IWMI Working Paper

155

Manual Well Drilling Investment Opportunity in Ethiopia

Elizabeth Weight, Robert Yoder and Andrew Keller

International Water Management Institute

RESEARCH PROGRAM ON Water, Land and Ecosystems

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IWMI's mission is to improve the management of land and water resources for food, livelihoods and the environment. In serving this mission, IWMI concentrates on the integration of policies, technologies and management systems to achieve workable solutions to real problems—practical, relevant results in the field of irrigation and land and water resources.

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Project

The AgWater Solutions Project was implemented in several countries in Africa and Asia between 2009 and 2012. The objective of the project was to identify investment options and opportunities in agricultural water management with the greatest potential to improve incomes and food security for poor farmers, and to develop tools and recommendations for stakeholders in the sector including policymakers, investors, non-governmental organizations (NGOs) and smallholder farmers. This report synthesizes the research findings and contributions made by the team and stakeholders in Ethiopia over the project period.

The leading implementing institutions were the International Water Management Institute (IWMI), the Food and Agriculture Organization on the United Nations (FAO), iDE, the International Food Policy Research Institute (IFPRI) and the Stockholm Environment Institute (SEI).

For more information on the project or for detailed reports, please visit the project website (http://awm-solutions.iwmi.org/home-page.aspx) or contact the AgWater Solutions Project Secretariat (AWMSolutions@cgiar.org).

Contents

Summary

Interventions that benefit the rural poor in Ethiopia could potentially improve the lives of almost 36 million people in the country. Approximately 83% of Ethiopia's population of 82.8 million lives in rural areas, and 52% of the rural population live in poverty (International Fund for Agricultural Development [IFAD]). Improving smallholder farmers' agricultural productivity and access to water can help to increase their incomes, improve food security, and provide water for livestock and domestic needs.

In many countries in Asia, Africa and Latin America, manual drilling of wells is one solution which allows farmers to reliably and affordably access shallow groundwater resources. Once a well is drilled, farmers have a variety of options for lifting the water, storing it and applying it to their crops.

While manual well drilling is common in many countries in Asia, Africa and Latin America, it is not widely available in Ethiopia. Pilot efforts made by iDE Ethiopia to test manual well drilling were successful in the areas selected: these efforts demonstrated profitability for farmers, well drillers and well drilling apprentices; high demand among farmers for manually drilled wells; and feasibility of manual well drilling in the hydrogeological settings of the pilot areas.

To scale-up these successes to meet the demand of farmers and improve their access to water requires investments in (a) creating a spatial database of key soil, hydrogeology, and water resources data and information. This will enable an assessment to be made of the potential scale of, and effective selection of areas with high potential for, manual well drilling; and (b) expanding private sector well drilling in the country. These are explained below:

a. Manual well drilling is viable only in specific hydrogeologic settings. With careful selection of areas in the pilot study, iDE Ethiopia had an 80% success rate in manual well drilling. There are, however, insufficiently detailed and accurate data, information, and maps regarding soil, hydrogeology and water resources throughout Ethiopia to determine all locations that are suitable for manual well drilling. Investments of approximately USD 3 million in mapping, data collection, ground-truthing and drilling of test wells are needed to determine areas suitable for manual well drilling. These investments would result in a spatial database of agricultural water information and data, which can be used by the government, investors, well drillers and others to assess the potential scale of the industry and to effectively target areas of high potential for manual well drilling. The database can also be used to assess the potential and monitor impacts of a variety of investments in water access, utilization and agricultural water management. Thus, establishing this database greatly increases the chances of success of a manual well drilling industry and other agricultural water-related investments in Ethiopia.

b. In locations where data and maps show physical suitability for manual well drilling and a potential customer base sufficiently large enough to support private sector manual drilling, further investments may be needed to support expansion of private sector drilling in Ethiopia through driller training, creating demand from farmers for manually drilled wells and stimulating smallholder agricultural value chains. If data and mapping show areas where manual well drilling is not feasible at scale, further investments in private sector well drilling would not be promoted in those areas.

Once the suitable areas are defined, it is then possible to estimate the potential scale (e.g., potential number of farmers reached) of manual well drilling in the country, the costs to reach those farmers, and the return on investments in scaling-up private sector manual well drilling. It is projected that external support for manual well drilling could catalyze the sector within 3 to 5 years. In that time frame, it is expected that private sector manual well drilling enterprises and associated supply chain actors would be financially self-sustaining. It is estimated that a flourishing manual well-drilling industry, supported by ongoing training and certification, could provide groundwater access for over 75,000 farmers within five years and close to one million farmers within 15 years. Without external support, private sector manual well drilling may advance independently but in a significantly longer time frame.

INTRODUCTION: AGRICULTURE IN ETHIOPIA

As stated in the "Agricultural Water Management National Situation Analysis Brief" for Ethiopia in January 2010, smallholder farmers in the midland and highland areas practice mixed farming systems, e.g., livestock and crop production are integrated and equally important; in the lowland areas of the country, agro-pastoral systems are less common; and most farmers utilize pastoral systems. Single cropping is the norm in Ethiopia, and double-cropping is practiced along rivers. Women play an important role in agricultural production, which is predominantly subsistence, rainfed agriculture. The potential irrigable area is 3.7 to 4.3 million hectares (Mha), but the actual irrigated area is approximately 7-10% of this potential (AgWater Solutions Project 2010).

Smallholder farmers without access to water are limited to rainfed crop production. As rainfall can be unreliable, improving smallholders' access to water reduces their vulnerability and risks, increases their incomes, improves food security, and provides water for livestock and domestic needs. In many areas in Ethiopia, farmers cannot easily access water for irrigation. Some farmers dig wells by hand to access shallow groundwater for irrigation; these wells provide some access to water, but often the water yield is too low for effective irrigation. Mechanized well drilling can drill deep wells and reach high-yield strata, but this option is too expensive for the majority of individual small-scale farmers and communities in Ethiopia. Manual well drilling is one option that enables farmers to access shallow groundwater resources for irrigation at an affordable cost.

BACKGROUND: AFFORDABLE MANUAL WELL DRILLING

Utilization of groundwater for crop production requires accessing this water from a hand-dug well, a manually drilled well or through mechanized well drilling. Both hand digging and manual drilling of wells rely on manual labor to access shallow groundwater resources. Table 1 provides a basic comparison of these three options for accessing groundwater. As shown in Table 1, each option is suited to a specific set of variables. Manual well drilling is the most appropriate low-cost option available for individual smallholder farmers to access groundwater resources under specific geophysical conditions.

Using manually drilled wells, smallholder farmers have installed millions of pumps mounted on tube wells (drilled wells with pipe casing) to access shallow groundwater resources for irrigated farming in at least 20 countries around the world, including Bangladesh, the Ganges Plain of India and Nepal, Bolivia, Chad, Madagascar, Mali, Nicaragua, Niger, Nigeria, northern Sudan and Uganda (RWSN 2013). In Bangladesh, more than 8 million hand-drilled wells have been developed primarily by small-scale private enterprises (RWSN 2013). In Niger, there are 50 manual drilling enterprises that are drilling wells primarily for irrigation; well diggers report that there is a demand for hand-drilled wells and little demand for hand-dug wells (UNICEF 2009). In Nigeria, more than 100,000 wells have been manually drilled. In Sudan, manual well drillers operate as private enterprises without support from the government or other sources.

In locations where private sector manual well drilling is common, drillers charge for their expertise and services at negotiated rates dictated by competition. The cost for a manually drilled well varies depending on depth: drilling deeper requires additional time and labor, which increases the cost. The cost ranges from approximately USD 18 to USD 200 and is significantly less expensive than motorized drilling, which costs approximately USD 1,200 to USD 1,600 for a 6-12 meter depth (Onimus et al. 2010). In Ethiopia, the average depth of wells drilled manually by iDE Ethiopia is 20 meters and the maximum depth is 36 meters. Manual drillers in Sudan typically drill to depths of 50 meters.

TABLE 1. Comparison of hand-dug wells, manually drilled wells and mechanized well drilling.

	Hand-dug wells	Manually drilled wells	Mechanized well drilling
Business entry costs	Very low cost for hand tools.	Low cost: an initial investment of approximately USD 1,300 for a business in Ethiopia.	High cost (varies depending on the equipment).
Cost to farmer	Labor cost if dug by self or if labor exchange is used. Low cost if hired labor (comparable to a manually drilled well); more expensive if lined.	Low cost (approximately USD 18 - USD 200 for a 6-12 meter depth).	Approximately USD 1,200-USD 1,600 for a 6-12 meter depth.
Benefits to women	In many contexts, it is not socially acceptable for women to dig wells. So, women do not dig their own wells and do not use labor exchange for well digging. Hiring well diggers may be an option to improve women's access to groundwater.	Hiring manual well drillers may be an option to improve women's access to groundwater.	Financial barriers often restrict well drilling on women's plots.
Accessibility of service for farm households	Wells are constructed either by experienced local well diggers or by villagers themselves, sometimes involving labor exchange. There are an estimated 31 million hand-dug wells in Africa (Cranfield University; Skat; WaterAid; and IRC International Water and Sanitation Centre 2011).	Where private sector services have scaled up, local small-scale businesses drill boreholes in villages.	In many sub-Saharan African (SSA) countries, motorized drilling rigs are used for municipal, industrial and domestic water supply development, but these are not affordable to smallholders. Access to sites far from paved roads can be difficult for motorized drilling rigs.
Time/labor requirements	Very laborious and time consuming.	Under ideal conditions, wells can be drilled and pumps installed in less than a day (average of 2-3 days).	Drilling is very fast, but transporting a motorized rig to a rural site can be time consuming.
Access to water	Depth of hand digging recorded up to 3 meters (Cranfield University; Skat; WaterAid; and IRC International Water and Sanitation Centre 2011). Difficult to dig below the water table without lining, which limits water yield.	Under the correct geophysical conditions, a depth of up to 50 meters can be achieved with deep penetration into the water table and good water yield in permeable stratum.	Water can be accessed at great depths.
Applicability under different geophysical conditions	Applicable under many geophysical conditions, with the exception of hard rock terrain. In sandy soils, wells must be lined (which increases costs).	Applicable in sand, loam and clay soils, as long as it penetrates the water table in permeable stratum. Not applicable if cobble or hard stone ≥ 5-10 cm or soft stone ≥ 20-30 cm thick.	Can be used under most geophysical conditions.

Once a well is drilled, farmers have a variety of pump options (e.g., treadle pumps, rope and washer pumps, motorized pumps) available for lifting water from the well; a variety of water storage technologies available for storing water; and a variety of water application methods (e.g., drip or sprinkler) available to apply water to crops.

Efforts to scale-up the successes of manual well drilling in Africa include the following:

- The United Nations Children's Fund (UNICEF) is mapping the feasibility of manual well drilling in 12 countries in sub-Saharan Africa: Chad, Madagascar, Niger, Sierra Leone, Central African Republic, Mauritania, Togo, Senegal, Benin, Côte d'Ivoire, Liberia and Mali (UNICEF 2012).
- Organizations supporting manual well drilling programs in Africa include UNICEF; Winrock International, USA; Enterprise Works/VITA (Volunteers in Technical Assistance), USA; PRACTICA Foundation, the Netherlands; the Rural Water Supply Network (RWSN), Switzerland; Ajuda de Desenvolvimento de Povo para Povo (ADPP), Mozambique; Arrakis, the Netherlands; Development Aid from People to People in Zambia (DAPP), Zambia; and Southern Highlands Participatory Organisation (SHIPO), Tanzania (Danert 2009).
- UNICEF has produced a series of technical notes on manual well drilling, including "The Case for Manual Drilling in Africa", "Professionalizing Manual Drilling in Africa" and technical support documents on methods, techniques, etc. (UNICEF 2012).

One alternative to private sector manual well drilling is communal well drilling, whereby community members rotate drilling responsibilities and provide community labor for well drilling. This approach is common in countries where manual well drilling is promoted for non-irrigation household needs. This approach minimizes households' cash requirements, but does not incentivize the establishment of private sector businesses.

MANUAL WELL DRILLING IN ETHIOPIA

In Ethiopia, low-cost manual well drilling is not widely available - there are no village-based private-sector craftsmen who can be hired by farmers to drill irrigation wells. In 2009, iDE Ethiopia started pilot studies in the country to determine the technical and financial feasibility of private sector manual well drilling and to assess the demand for wells amongst farmers. Following the pilot study, iDE Ethiopia and partner organizations introduced larger-scale efforts to create an industry of private well drillers. This has been possible because of the financial support provided by United States Agency for International Development (USAID) and the AgWater Solutions Project, which is funded by the Bill & Melinda Gates Foundation.

The goals of the pilot efforts were to:

- create an industry of private well drillers skilled in a variety of drilling techniques suitable for Ethiopia's challenging geologic conditions;
- map new areas with potential for manual well drilling using geographic information systems (GIS); and
- develop the necessary equipment in order to reduce the cost and improve efficiency.

Figure 1 shows a farmer in Ethiopia using a treadle pump installed on a manually drilled well to irrigate a small plot (1,000 m^2) of high-value vegetable crops for the Ziway market. Figure 2 shows an Ethiopian crew manually drilling a well using the percussion technique adapted from Asia.

FIGURE 1. Treadle pump installed on a manually drilled well in Ethiopia.

Source: iDE Ethiopia.

FIGURE 2. Ethiopian manual well drilling crew.

Source: iDE Ethiopia.

As a result of these efforts to initiate private sector manual well drilling, from 2009 to the end of 2010, 175 manually drilled wells were completed (more than 90 farmers paid to have wells drilled and pumps installed for irrigation; the remaining 85 wells were test/training/demonstration wells, where iDE Ethiopia paid for drilling and farmers or the community paid for the pump). By the end of 2011, 450 wells had been drilled; 20 drillers were certified and 9 drillers purchased their own drilling equipment to start their own businesses.

These pilot efforts have demonstrated the following:

- The drilled wells provide irrigation water to small-scale farmers; in addition, many wells are also used by farmers and neighboring households for livestock and domestic needs.
- Private sector manual well drilling businesses can operate profitably once someone is trained in technical manual well drilling and business management skills.
- Creating a private-sector industry of affordable manual well drilling services is financially viable.
- Female farmers benefit from improved access to water. A well means they no longer have to travel long distances to collect water for domestic use and crop production, which saves time and labor.

Regarding competing products and/or services, IWMI conducted an analysis of the manual well drilling activities in Ethiopia and concluded that there is no substitute for manual drilling. Hand digging a well has a similar or slightly lower cost than manual drilling, but a hand-dug well cannot be dug deeper than about 75 cm below the water table unless a dewatering pump is used. Mechanized well drilling has the advantage of penetrating rock and reaching deeper strata, but is much more expensive (for example, the cost for one of the least expensive motorized drilling rigs is approximately USD 10,200).

Pilot manual well drilling activities undertaken by iDE Ethiopia demonstrated high potential for manual drilling in areas with suitable geophysical conditions. In addition, there is a huge demand among smallholder and large-scale farmers to access groundwater: for every well drilled, an additional three farmers were interested in investing in a well. In addition, stakeholder consultations undertaken by the AgWater Solutions Project showed both interest in manual well drilling and emerging financial support (e.g., from the World Bank, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, PRACTICA Foundation and Water For All) for this sector. Furthermore, the Government of Ethiopia sees manual well drilling as an effective and scalable way to develop the country's shallow groundwater reserves to benefit smallholder farmers. For example, with support from the World Food Programme (WFP), the government invited Sudanese manual well drilling craftsmen to train Ethiopian drillers.

PRIVATE SECTOR MANUAL WELL DRILLING BUSINESS MODEL IN ETHIOPIA

Building on data and information collected through the pilot activities conducted in Ethiopia, a private sector manual well drilling business model is described below.

In this model, private sector input suppliers and warehouses sell well drilling equipment and supplies, as well as irrigation pumps and accessories, to well drilling enterprises who are knowledgeable about local drilling conditions; experienced in drilling as well as selection and installation of irrigation pumps; and equipped with the knowledge, skills and tools needed to respond to farmers' requests to drill affordable wells.

Farmers pay the enterprise to drill a well and install a pump on their property. They then have improved access to water, which in turn can increase their crop productivity and the number of crops grown per year. Higher yields combined with market access can raise farmers' incomes.

Financial products and services are available along the value chain and tailored to the needs of farmers and other enterprises in this model.

The key features of this model are summarized in Table 2 and described below.

TABLE 2. Summary of estimated investment cost in well drilling and additional annual income values (in USD[a]).

	Investment cost	Additional annual income	Profit in year 1
Farmer	156	490	334
Well driller	1,247	2,740	2,493
Well driller apprentices[b]	0	667	667

Notes: [a] Exchange rates calculated at ETB 16.5 = USD 1.
[b] Calculated at an average of two apprentices at ETB 60 and ETB 80 per day for 200 days.

1. Farmers: Investment and return. Farmers invest in a manually drilled well, which provides affordable access to reliable irrigation water. The total cost to the farmer depends on the depth of the well and the choice of pump. At an average depth of 20 meters, the cost to the farmer is USD 156 for the well and suction-only treadle pump (in comparison, a larger bore manually drilled well together with an engine pump costs approximately USD 1,000). Farmers also invest in improving their knowledge and skills to grow irrigated high-value crops for the market in order to recover the costs incurred in constructing the well. While numerous variables affect the estimated cost and income figures (e.g., depth of water, market access, agricultural risks and smallholders' agronomic knowledge), the estimated additional income for a farmer with a manually drilled well and a suction treadle pump, and a 700 m^2 plot is approximately USD 490 (returns to land and labor are calculated as follows: if the farming household operates the treadle pump for 3 hours per day with a 5-meter water lift to irrigate a 700 m^2 plot and if the net return to land, labor and water is USD 0.35/m^2, the net return per crop is USD 245 or USD 490 for two crop seasons per year. The cost of the well and the irrigation pump are USD 156, so the total net additional income is USD 334. This assumes that the farm family contributes 110 person days of labor per crop season for two seasons (a total of 220 days per year) for land clearing, seed preparation, irrigation, production, harvesting and selling). This income pays for the cost of the well and the treadle pump within one year and provides an additional net income of USD 334.
2. Well drillers and apprentices: Investment and return. Private well drillers invest in improving their knowledge and skills and in establishing and operating a well drilling business. Drillers are qualified to drill, develop the well and install a variety of pumps. The drilling enterprise owner manages all drilling activities; hires and supervises helpers at the drilling site; provides equipment and organizes transportation of equipment to the site; pays for miscellaneous costs (e.g., broken tools); cleans the well and installs casing/filter/gravel pack; develops the well and confirms that the water yield is acceptable; installs the pump; and collects payment from the farmer. Drillers know how to interact with customers, set drilling rates that provide a reasonable profit, and determine policies to cover the cost of failed wells and pay for broken equipment.

As an example of the process implemented during the well drilling pilot study conducted in Ethiopia, the driller and farmer discuss and agree on the cost to drill a well. An advance payment of USD 18 (ETB 300) is paid; if the well is unsuccessful (e.g., if no permeable strata to sustain pump flow or if the water table is too deep), the driller refunds 50% of the advance. If the well is successful, a fee of USD 2.40 (ETB 40) per meter is paid by the farmer to the driller, which pays for the fees of the driller and the driller's apprentices, amortized drilling equipment costs, driller team and transport (an additional fee is charged to enlarge the hole if required for a rope or engine pump). If the driller hits stone, they move to a new site selected by the farmer and commence drilling again at no additional cost. The farmer pays for pump, casing, gravel pack, transport, etc.

The estimated profit for a lead well driller from well drilling and pump installation is USD 1,493/year. A well driller's annual profit of USD 1,493 (ETB 24,640) is calculated as USD 17.77 (ETB 293) per well, with an average of 7 wells drilled manually per month for the entire year (or 84 wells per year). The key variables for calculating the well driller's income are: the total cost of equipment (USD 1,247 [ETB 20,560] or USD 15 [ETB 245] per well) plus labor (USD 1,333 [ETB 22,000] or USD 16 [ETB 262] per well), the number of wells that can be drilled with each set of equipment (approximately 25 wells), and the average depth of the well. Many manual well drillers operate their business during part of the year and continue to farm or work in another trade during the rainy season when drilling is difficult.

Lead well drillers hire and train apprentices, who become experienced in a wide range of drilling situations. Apprentices often establish their own profitable well drilling businesses. Apprentices earn USD 3.64 (ETB 60) per day and a junior apprentice earns USD 3 (ETB 50) per day. Excluding the rainy season, when well drilling is difficult, apprentices and helpers can expect approximately 200 days of work each year. Assuming that there is no drilling during the three-month rainy season and an average five-day work week for the rest of the year, there would be about 200 days of well drilling by an enterprise each year. For an apprentice earning ETB 60 a day, the annual income for drilling work would be ETB 12,000 (USD 727). Increasingly, the drillers pay their apprentices/ helpers on a per-meter drilled basis to provide greater incentive for efficient work. The per-meter payment rate is estimated to approximate the average daily rate.

This income is competitive with alternative sources of income for unskilled labor, where the rates are approximately USD 3 (ETB 50) per day in Ziway town. Thus, the income of the lead drillers is 140% higher; 20% higher for apprentices; and the income of junior apprentices is comparable to alternative sources of income for unskilled labor.

3. Supply chain profitability. Supply chain actors profit by providing parts required for drilling and inputs required by farmers who invest in their farm businesses. For example, the drilling enterprise owner purchases hand tools, drill pipe fittings, chains, ropes and pulley from retail supply shops; each farmer purchases the PVC casing, eucalyptus and the irrigation pump. Each drilling enterprise owner invests approximately USD 1,247 (calculated at USD 371 (ETB 6,122) per set of well drilling equipment, which drills approximately 25 wells and each well driller drills approximately 84 wells per year) in well drilling equipment each year, so the supply chain actors profit when well drilling enterprises replace equipment and when the industry scales up in the country.

4. Financial products and services. Financial products and services are available throughout the value chain to enable farmers to invest in a well, and to enable well drilling enterprises and supply chain enterprises to invest in establishing and growing their businesses.

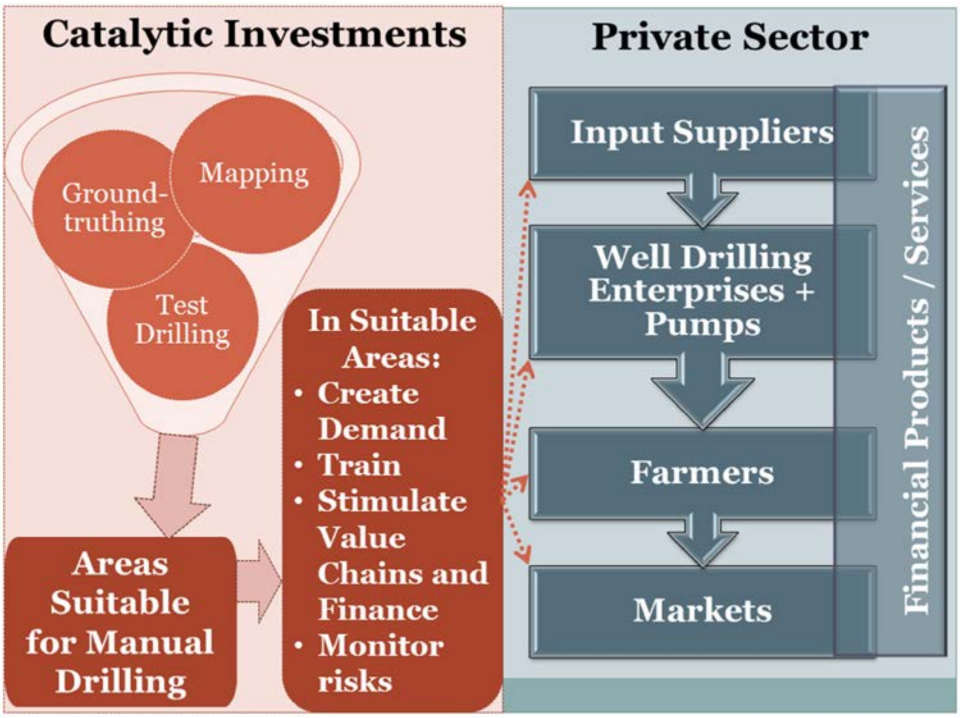
There are numerous synergistic products and services that leverage farmers' investments in water access and increase farmers' incomes. These products and services include irrigation equipment, quality seeds and support services for high-value crop production, soil management and market access.

INVESTMENTS NEEDED TO CATALYZE PRIVATE SECTOR MANUAL WELL DRILLING IN ETHIOPIA

The pilot manual drilling work demonstrated high demand; a high (80%) success rate in the pilot areas; and profitability for farmers, well drillers and well drilling apprentices. Based on the success of the pilot work in Ethiopia and building on experiences of private sector manual well drilling worldwide, there is potential to scale-up manual drilling in Ethiopia to increase smallholder farmers' access to water. As shown in Figure 3 and explained in more detail below, scaling-up the pilot initiatives requires investments in two key areas:

1. Creating a spatial database of agricultural water information and data, which can be used by the government, investors, well drillers and others to identify suitable areas for manual well drilling and to effectively target areas of high potential. Once the suitable areas have been identified, it is possible to estimate the potential scale (e.g., number of farmers reached) of manual well drilling, costs involved in reaching those farmers, and return on investment in scaling-up private sector manual well drilling. If data and mapping show areas where manual well drilling is not feasible at scale, further investments in private sector drilling would not be promoted in those areas.
2. In locations where data and maps show physical suitability for manual well drilling and a potential customer base sufficiently large enough to support private sector manual drilling, further investments may be needed to support expansion of private sector drilling in Ethiopia through training of drillers; creating demand from farmers for manually drilled wells; and stimulating smallholder agricultural value chains.

FIGURE 3. Catalytic investments needed to stimulate private sector manual well drilling.



It is projected that external support to manual well drilling will catalyze the sector within 3 to 5 years. At that time, it is expected that input suppliers, manual drilling enterprises and pump suppliers, farmers, financial products and services, and output markets will be linked through financially self-sustaining value chains. It is estimated that a flourishing manual well-drilling industry, supported by ongoing training and certification, could provide groundwater access for over 75,000 farmers within five years and close to one million farmers within 15 years. Without external support, private sector manual well drilling may advance independently but in a significantly longer time frame.

Investments in a Spatial Database of Agricultural Water Information and Data

Manual well drilling is viable only in specific hydrogeologic settings with suitable soil conditions: where well yields are sufficient for sustainable extraction of water resources for productive irrigation; where the water table is shallow; and where the water-bearing layers have sufficient permeability and thickness to provide the flow rate necessary for irrigation pumps. Sand, loam, and clay are generally easy to drill; compacted and cemented soils can often be drilled, but may require much more time and labor (and, therefore, additional cost) to drill. Manual drilling is, generally, not successful if boulders or stones larger than 5 cm are encountered or if drilling must penetrate hard stone layers more than 5-10 cm or soft stone layers 20 or 30 cm thick.

Ethiopia has a challenging geology for drilling when compared to river deltas and outwash plains in many countries in Asia and other African countries, where manual well drilling proliferates. This challenging geology creates geographical limitations for manual well drilling and can lead to increased costs if drilling failure rates are high. The pilot studies carried out established that areas exist in Ethiopia with high potential for manual well drilling due to shallow water and permeable soil layers. These areas are smaller than in the Gangetic Plain of Asia; however, with careful selection of areas, the success rate for manual well drilling was approximately 80%.

Current data, information and maps regarding soil, hydrogeology and water resources for Ethiopia are insufficiently detailed and accurate to determine specific locations that are suitable for manual well drilling. Therefore, investments of approximately USD 3 million in field-level data collection on surface geology and aquifer conditions, together with mapping and drilling of test wells, are needed to determine areas suitable for manual well drilling and to estimate the number of smallholder farmers who could potentially benefit from manually drilled wells. These investments would result in a spatial database of agricultural water information and data, which can be used by the government, investors, well drillers and others to assess the potential scale of the industry and to effectively target areas of high potential. The database could also be used to assess potential and monitor impacts of a variety of investments in water access, utilization and agricultural water management. Thus, establishing this database greatly increases the chances of success of a manual well drilling industry and other related agricultural water investments in Ethiopia.

For areas where data collection, mapping and test well development demonstrate sufficiently large potential market size and customer base for manual drilling, further investments can accelerate expansion of private sector drilling (e.g., driller training and certification; creating supply chains; marketing to farmers to create demand; and linking farmers to processing, storage and market opportunities). The information collected through the mapping work will be useful to support these expansion efforts, because it will improve the likelihood of drilling success and lower the cost of driller training. For areas where a sufficiently large customer base cannot be reached for manual well drilling to be financially viable using a private sector approach, further investments to scale-up the industry would not be recommended.

Investments needed to delineate the geographical limitations of manual well drilling and to determine the potential number of farmers who can benefit from this are detailed in the process described below. Each step in this process results in a finer level of detail regarding the potential feasibility of manual well drilling.

1. *Initial nationwide mapping.* Mapping of estimated shallow (< 18 m) groundwater, rural population density and geology throughout Ethiopia using digital data (images and terrain data from global sources, drilling logs from hand- or machine-drilled wells, soil and population data, etc.) is necessary in order to select areas with higher potential for manual well drilling. The estimated cost for a team of GIS experts, hydrogeologists, manual well drilling experts, etc., to develop maps for Ethiopia is USD 60,000.

2. *Verifying areas with higher potential.* In this stage, areas identified through the initial digital mapping process as having high potential for manual well drilling are visited for visual inspection and to adjust and refine the digital mapping analysis.

This inspection:

- confirms that land use, landforms and topography are suitable for manual well drilling;
- collects global positioning system (GPS) elevation data and data on surface-to-static water level depth in representative hand-dug wells; visually examines soil profiles in hand-dug wells; and
- interviews well diggers and/or inspects well drilling logs (if available) to learn about the soil profile, variation experienced in digging other wells in the area, potential well yield and seasonal water level fluctuation.

The process of verifying the initial mapping information can be divided into two phases. First, a team of international experts train national experts in the methodology. The approximate cost for this first phase is USD 250,000.

Second, the teams of international and national experts jointly refine the initial maps based on detailed on-the-ground research in areas highlighted from the first phase as having shallow groundwater potential. It would take several years to complete the second phase throughout the country at an estimated cost of USD 1.3 million.

Through these two phases, the most promising areas for manual well drilling would be identified for physical testing.

3. *Test Drilling.* For areas where initial mapping and verification confirm that surface characteristics are favorable for manual well drilling, test drilling is used to validate the potential. This establishes subsurface conditions and well yield; confirms surface-to-static water table depth; establishes that manual well drilling techniques are viable with the given soil conditions; determines the type of pump suitable to the conditions; and confirms that there is sufficient flow of water for the desired pumping rate.

Test drilling information (e.g., vertical soil profiles, geological formations, depth to water table, water yield rate and water quality) is recorded in geo-referenced drilling logs (see Appendix 1 for a sample drilling log) and managed in a GIS database. These data are integrated into the preliminary maps and used to identify the periphery where manual drilling/pumping is possible, and to confirm locations for demonstrating and promoting manual well drilling techniques.

Although test drilling can be done manually, mechanized test drilling using a trailer-mounted portable machine drilling rig is recommended for several reasons. First, machine drilling provides information rapidly, permitting faster determination of the periphery of areas suitable for manual well drilling. Second, it penetrates most geological formations to depths of at least 50 meters, including locations where manual drilling cannot proceed because of difficult drilling conditions. Therefore, machine drilling provides information regarding subsurface conditions that is useful for multiple purposes. For example, in locations where stone is encountered, manual well drilling would not be feasible but the information from penetrating the stone formation would determine if machine drilling is feasible. As such, machine test drilling expands the value of the shallow groundwater mapping to include machine-drilled groundwater access for irrigation and domestic needs.

The estimated cost for two drilling teams to drill 1,600 to 2,400 test wells in Ethiopia over five years is USD 1.4 million. One drilling team with a portable machine drilling rig can drill approximately 8-12 strategically placed wells per location at 20 locations per year. Therefore, two teams can drill 1,600 to 2,400 wells at 200 locations over 5 years. The cost estimate is calculated at USD 684,000 per team (including international technical assistance), for a total cost of USD 1.4 million for two teams. While this does not comprehensively cover the country, it provides an extremely useful sample from which much information can be extrapolated for manual and mechanized well drilling for domestic and other needs.

Investments Needed to Accelerate a Private Sector Manual Well Drilling Industry

Additional investments could accelerate expansion of private sector manual well drilling in Ethiopia. This is particularly true for areas in Ethiopia where data collection, mapping and test well development demonstrate a sufficiently large potential market size and customer base to scale-up private sector manual well drilling. Support to accelerate establishment of this sector can focus on training, creating demand for wells, stimulating value chains and value chain finance, and monitoring of risks (as described below). It is possible to estimate the cost of these investments once the potential suitability domains for manual well drilling are determined.

1. <u>Create demand</u>. In Ethiopia, low-cost drilling for irrigation is unknown. Poor farmers are reluctant to invest in an unknown solution, so there is little demand for manually drilled wells. Demonstrations of manual well drilling, model farm demonstrations, farmer-to-farmer visits, extension services, etc., could create customer demand. Through demonstrations and visits, smallholder farmers become aware of manual well drilling, pump options and potential income opportunities of higher-value irrigated crop production. Involving local and international organizations, as well as *woredas* and local agricultural extension staff in manual well drilling demonstrations also helps to build their knowledge of manual drilling as a technique to improve groundwater access. In addition to demonstrations, well drillers and government extension staff can promote manual well drilling by providing information to farmers on the benefits and costs of the technique.
2. <u>Train</u>. To ensure that private sector manual well drilling enterprises emerge to meet customer demand, training can be provided in business management and the technical aspects of manual drilling which includes guidance on proper well development to safeguard against point-source contamination. In addition, a sufficient number of skilled manual well drillers are necessary to create competition, lower the price of drilling wells, maintain competitive quality, etc. Therefore, investment in training increases the number of drillers and improves their skills. Once well drillers are trained and operating as successful businesses, it is expected that they will employ and train driller apprentices to ensure that manual drilling businesses will self-replicate and scale-up.

A field-based manual driller training program was initiated by iDE Ethiopia that recruits, trains and certifies manual well drillers. This experience demonstrated that approximately four months are required for a driller trainee to be trained to the level of certification. Certified drillers are trained to provide technical support if needed and customers of certified drillers are provided a limited guarantee of workmanship. This helps to create a workforce of skilled and competitive drillers. A recently proposed training program for the Government of Ethiopia estimated the cost to establish and operate an intensive 4-month manual well driller training program at approximately USD 950,000 for the first year and operating costs of USD 680,000 per year after the first year. This type of training program would greatly accelerate well drilling capacity. As detailed in Appendix 2, the potential impact of the training program is significant: as the number of trained drillers increases, the total number of wells drilled for smallholder farmers increases rapidly. It is estimated that 966,000 wells could be drilled after 15 years of conducting the training program.

Well drilling to access groundwater for irrigation is only one component of the irrigated crop production value chain for smallholders. Most smallholder farmers do not have experience with irrigation, so accelerating demand for manually drilled wells involves the provision of training and support to farmers to grow and market irrigated high-value crops to increase their incomes. This training, which includes irrigated agricultural production (e.g., timing of market-oriented crop production, crop water requirements, soil management) and production output services (e.g., post-harvest processing, storage, and aggregation and marketing), ensures that farmers capitalize on their investment in a well. The costs to train smallholder farmers to integrate irrigated cropping into their livelihood strategies are not included in this document.

3. Stimulate value chains and finance. Catalyzing agricultural value chains include stimulating supply chains for spare parts and equipment for manual well drilling, aggregating small-farm production, and connecting farmers to quality input suppliers and output markets. Additional value chain considerations include linking farmers to manufacturers for direct sales, to retail input suppliers, and creating more effective supply chains for inputs and services needed by farmers for improved crop production (e.g., seed, fertilizer, irrigation pumps, high-value agricultural knowledge). Ideally, manual well drilling supplies (e.g., metal pipes, wood, chains, clamps) are available in rural shops through private sector supply chains; however, dealers in rural areas are often reluctant to stock supplies and accessories for well drilling and pump installation due to low sales volumes. To address this issue, iDE Ethiopia tested various supply chain models. For example, the organization introduced warehousing, whereby they purchase and store supplies and accessories (e.g., PVC pipe and glue, pipe connectors) in bulk in project areas. Manufacturers and dealers then purchase these goods at cost from the warehouse, which makes it easier for them to access quality materials in a timely fashion at lower prices. Investments may be needed to test a variety of supply chain models to determine the most cost-effective model for Ethiopia.

Financial products and services are important to address financial constraints along the value chain, from manufacturing to well drilling enterprises and to smallholder farmers' investments in manually drilled wells. Institutions can be encouraged to provide agricultural finance through training and field visits, discussions and negotiations, farmer group formations and by providing capital input to micro-finance institutions (if needed) in order to reduce risk.

4. Monitor. Several aspects of monitoring are important:

- Well drillers should conduct regular visits to previously drilled wells and installed pumps to evaluate their performance, and to gather regular customer feedback from female and male farmers to ensure that well drilling products and services address their needs.

- The Government of Ethiopia should establish environmental monitoring measures. Since the manual well drilling program taps the uppermost aquifer, which has the highest annual recharge, there is little danger that it will be damaged by over-pumping. There is, however, the possibility that a high density of wells results in interference among wells and impacts intra-annual water supply, resulting in seasonal water conflicts. To avoid this, it is recommended that the minimum distance between wells and maximum number of wells per hectare be determined for each location and enforced by the government. It is recommended that the government establishes and maintains a nationwide database of availability and quality of water resources, and manual well drilling conditions, in order to effectively monitor environmental risks (e.g., groundwater depletion and water quality impacts) associated with well drilling and agricultural production.
- In addition, the government, private sector and non-profit agricultural support programs need to expand training and support for safe agricultural chemical use to reduce farmers' costs, and protect the health of rural families and the natural environment.

CONCLUSIONS

Increasing female and male farmers' access to groundwater can contribute to increased incomes, improved food security and improved access to water for livestock and domestic needs. In many contexts, private sector manual well drilling is a reliable and affordable means to access shallow groundwater, but it is not widely available in Ethiopia. Data, information and mapping on pilot manual well drilling efforts in selected areas of Ethiopia indicated that the technique provided affordable access to shallow groundwater for farmers and demonstrated high demand among farmers for manually drilled wells, as well as profitability for drilling businesses. The pilot study also demonstrated a large potential to scale-up private sector manual well drilling in selected areas of the country. The authors of this paper suggest that investments in creating a spatial database of hydrogeologic suitability domains, investments in driller training, and associated investments in accelerating the drilling industry could catalyze a manual well drilling industry and significantly improve smallholder farmers' affordable access to shallow groundwater.

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APPENDIX 1. SAMPLE DRILLING LOG REPORT.

FIGURE A1.1. Sample drilling log report.

Data Collect by	Berhanu	Serial #	AB01031002	Date Started/Completed (mm/dd/yy)	3/1/2010	-	3/2/2010

GPS and Photo Information

Latitude (dd.ddddd)	8.849
Longitude (dd.ddddd)	38.41177
Elevation (m)	2060
Photo	
Photo_Date	

General Information

Owners Name:	Gudnye Mekonen
Village Name:	Awash Balo
Family Size (person):	6
Type of Pump Intalled:	Treadle suction Pump
Well Primary Use:	Irrigation
Estimated Irrigated Area (m^2)	
Outcome:	Successful

Drilling Information

Drilling Type:	Simple Sludge
Bit Diameter (mm):	54
Casing Diameter (mm)	50
Augering Start Depth (m)	0
Augering End Depth (m)	0.75
Sludging Start Depth (m)	0.75
Sludging End Depth (m)	16.5
Total Drill Time (hr)	10
Static Water Level (m)	
Drillers Name:	Mustefa Kiri
Helpers Name	Berhanu & Mehamed

Promblems Encountered Drilling:

Type	None

None

Well Log Measurements from Surface

Drilled Depth (m):	16.5
Depth to Top of Filter (m)	
Depth to Bottom of Filter (m)	
Depth to Top of Gravel Pack (m)	
Depth to Bottom of Gravel Pack (m)	
Depth to Top of Sanitary Seal (m)	
Depth to Bottom of Sanitary Seal (m)	

Additional Notes:

Soil Log Key

Description	Texture		Compaction	
Clay, Sandy clay, Silty clay, Sandy clay loam	Fine	f	Soft	S
Loam, Silty clay loam, Sand , Sandy loam, Loam	Meduim	m	Semi-Compact	SC
Silty loam, Gravel, Rock, Pumice	Course	c	Compact	C

Permeablility		Casing		Fill	
Permeable	p	Blank Pipe	bp	Sanitary Seal	ss
Semi-permeable	sp	Filter	F	Cuttings	c
Non-permeable	np			Gravel/Sand	g/s

Soil Log Profile

Depth (m)	Description	Texture	Compaction	Permeability	Casing	Fill	Observations
0.0	Silty clay	m	S -	np -			
0.25	Silty clay	m	S -	np -			
0.5	Silty clay	m	S -	np -			
0.75	Silty clay	m	S -	np -			
1.0	Clay	f	S -	np -			
1.5	Clay	f	S -	np -			
2.0	Clay	f	S -	np -			
2.5	Clay	f	S -	np -			
3.0	Clay	f	S -	np -			
3.5	Clay	f	S -	np -			
4.0	Clay	f	S -	np -			
4.5	Clay	f	S -	np -			
5.0	Clay	f	S -	np -			
5.5	Clay	f	S -	np -			
6.0	Clay	f	S -	np -			
6.5	Clay	f	S -	np -			
7.0	Clay	f	S -	np -			
7.5	Clay	f	S -	np -			
8.0	Clay	f	S -	np -			
8.5	Clay	f	S -	np -			
9.0	Clay	f	S -	np -			
9.5	Clay	f	S -	np -			
10.0	Clay	m	C -	sp -			
10.5	Clay	m	C -	sp -			
11.0	Clay	m	C -	sp -			
11.5	Clay	m	C -	sp -			
12.0	Sandy clay	m	SC -	sp -			
12.5	Sandy clay	m	SC -	sp -			
13.0	Sandy clay	m	SC -	sp -			
13.5	Sandy clay	m	SC -	sp -			
14.0	Sandy clay	m	SC -	sp -			
14.5	Sandy clay	m	SC -	sp -			
15.0	Sandy clay	m	SC -	sp -			
15.5	Sandy clay	m	SC -	sp -			
16.0	Sandy clay	m	SC -	sp -			
16.5	Sandy clay	m	SC -	sp -			
17.0							
17.5							
18.0							
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24.5							
25.0							

Source: iDE Ethiopia.

APPENDIX 2. MANUAL WELL DRILLING TRAINING AND CERTIFICATION.

The manual well driller training program conducted by iDE Ethiopia is field-based. Trainees start as driller helpers and move progressively from assistant driller to junior and senior assistant driller before becoming a lead driller. This process requires participation in drilling approximately 15 wells. After experience as a lead driller, the trainee attends a weeklong classroom-based course covering the hydrogeology of manual well drilling, casing installation and well development. The driller's training is then considered complete, but the driller will only receive an iDE Ethiopia certificate after they demonstrate competency by successfully managing a team in drilling 10 additional wells without direct supervision. It takes a minimum of 4 months for a trainee to be trained to the level of certification. Certified drillers are trained to provide technical support if needed and customers of certified drillers are provided a limited guarantee of workmanship. This helps to create an industry of quality, skilled and competitive drillers. Not all trained drillers are interested or able to manage a business; many prefer to work as drilling assistants.

The hands-on driller training includes developing pump installation skills; reaming 60 mm bore wells used for treadle pumps to 90 or 125 mm for installation of rope and washer pumps and engine-driven pump sets; installation of "small-bore (40 mm) pumps" for household water needs; developing diagnostic/remediation skills for situations where the well yield is less than desired; preparing tools for well development and determining if development is complete; and negotiation of business agreements by a driller with customers.

Regarding costs for a manual well driller training program, a recently proposed training program for the Government of Ethiopia estimated the cost to establish and operate an intensive four-month manual well driller training program at approximately USD 950,000 for the first year and operating costs of USD 680,000 per year after the first year. This type of training program would greatly accelerate well drilling capacity. As shown in Table A2.1, the potential impact of the training program is significant: as the number of trained drillers increases, the total number of wells drilled for smallholder farmers increases rapidly. It is estimated that 966,000 wells could be drilled after 15 years of conducting the training program.

Table A2.1 assumes that there are 25 trainees per group in the first year, with four groups in the first year, 10 groups per year in the second and each subsequent year. The Table assumes that 80% of trainees become certified as drillers, 50% of certified drillers establish their own businesses, demand for wells will fully employ the new drilling enterprises and each enterprise will be able to drill 90-100 wells/year (five wells every two weeks for nine months of each year).

The proposed training program would have a classroom and practice field located at an existing Agricultural Technical and Vocational Educational Training (ATVET) center. In the first three weeks, trainees would be at the ATVET center and learn the basic manual well drilling techniques. They would then spend two months with field-based instructors drilling wells in farmers' fields. Each trainee would participate in drilling about 15 wells in the field, which will also include being the lead driller for five wells. The final five weeks of training would be back at the training center where hydrogeological, pump selection, installation and maintenance issues would be discussed. In addition, there would be a training unit on enterprise development and business practice. The training program would have 25 trainees in a course and be able to conduct ten courses per year after the first year. Table A2.1 demonstrates the potential impact of such a training program. It assumes that 80% of the trainees become certified drillers, with half of the certified drillers establishing their own drilling businesses. It further assumes that the demand for wells will fully employ the new drilling enterprises and that each enterprise will be able to drill about 100 wells per year. As illustrated in Table A2.1, a formal training program will greatly accelerate well drilling capacity.

TABLE A2.1. Estimated number of wells drilled as a result of driller training programs and certification.

Year	Number of drillers certified each year	Number of new drilling enterprises each year	Cumulative drilling enterprises	Cumulative number of wells drilled
1	80	40	Training only	0
2	200	100	40	4,000
3	200	100	140	18,000
4	200	100	240	42,000
5	200	100	340	76,000
6	200	100	440	120,000
7	200	100	540	174,000
8	200	100	640	238,999
9	200	100	740	312,000
10	200	100	840	396,000
11	200	100	940	490,000
12	200	100	1,040	594,000
13	200	100	1,140	708,000
14	200	100	1,240	832,000
15	200	100	1,340	966,000

Important aspects to consider for training include the following:

- Training needs to include both classroom instruction and experiential learning to master handling of tools, directing the drilling activity and to resolve problems resulting from different hydrogeological conditions.
- Manual drilling is physically very demanding - as many as 50% of potential trainees drop out of training within a week. A screening process enabling interested trainees to see and experience the working conditions before applying for in-depth training is important to improve retention of trainees.
- The number of wells drilled is less important than the number of different geological conditions experienced to determine if the trainee has sufficient experience for certification.

Most manual drillers have learned the trade by working with experienced well drillers. While hands-on experience is essential, the field-based training period can be shortened if classroom instruction uses examples and illustrations to explain different techniques required for different geological conditions. Classroom instruction is more effective if trainees have at least an eight-grade education to perform better in the classroom than those with no education.

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Postal Address
P O Box 2075
Colombo
Sri Lanka

Location
127 Sunil Mawatha
Pelawatta
Battaramulla
Sri Lanka

Telephone
+94-11-2880000

Fax
+94-11-2786854

E-mail
iwmi@cgiar.org

Website
www.iwmi.org

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Summary

Interventions that benefit the rural poor in Ethiopia could potentially improve the lives of almost 36 million people in the country. Approximately 83% of Ethiopia's population of 82.8 million lives in rural areas, and 52% of the rural population live in poverty (International Fund for Agricultural Development [IFAD]). Improving smallholder farmers' agricultural productivity and access to water can help to increase their incomes, improve food security, and provide water for livestock and domestic needs.

In many countries in Asia, Africa and Latin America, manual drilling of wells is one solution which allows farmers to reliably and affordably access shallow groundwater resources. Once a well is drilled, farmers have a variety of options for lifting the water, storing it and applying it to their crops.

While manual well drilling is common in many countries in Asia, Africa and Latin America, it is not widely available in Ethiopia. Pilot efforts made by iDE Ethiopia to test manual well drilling were successful in the areas selected: these efforts demonstrated profitability for farmers, well drillers and well drilling apprentices; high demand among farmers for manually drilled wells; and feasibility of manual well drilling in the hydrogeological settings of the pilot areas.

To scale-up these successes to meet the demand of farmers and improve their access to water requires investments in (a) creating a spatial database of key soil, hydrogeology, and water resources data and information. This will enable an assessment to be made of the potential scale of, and effective selection of areas with high potential for, manual well drilling; and (b) expanding private sector well drilling in the country. These are explained below:

a. Manual well drilling is viable only in specific hydrogeologic settings. With careful selection of areas in the pilot study, iDE Ethiopia had an 80% success rate in manual well drilling. There are, however, insufficiently detailed and accurate data, information, and maps regarding soil, hydrogeology and water resources throughout Ethiopia to determine all locations that are suitable for manual well drilling. Investments of approximately USD 3 million in mapping, data collection, ground-truthing and drilling of test wells are needed to determine areas suitable for manual well drilling. These investments would result in a spatial database of agricultural water information and data, which can be used by the government, investors, well drillers and others to assess the potential scale of the industry and to effectively target areas of high potential for manual well drilling. The database can also be used to assess the potential and monitor impacts of a variety of investments in water access, utilization and agricultural water management. Thus, establishing this database greatly increases the chances of success of a manual well drilling industry and other agricultural water-related investments in Ethiopia.

b. In locations where data and maps show physical suitability for manual well drilling and a potential customer base sufficiently large enough to support private sector manual drilling, further investments may be needed to support expansion of private sector drilling in Ethiopia through driller training, creating demand from farmers for manually drilled wells and stimulating smallholder agricultural value chains. If data and mapping show areas where manual well drilling is not feasible at scale, further investments in private sector well drilling would not be promoted in those areas.

FIGURE 1. Treadle pump installed on a manually drilled well in Ethiopia.

Source: iDE Ethiopia.

FIGURE 2. Ethiopian manual well drilling crew.

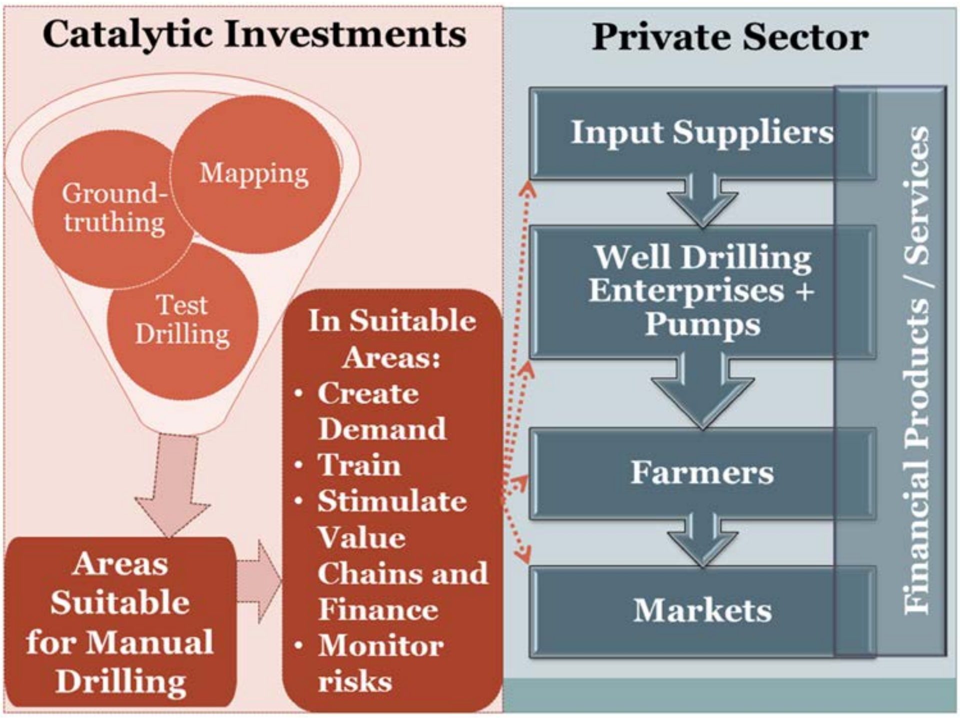
Source: iDE Ethiopia.

INVESTMENTS NEEDED TO CATALYZE PRIVATE SECTOR MANUAL WELL DRILLING IN ETHIOPIA

The pilot manual drilling work demonstrated high demand; a high (80%) success rate in the pilot areas; and profitability for farmers, well drillers and well drilling apprentices. Based on the success of the pilot work in Ethiopia and building on experiences of private sector manual well drilling worldwide, there is potential to scale-up manual drilling in Ethiopia to increase smallholder farmers' access to water. As shown in Figure 3 and explained in more detail below, scaling-up the pilot initiatives requires investments in two key areas:

1. Creating a spatial database of agricultural water information and data, which can be used by the government, investors, well drillers and others to identify suitable areas for manual well drilling and to effectively target areas of high potential. Once the suitable areas have been identified, it is possible to estimate the potential scale (e.g., number of farmers reached) of manual well drilling, costs involved in reaching those farmers, and return on investment in scaling-up private sector manual well drilling. If data and mapping show areas where manual well drilling is not feasible at scale, further investments in private sector drilling would not be promoted in those areas.
2. In locations where data and maps show physical suitability for manual well drilling and a potential customer base sufficiently large enough to support private sector manual drilling, further investments may be needed to support expansion of private sector drilling in Ethiopia through training of drillers; creating demand from farmers for manually drilled wells; and stimulating smallholder agricultural value chains.

FIGURE 3. Catalytic investments needed to stimulate private sector manual well drilling.



It is projected that external support to manual well drilling will catalyze the sector within 3 to 5 years. At that time, it is expected that input suppliers, manual drilling enterprises and pump suppliers, farmers, financial products and services, and output markets will be linked through financially self-sustaining value chains. It is estimated that a flourishing manual well-drilling industry, supported by ongoing training and certification, could provide groundwater access for over 75,000 farmers within five years and close to one million farmers within 15 years. Without external support, private sector manual well drilling may advance independently but in a significantly longer time frame.

Investments in a Spatial Database of Agricultural Water Information and Data

Manual well drilling is viable only in specific hydrogeologic settings with suitable soil conditions: where well yields are sufficient for sustainable extraction of water resources for productive irrigation; where the water table is shallow; and where the water-bearing layers have sufficient permeability and thickness to provide the flow rate necessary for irrigation pumps. Sand, loam, and clay are generally easy to drill; compacted and cemented soils can often be drilled, but may require much more time and labor (and, therefore, additional cost) to drill. Manual drilling is, generally, not successful if boulders or stones larger than 5 cm are encountered or if drilling must penetrate hard stone layers more than 5-10 cm or soft stone layers 20 or 30 cm thick.

Ethiopia has a challenging geology for drilling when compared to river deltas and outwash plains in many countries in Asia and other African countries, where manual well drilling proliferates. This challenging geology creates geographical limitations for manual well drilling and can lead to increased costs if drilling failure rates are high. The pilot studies carried out established that areas exist in Ethiopia with high potential for manual well drilling due to shallow water and permeable soil layers. These areas are smaller than in the Gangetic Plain of Asia; however, with careful selection of areas, the success rate for manual well drilling was approximately 80%.

Current data, information and maps regarding soil, hydrogeology and water resources for Ethiopia are insufficiently detailed and accurate to determine specific locations that are suitable for manual well drilling. Therefore, investments of approximately USD 3 million in field-level data collection on surface geology and aquifer conditions, together with mapping and drilling of test wells, are needed to determine areas suitable for manual well drilling and to estimate the number of smallholder farmers who could potentially benefit from manually drilled wells. These investments would result in a spatial database of agricultural water information and data, which can be used by the government, investors, well drillers and others to assess the potential scale of the industry and to effectively target areas of high potential. The database could also be used to assess potential and monitor impacts of a variety of investments in water access, utilization and agricultural water management. Thus, establishing this database greatly increases the chances of success of a manual well drilling industry and other related agricultural water investments in Ethiopia.

For areas where data collection, mapping and test well development demonstrate sufficiently large potential market size and customer base for manual drilling, further investments can accelerate expansion of private sector drilling (e.g., driller training and certification; creating supply chains; marketing to farmers to create demand; and linking farmers to processing, storage and market opportunities). The information collected through the mapping work will be useful to support these expansion efforts, because it will improve the likelihood of drilling success and lower the cost of driller training. For areas where a sufficiently large customer base cannot be reached for manual well drilling to be financially viable using a private sector approach, further investments to scale-up the industry would not be recommended.

APPENDIX 1. SAMPLE DRILLING LOG REPORT.

FIGURE A1.1. Sample drilling log report.

Data Collect by	Berhanu	Serial #	AB01031002	Date Started/Completed (mm/dd/yy)	3/1/2010	-	3/2/2010

GPS and Photo Information

Latitude (dd.ddddd)	8.849
Longitude (dd.ddddd)	38.41177
Elevation (m)	2060
Photo	
Photo_Date	

General Information

Owners Name:	Gudnye Mekonen
Village Name:	Awash Balo
Family Size (person):	6
Type of Pump Intalled:	Treadle suction Pump
Well Primary Use:	Irrigation
Estimated Irrigated Area (m^2)	
Outcome:	Successful

Drilling Information

Drilling Type:	Simple Sludge
Bit Diameter (mm):	54
Casing Diameter (mm)	50
Augering Start Depth (m)	0
Augering End Depth (m)	0.75
Sludging Start Depth (m)	0.75
Sludging End Depth (m)	16.5
Total Drill Time (hr)	10
Static Water Level (m)	
Drillers Name:	Mustefa Kiri
Helpers Name	Berhanu & Mehamed

Promblems Encountered Drilling:

Type	None
None	

Well Log Measurements from Surface

Drilled Depth (m):	16.5
Depth to Top of Filter (m)	
Depth to Bottom of Filter (m)	
Depth to Top of Gravel Pack (m)	
Depth to Bottom of Gravel Pack (m)	
Depth to Top of Sanitary Seal (m)	
Depth to Bottom of Sanitary Seal (m)	

Additional Notes:

Soil Log Key

Description	Texture		Compaction	
Clay, Sandy clay, Silty clay, Sandy clay loam	Fine	f	Soft	S
Loam, Silty clay loam, Sand , Sandy loam, Loam	Meduim	m	Semi-Compact	SC
Silty loam, Gravel, Rock, Pumice	Course	c	Compact	C

Permeablility		Casing		Fill	
Permeable	p	Blank Pipe	bp	Sanitary Seal	ss
Semi-permeable	sp	Filter	F	Cuttings	c
Non-permeable	np			Gravel/Sand	g/s

Soil Log Profile

Depth (m)	Description	Texture	Compaction	Permeability	Casing	Fill	Observations
0.0	Silty clay	m	S -	np -			
0.25	Silty clay	m	S -	np -			
0.5	Silty clay	m	S -	np -			
0.75	Silty clay	m	S -	np -			
1.0	Clay	f	S -	np -			
1.5	Clay	f	S -	np -			
2.0	Clay	f	S -	np -			
2.5	Clay	f	S -	np -			
3.0	Clay	f	S -	np -			
3.5	Clay	f	S -	np -			
4.0	Clay	f	S -	np -			
4.5	Clay	f	S -	np -			
5.0	Clay	f	S -	np -			
5.5	Clay	f	S -	np -			
6.0	Clay	f	S -	np -			
6.5	Clay	f	S -	np -			
7.0	Clay	f	S -	np -			
7.5	Clay	f	S -	np -			
8.0	Clay	f	S -	np -			
8.5	Clay	f	S -	np -			
9.0	Clay	f	S -	np -			
9.5	Clay	f	S -	np -			
10.0	Clay	m	C -	sp -			
10.5	Clay	m	C -	sp -			
11.0	Clay	m	C -	sp -			
11.5	Clay	m	C -	sp -			
12.0	Sandy clay	m	SC -	sp -			
12.5	Sandy clay	m	SC -	sp -			
13.0	Sandy clay	m	SC -	sp -			
13.5	Sandy clay	m	SC -	sp -			
14.0	Sandy clay	m	SC -	sp -			
14.5	Sandy clay	m	SC -	sp -			
15.0	Sandy clay	m	SC -	sp -			
15.5	Sandy clay	m	SC -	sp -			
16.0	Sandy clay	m	SC -	sp -			
16.5	Sandy clay	m	SC -	sp -			
17.0							
17.5							
18.0							
18.5							
19.0							
19.5							
20.0							
20.5							
21.0							
21.5							
22.0							
22.5							
23.0							
23.5							
24.0							
24.5							
25.0							

Source: iDE Ethiopia.

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Postal Address
P O Box 2075
Colombo
Sri Lanka

Location
127 Sunil Mawatha
Pelawatta
Battaramulla
Sri Lanka

Telephone
+94-11-2880000

Fax
+94-11-2786854

E-mail
iwmi@cgiar.org

Website
www.iwmi.org

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