Manual well drilling: an alternative for shallow groundwater development for multiple use services (MUS)

Case studies of multiple use of water in Ethiopia (MUStRAIN case 8)

As part of the MUStRAIN project in Ethiopia, various approaches to water harvesting, multiple use of water and ecological sanitation have been studied. Here experiences with manual drilling are discussed, originally introduced for irrigation, but increasingly used for domestic purposes as well.

Manual well drilling at a glance

Main features:
Manual drilling is a fast way of drilling a small diameter borehole with manual labour to access shallow groundwater. It is usually combined with a rope and washer pump or a suction-only treadle pump.

Implementation:
A number of international NGOs, including Practica Foundation, IDE and World Vision, introduced and developed this technology in Ethiopia. Recently the government has promoted formation and training of private sector micro-enterprises able to provide manual drilling services. Although it is being scaled-up there is not yet wide access to the technology.

Options for multiple use of water:
With some adaptations to the drilling method and headworks, contamination of groundwater can be prevented making supplies safe for drinking as well as irrigation. Water quality may then be better than that in traditional, open, hand dug wells. Additional facilities such as cattle troughs can stimulate the use of water for livestock.

Challenges for uptake:
There is often a lack of knowledge about rock formations and groundwater levels with mapping only available for some areas. Drilling services are not yet widely available in all areas, with long delays and high prices reported. Different manual drilling techniques may be needed according to geological conditions, but NGOs and enterprises are usually specialised in a single technique.

Introduction

Unless groundwater comes to the surface naturally at a spring, holes have to be dug or drilled to reach it. Wells or boreholes are usually named after the excavation or drilling technique used, such as hand dug well, machine-drilled well, manually-drilled well etc. Manual drilling is an innovative low-cost technique for groundwater development where human labour is used for drilling the hole.

The introduction of manual well drilling in Ethiopia was initially aimed at the promotion of irrigation at household level, but more recently the technology has been applied to development of domestic water supplies as well. In practice, people use the manually drilled wells for various purposes, be it drinking, irrigation or watering of livestock, depending on their needs.

Implementation

The technique of manual well drilling was introduced to Ethiopia by NGOs. These included Practica Foundation, International Development Enterprises (IDE) and World Vision. This case focuses on the experiences of IDE and its sludging technique. IDE, an NGO established to operate in the country in 2007[a], has its head office in Addis Ababa with project offices located throughout the country, from

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

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where field officers work directly with communities and households.

Initially, IDE promoted manual drilling as part of a package of small-scale irrigation technologies to be used at household level. In 2008 two demonstration wells were drilled at the Ziway and Maki Farmer Training Centres (FTC) and installed with rope and washer pumps. The next year, eight more wells were drilled in the Arsi Negele district but these were unsuccessful because of the hard geological formation and depth to groundwater.

As it mainly targets water for small holder irrigation, IDE has a strong link with the agricultural sector, with other critical interventions including advisory services in marketing for the rural poor. In practice, many stakeholders use the facilities for multiple purposes, including domestic supply. This can be easily integrated into the design with some adaptations in the technique as discussed below. IDE has extended its collaboration to the Ministry of Water & Energy for work in drinking water supply. Currently the technology is being promoted by other NGOs and government for domestic water supplies too.

IDE also help to facilitate access to credit by injecting seed money into micro finance institutions to lend for households to invest in manually-drilled wells. The micro finance institution itself advises farmers on potential credit services and saving issues.

Features of manual drilling

Manual drilling is one of the more affordable solutions for farmers to use groundwater for irrigation[1]. The working principle of this drilling technique is 'hit and loosen', i.e. percussion, with some rotation if required[2]. It works best in loose soil and soft geological formations. Theoretically, manual drilling techniques such as the Baptist method (a type of sludging) can go down to 100 m[3], though in Ethiopia, IDE has been able to reach 50 m so far.

Manually drilled wells for rural water supply have a small diameter, 5-15 centimetres, whereas hand dug wells are at least 80 centimetres wide to allow a person to enter and move freely during digging. Machine-drilled wells for rural community water supply, are usually drilled a minimum 20 cm wide. Manual drilling can be a good alternative to digging that is tedious and labour-intensive. Because of the smaller diameter of the well these wells are more easily protected and covered so there is less risk of surface contamination.

The selection of a well drilling or digging technique depends on different factors including knowledge, technical support, costs, geological formations (hard or soft), and the required amount of water. Deeper aquifers tend to provide more water and suffer less from microbial contamination.

Multiple attempts may be needed before a well is successful. Dug wells may collapse during construction, particularly in clay soil areas, whereas drilling may be unable to get through stones. Abandoned dug wells can scar the landscape, whereas failed manually-drilled wells are easily covered.

IDE so far has used three main types of manual well drilling: the simple sludge method, the Baptist method and the Rota-sludge method. As the need for manual drilling grows, additional techniques such as auguring (as used by World Vision), and percussion may be introduced. All methods use some sort of lubricant to facilitate the drilling. Often a mix of water and cow dung is used. When the well will be used for drinking, alternative materials, such as clay, can be used to avoid contamination with faecal matter.

The simple sludge method is promoted due to its simplicity and low costs in terms of labour and time: it takes three persons to drill a well up to 20 m deep. Baptist methods are more labour intensive and require at least five persons for a well up to 10 m deep. If depth increases, more people are required and this makes it more expensive. The Rota-sludge method requires even more labour (a minimum of six persons) and is much slower, and hence incurs more cost than the other two methods. With this method of drilling a 30 m deep well may take a month, instead of five days as with the other methods. However, the advantage of the Rota-sludge technique is that a bigger diameter well (about 14 cm) can be drilled in one go, and this eliminates the need for well rimming (widening) to install a rope and washer or Afridev-type hand pump. All methods are suited to specific geological conditions, with sludging generally restricted to clay soil formations.

Once wells are excavated, they may need internal lining or casing, depending on geological formations. Lining is required for two main purposes: to avoid collapse and damage of the well, and to avoid contamination, including high turbidity, from surface inflow when the surrounding geological formation is highly permeable. The latter situation requires grouting (putting cement slurry or concrete) in the space between well wall and casing. Various materials can be used for well lining, depending on availability, diameter and depth of the well depth, water chemistry, etc. Accordingly, materials such as bricks, stone, concrete, wood, and clay are used for hand dug wells, while plastic (PVC, polyvinyl chloride) and steel sheets are more frequently used in machine drilled wells. PVC is used for low-cost manually-drilled wells.

Hybrid well

In some cases a well is dug or upgraded by a combination of digging by hand and manual drilling, creating a so-called telescopic or hybrid well. This practice is now growing around Ziway area in Oromiya region (e.g. in the districts of Adami Tulu and Dugda), especially among commercial farmers.

A telescopic well refers to gradually or step-wise decreased well diameter with depth, where the first part is usually dug with wider diameter, followed by drilling the lower part with smaller diameter (Figure 1). The purposes of this design are to minimize well collapse and increase the water yield of the well.

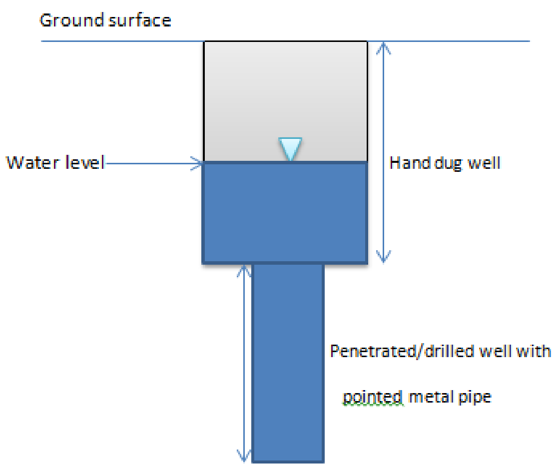

Figure 1. Sketch of a telescopic or hybrid well.

In the Ziway area, the first part of the well is hand dug and the lower part drilled by pushing (sometimes pointed) steel pipes of 5-9 cm diameter into the bottom. This requires loose soil such as silt and sand. The drill pipes are extended by adding more pieces, penetrating up to 24 m depth below the bottom of the hand dug well. After withdrawal of the steel pipes, PVC casing is installed to avoid collapsing. When the water rises, the upper part of the well serves as a sort of reservoir from where it can be pumped, e.g. by a diesel pump at the surface as in the case of the Dugda district.

Mr. Mola Tesfaye lives in the ward of Walda Makdala in the Dugda district. He is 25 years old and has a family with one child. He has constructed more than 25 hybrid wells. Mr. Mola gained the skill from colleagues in Maki town. The deepest well he made so far was 10 m hand dug plus 24 m drilled, together 34 m. His tariff is around € 78[b] per well in his own ward, irrespective of the depth. In other villages he charges up to € 155 to construct a telescopic well.

Pumps

After the lining is installed, the well needs to be fitted with a water lifting device, unless the well is artesian (tapping water from a confined aquifer, from which pressurized groundwater flows up through the well to above the ground surface when a well is drilled to it). There are different water lifting devices available. These include the traditional rope and bucket (with or without pulley) as commonly used for hand dug wells, various human- or animal-powered mechanical pumps such as different types of hand pumps and treadle pumps, as well as mechanised or engine pumps (using solar power, electricity or diesel and petrol fuel).

The selection of lifting device is determined by factors such as availability, depth to groundwater, diameter of the well (e.g. the Afridev hand pump needs 13.75 cm), number of uses and type of use (resulting in a required discharge over time) and costs. Engine pumps are more expensive than mechanical pumps, both in the initial investment and in their operation and maintenance costs. In addition, engine pumps require more skilled labour for operation and maintenance than mechanical pumps.

Currently the most common lifting devices are the Afridev type hand pump for communal domestic water supply, the suction-only treadle pump for household-based irrigation, and the rope and washer pump for family-owned wells used for irrigation and domestic purposes.

When the well is used for drinking and other domestic purposes, the pump and head works need special attention to prevent return flow and surface runoff from contaminating the well. Similarly, the quality of well casing has to be at least 3 mm thick PVC, a higher quality than that is usually used in an irrigation well.

Water quality

Regardless of any adaptations, households use the manually-drilled wells for domestic water supply, including drinking. Reasons for this include convenience, absence of alternative water sources and, interestingly, a perception that manually drilled wells have better quality water than rivers, streams or ponds. This may actually be true from a microbiological point of view as groundwater

[b] Conversion rates according to xe.com, November 2013: € 1 ≈ ETB 25.9.

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is generally less polluted with faecal matter than surface water. Moreover, the small diameter manually drilled wells are often better protected from surface pollution than traditional open hand dug wells with a larger diameter. However, there may be geochemical pollution, such as fluoride that is common in the Rift Valley.

Manually drilled wells in the Dugda district

Mr. Bejiga lives in the ward of Walda Makdela in Dugda district and is 70 years old, with 12 children, two of which have married. His well was constructed as part of the training activities organized by the Ministry of Water and Energy with IDE and funded by UNICEF. The total costs of the facility were € 175-200, which could be borne by farmers. However, farmers in the area are suspicious of making advance payments because of bad experiences in the past. The farmer paid around € 12 in cash towards the well construction and pump and contributed labour and coffee for the construction team. Previously Mr. Bejiga had two traditional wells: one on his farmland for irrigation and another near the house for watering cattle, though it required quite some labour to draw water for the cattle. The second well has been closed and the family now only uses the manually drilled well, both for domestic uses including drinking (some 70 litres), and watering of 25 heads of cattle, daily. The farmer waters his cattle by carrying buckets to the animals to keep the well surroundings clean. Moreover, the initial design of the manually-drilled well did not include a cattle trough. There are plans to use this well for irrigation and washing in the future. So far no water shortage has been observed.


Figure 2. Mr. Bejiga Chali pumps water from the manually drilled well with a rope and washer pump.

Mr. Bejiga likes the closed nature of the well and comments that no visible contaminants can enter the well, nor can animals or children fall into it. He also appreciates the light operation since the rope and washer pump requires much less labour. Another advantage is that there is no disruption of the water service as with the traditional well that had to be cleaned and deepened regularly.
For irrigation, the family still uses the traditional hand dug well in the farm land, away from their house. The costs of this well and its petrol pump were met by the farmer himself.

Ms. Kebebush is 60 years old with seven children (one daughter and six sons) and also lives in the ward of Walda Makdela in Dugda. The family has one manually drilled well for domestic use and one traditional well for irrigation. The manually drilled well is 27 m deep and also equipped with a rope and washer pump. The well was again constructed as part of the training that IDE provided for the Ministry of Water and Energy to technicians from different regions. Hence, the family had to contribute only around € 12 plus water for drilling and labour. The rest was covered by the Ministry. Water from the manually drilled well is used for drinking, cooking and washing as well as for cattle watering. The future plan is to use it for irrigation as well.

Figure 3. Ms. Kebebush Ergicho and her manually drilled well with rope and washer pump**.**

The traditional well is of the hybrid type, with a total depth of 25 m: first 7 m dug by hand and the next 18 m drilled with steel pipes. Water from the well is pumped out with a petrol pump through a long hose to irrigate the family's 1.5 hectares of farmland. The irrigated crops are tomato and onion, with two harvests a year.

Figure 4. Hybrid well for irrigation (left) and plastic hose leading the water to the farmland (right).

According to Ms. Kebebush and her son Wodaje Zemede, the expenditure for an onion crop on a quarter hectare of irrigated land is between € 500 and € 545 for seed, fertilizer, pesticide, labour and watering (fuel). The income varies from € 231 to € 3856. Onions are watered every three days on average and the farmers need seven litres of fuel for a single irrigation of the quarter hectare.

Mr. Dago Bote is a 45 years old farmer living in the ward of Bakale Girissa with five children. The farmer has a manually drilled well of 22 m depth, installed with a suction-only treadle pump, delivering a discharge of 0.3 l/s. The well was constructed late 2011 at a total cost of € 64.50[c]. The farmer has contributed around € 30[c] in cash and the rest by labour, water for drilling, clay and other local materials. No credit was received.

The facility is used for irrigation, cattle watering (15 heads) and domestic supplies, including drinking and cooking. The cattle's water consumption from this supply is 20 l/capita/day. Nine other households collect water from the well for drinking, without payment. In return, Mr. Dago's family uses the 4 m deep traditional well at the neighbour's for washing as the water from the manually drilled well consumes a lot of soap (it could be hard water).

Figure 5. Mr. Dago with his manually drilled well, suction-only treadle pump and some of his children in front of his irrigated land.

[c] November 2011 exchange rate: € 1 ≈ ETB 23.2.

The irrigated land is 300 m^2 and cultivated with chili, onion, kale, green pepper and potato, used both for family consumption and sale (Table 1). Other costs include maintenance of the treadle pump, such as replacement of the wooden pole for moving the treadle up and down (€ 2.47).

Table 1. Expenses and income (in €) from crops irrigated from the manually drilled well of Mr. Dago in 2011/12 (Ethiopian year 2004).

Item	Potato	Onion	Chili	Kale
Expenses				
Seed	2.70	15.42	0.39	1.93
Compost	96.41	9.64	1.16	2.89
Labour	Yes	Yes		
Income	2.31	53.99		7.71
Home consumption (months)	2	3	3	6

Mr. Girma Bulfato is 39 years old, lives in the ward of Darara Dalacha in the Dugda district and has nine children. Mr. Girma has two wells: one hand dug well and one manually drilled well. The first well, 10 m deep, was dug by the family during six days in 2009. At current price, the costs would have been € 23.14. The farmer bought a rope and washer pump for € 57.85 with the assistance from a private microfinance institution called 'Metemamen'. Mr. Girma paid € 28.92 upfront and the remaining € 28.92 within a year. Water from the well is used for irrigation of cabbage, green pepper and other crops, for cattle watering (25 animals) and domestic uses such as drinking, cooking and washing.

Figure 6. Mr. Girma Bulfato next to his hand dug well equipped with rope and washer pump.

The second water supply facility of Mr. Girma is a manually drilled well installed with a suction-only treadle pump. The well has a depth of 16 m and was constructed in 2011. The entire price of the facility was € 64.65[c] out of which the farmer contributed € 32.33 in cash, as well as labour, food for the IDE drilling team, and materials, such as water and cow dung as drilling lubricant. It took the drillers three days to finalize the construction of the well. The farmer was interested in a second well because he needed more water to irrigate more land. Both wells are used for all purposes. No other households have to come and collect water, as they did earlier from Mr. Girma's manually drilled well, as all households in the area now have their own wells. Few households even use the hand dug well with Afridev-type hand pump[d], recently installed in the village by an NGO.

[d] See MUStRAIN case study 7 for an illustration of the Afridev pump.

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Figure 7. Mr. Girma's manually drilled well with suction-only treadle pump.

Mr. Girma irrigates 1325 m^2 from his two wells and grows kale and green pepper (Table 2).

Table 2. Expenses and income (in €) from crops irrigated from the two wells of Mr. Girma in one year.

Item	Green pepper	Kale
Expenses		
Seedling	11.60	5.79
Compost	5.79	5.79
Labour	Yes	Yes
Income	140.39	96.41
Home consumption (months)	12	7

Costs and benefits

The unit rate of drilling depends on the well diameter to be drilled, the size of the team and the duration of the drilling as the farmers are responsible for the provision of food and shelter for the entire duration of the drilling process. Drilling alone costs around € 1.28 per meter depth as per IDE's current practices.

The price of drilling increases with the diameter of the well. The usual practice is to start drilling with the smallest diameter (3.75 cm) drill and then gradually widen it through rimming until the required diameter is achieved. Accordingly, a 11.25 cm diameter well can be made by rimming the initial 3.75 cm hole twice, so the total cost becomes € 3.82/m. Hand digging costs (€ 1.29-€ 5.17/m) excluding lining are about the same per metre as manual drilling including lining. Lining costs of hand-dug wells are variable but can be high. Lining is sometimes avoided where hand-dug wells are used for irrigation (assuming the formation is not prone to collapse), but some lining is desirable where wells are to be used for drinking.

Separately sold, according to IDE, a suction-only treadle pump would cost € 23 and a rope and washer pump € 69, for a maximum depth of 24 m. These prices are exclusive of lining or casing. The cost of PVC well casing varies depending on its quality and diameter. In March 2013, the local market price for 3.75 cm diameter PVC was € 0.60/m, while that of a 10 cm pipe varied between € 1.27 and € 3.86/m. Community Marketing Agents (CMA) install the pump for some € 1.50. For manually drilled wells total costs including a rope and washer pump are € 174-€ 193.

Generally, farmers are familiar with the construction, maintenance and use of traditional hand dug wells and hence know the associated costs and benefits. They are less aware of the recently introduced manually drilled wells. Many see advantages of hand dug wells: easy to clean, can be deepened if they fall dry during the dry season and store more water for multiple uses. However, users prefer manually drilled wells for domestic water supply as they are thought to have better water quality. Hence Ms. Kebebush Ergicho and her family use the manually drilled well for domestic supply and the traditional hand dug well for irrigation.

Potential challenges of scaling up

The technique of manual drilling cannot be applied everywhere and is largely confined to soft rocks and soils. Hard rock areas can hardly be penetrated with human labour and machine drilling is needed. Unfortunately in many parts of Ethiopia there is a lack of detailed subsurface geological information, so it is only possible to differentiate between hard and soft rock underground through trial and error. In addition, there is a general lack of knowledge on groundwater tables and their seasonal fluctuation.

Access to credit is a major obstacle. Theoretically, the provision of credit is based on an assessment of the farmer's need for the technology. Furthermore, the farmers need to meet criteria that include a landownership certificate, maximum loan amount, its duration and interest, as well as consensus of the family (both husband and spouse must sign), and finally the collateral required by the micro finance institution. The latter can be problematic as some farmers, particularly young people who recently established families. Often these do not have a land ownership certificate that can be used as collateral.

Conclusions

Manual drilling is a fast and relatively low-cost method of accessing shallow groundwater for multiple uses. There is a large variation in cost between the enterprise or organisations involved, and diameter. Manual drilling is normally cheaper than hand digging. One reason is the time taken, as the farmers have to provide food and shelter to the well construction team throughout the period of digging (usually several days) or drilling (generally less than a day). Another key reason is the lower cost of lining.

Initially the promotion and distribution of manually drilled wells was set up for irrigation, but in practice people use these wells, especially when equipped with rope and washer pumps, for various purposes. It is convenient, with higher discharges at lower effort than hauling a bucket on a rope from an open dug well. Moreover, the smaller diameter well and its covering slab prevent inflow from dirty surface water. However, if the water is to be used for human consumption, contamination of the groundwater during drilling needs to be prevented by replacing manure with other lubricants and ensuring cleanliness of the material. Other uses of water could be supported by additional facilities, such as cattle troughs. Hence, more value can be obtained from manually drilled wells by incorporating future uses into the choice of technology and practice of construction.

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 rainwater harvesting (RWH) and shallow groundwater development (Self-supply) for multiple use services (MUS) have 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

The methodology for the current case study (8) included a review of documentation provided by IDE, who introduced manual drilling to Ethiopia, complemented with information from internet. A field visit was carried out in the Dugda district in the East Showa sub-region of Oromia Region (March 2013).

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