps are that they are labour and time intensive, which restrains their popularity for irrigation use. They are often considered as a first step out of poverty for very poor farmers who cannot afford to buy motor. The experience from IDE in some of its project areas is that indeed farmers after one or two season promote themselves out of manual pumping and obtain a motorized pump.

Figure 4: Rope pump lifting water from a dugwell in Ethiopia. Photo: MetaMeta.

Different types of motorised small pumps are in use - either driven by fuel (petrol and diesel) or electric power. They irrigate from 0.5 ha up to 2 ha. The two types of motorized pumps are common: centrifugal pump sand small submersible pumps. Centrifugal pumps – usually in mono-block models - have a suction depth of 7 meter. This can (but only in the case of hand dugwells) be circumvented by placing the centrifugal pumps at lower depth. The cost of a centrifugal pump is often around USD 350-500. In recent years the price increased substantially.

Small submersible pumps are popular in some areas, where they are installed on smaller diameter hand dug wells, driven by electric power. While they work very well with hand dug wells, they are not suitable for the types of manually drilled narrow (<4") tube wells visited in Becho plain. A potential new development is the introduction of extremely low cost centrifugal pumps, manufactured in China, both self priming and non self priming. They have capacities of around 25m3 per hour. These are priced (excluding shipment) at USD 100– cheaper than rope pumps or treadle pumps. Often the cost of mechanized pumps is not much higher than of manual pumps. It explains why in some areas (irrigation has made a surge - with small capacity diesel pump-sets or small electric submersible pump. A new development that is the solar pumps – one example sunflower pump. At present the initiial costs of solar pump are still relatively high requiring some initiial subsidy.

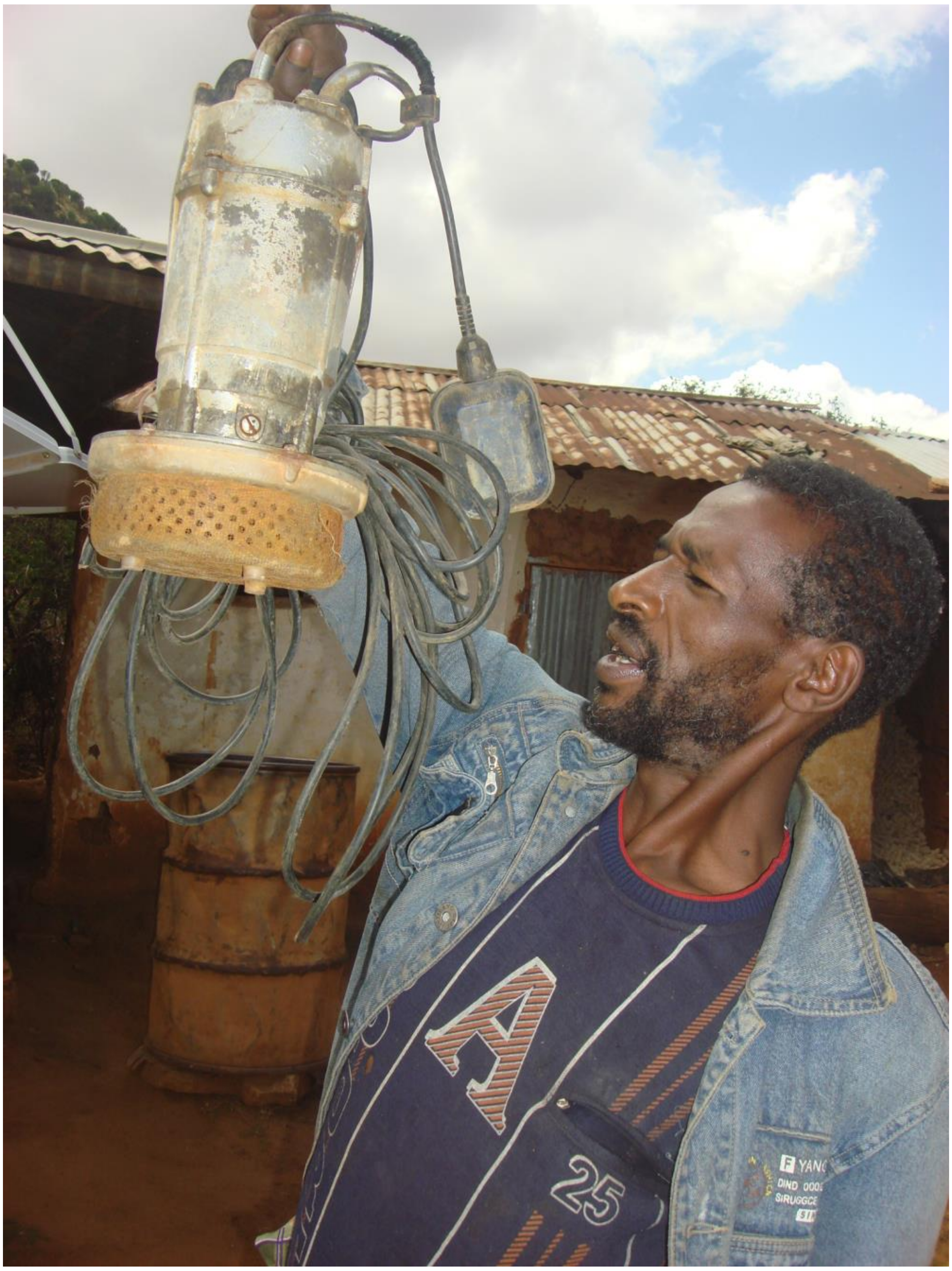

Figure 5: Showing small submersible pump in Ethiopia. Photo: MetaMeta.

4. Maintaining the groundwater systems

Most groundwater systems are used for multiple purposes, irrigation but also poulty and livestock and domestic water supply, especially when the irrigation system is developed close to the homestead. What is sometimes forgotten and not part of local practice is the maintenance of the well systems. Open wells for instance may be need to be cleaned regularly by adding chlorine. Depending on the climate, but particularly in humid areas vegetation may develop on the edges of the well and falll in the water, putrifying it. In case of shallow tubewells the filters may be clogged over time. This happens particularly when the filter diameter is large and the suction of pumping is high: fine particules then accumulate around the filter section and discharge capacity is reduced. This may be restored by backwashing the filter using a plunger.

5. Promoting shallow groundwater based irrigation

The potential for groundwater based small irrigation is high. This applies both for food production through techniques that improve on-farm recharge and add to soil moisture (infiltration pits, half-moons, check dams. The priority actions needed to enhance the water buffering in the country are:

- Introduce a systematic mapping tool for the site selection and technology choice of water buffer systems.
- Introduction of “new” technologies and their application criteria preferably through programs that are implemented at scale.
- Develop extension packages for community mobilization in construction operation and maintenance.

There is also a need to promote the use of groundwater. In general the returns to groundwater based farming from shallow groundwater systems are very good. It is not the general returns that drive the uptake of such farming however. The limitations to commercial farming appear to have more linked with the ability of farmers to absorb risks; have access to markets, especially in perishables where price manipulation is common; and access to good land. In some areas it has been observed that the cultivation of vegetables is often introduced by young farmer-entrepreneurs that often originate from other areas. They take the land on lease and even in a number of cases re-employ the owners of the land as laborers. Their assets are the skills both in vegetable production and in marketing. They also often have access to small private sources of capital. Such young enterprising farmers are often an important force for change, as they introduce new techniques and markets, which are often beyond the traditional land owners. It happens for the original land owners to take back the land once they have observed the skills of their leases.

Another bottleneck is in the availability of local well development capacity. The initial investment costs for a shallow tubewell drilling team is relatively high at USD 2000, whereas the equipment for manual dug well development is USD 25. In the long run the business of a shallow tubewell drilling team is more profitable –but it would need financing support to overcome the first step of ordering the equipment.

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