IWMI Working Paper 152

Investing in Agricultural Water Management to Benefit Smallholder Farmers in Ethiopia

AgWater Solutions Project Country Synthesis Report

International Water Management Institute
CGIAR Research Program on Water, Land and Ecosystems
AgWater Solutions — Improved livelihoods for smallholder farmers
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AgWater Solutions Project Country Synthesis Report

Edited by

Alexandra E. V. Evans

Meredith Giordano

and

Terry Clayton

International Water Management Institute (IWMI)
P. O. Box 2075, Colombo, Sri Lanka

The editors: Alexandra E. V. Evans is Strategic Science Uptake Coordinator at the International Water Management Institute (IWMI) in Colombo, Sri Lanka; Meredith Giordano is Co-Project Manager, AgWater Solutions at IWMI in Colombo, Sri Lanka; and Terry Clayton is a Consultant to IWMI based in Udon Thani, Thailand.

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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, 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 of 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/) or contact the AgWater Solutions Project Secretariat (AWMSolutions@cgiar.org).

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Summary

This Working Paper summarizes research conducted as part of the AgWater Solutions Project in Ethiopia between 2009 and 2012. Rainfed agriculture and subsistence farming are the main features of agriculture. The midlands and highlands are dominated by mixed farming systems where livestock and crop production are equally important and highly integrated. In the lowlands, pastoral systems dominate. Single cropping is the norm but double-cropping is practiced along rivers in some parts of the country. Over half of Ethiopia's 64 million rural people live in poverty. Less than 10% of the 3.7 to 4.3 million hectares (Mha) of irrigable land is currently irrigated. The potential irrigable land in Ethiopia is between 3.7 and 4.3 Mha with the actual irrigated area estimated at just 7 to 10%.

Researchers from the AgWater Solutions Project conducted a situation analysis in 2009, which identified a range of options deemed to be technically feasible, affordable and practical for smallholder farmers: water-lifting technologies, groundwater for agriculture and manual well drilling, community-based watershed management, on-farm water storage, small reservoirs and rainwater harvesting.

The main findings of the project indicate that:

- Water-lifting technologies could benefit between 1 and 2 million farm households. The main barriers to its adoption are weak supply chains, lack of extension services and access to credit.
- In the coming five years, 8,000 hectares (ha) will be developed as a pilot study using groundwater. Groundwater and manual well drilling could be greatly expanded with investments in hydrogeological maps and groundwater data; and financing for private sector drilling and building a pool of skilled labor for the drilling industry.
- Watershed size and hydrogeology are the key physical factors in community watershed management. Macro-watersheds performed better on all indicators than smaller watersheds. Land and crop productivity and area for cultivation increased over the years as a result of land rehabilitation, water availability for supplementary or full-scale irrigation, and new agronomic practices.
- Farmers could gain considerable benefit from on-farm ponds, including higher yields and greater incomes. The government is already promoting on-farm ponds, but this is usually to store rainfall in dry areas to supplement rainfed crops.
- Small reservoirs support soil and water conservation, drought proofing and small-scale community irrigation. A well-designed reservoir can sustain multiple uses, including livestock, fisheries, domestic needs and small businesses.

INTRODUCTION: SMALLHOLDER AGRICULTURAL WATER MANAGEMENT

Across Africa and Asia, a growing number of smallholder farmers are finding ways to better manage water for agriculture to increase yields and income, and diversify their cropping and livelihood options. Farmers buy or rent irrigation equipment, draw water from nearby sources, and individually or collectively build small water storage structures. This development is often overlooked by external investors, yet the smallholder agricultural water management (AWM) sector is contributing to food security, rural incomes, health and nutrition. While small-scale AWM practices could potentially benefit hundreds of millions of farmers, this potential is far from being realized.

The AgWater Solutions Project examined this trend together with the opportunities and constraints associated with smallholder AWM in five countries in Africa, Ethiopia, Tanzania, Burkina Faso, Ghana and Zambia, and two states in India, West Bengal and Madhya Pradesh. Through this, the project identified a number of ways in which the potential of the smallholder AWM sector can be realized, including:

- **Building supportive institutional structures:** Existing governing bodies typically cater for public irrigation systems and are often not adapted to capitalize on the opportunities and to handle the challenges posed by this alternative mode of irrigation development. Traditional agricultural institutions rarely focus on market-oriented smallholder crop production, such as high-value vegetable production in the dry season.
- **Overcoming value chain inefficiencies:** Market inefficiencies negatively affect farmer decision-making and access to technology. Inefficiencies include: poorly developed supply chains; high taxes and transaction costs; lack of information and knowledge on irrigation, seeds, marketing and equipment; and uneven information and power in output markets.
- **Improving access to technology for all sectors of society:** Better-off farmers have greater access to information and technology than their poorer counterparts and women who face several hurdles: high upfront investment costs, absence of financing tools, and limited access to information to make informed investment and marketing choices.
- **Managing potential trade-offs:** While smallholder AWM can be beneficial for an individual farmer, its uncontrolled spread can have unexpected consequences. If not managed within the landscape context, the many small dispersed points of water extraction, can negatively impact downstream users and cause environmental damage.

Addressing these challenges requires a fresh look at new and existing AWM technologies, products and practices to enhance the potential of the smallholder AWM sector and find solutions.

WHY INVEST IN SMALLHOLDER AWM IN ETHIOPIA[1]

Rainfed agriculture dominates even though rainfall distribution and intensity vary considerably, resulting in incidents of drought every four to five years. Such variability affects crop and livestock production, and contributes to volatility in food prices.

[1] Based on AgWater Solutions Project 2010.

Subsistence farming is another main feature of agriculture in Ethiopia. The midlands and highlands are dominated by mixed farming systems where livestock and crop production are equally important and highly integrated. In the lowlands, pastoral systems dominate. Single cropping is the norm, but double-cropping is practiced along rivers in areas with distinct bimodal rainfall distribution patterns.

Just over half of Ethiopia's 64 million rural people live in poverty. Less than 10% of the 3.7 to 4.3 Mha of irrigable land is currently irrigated, more than half of which is traditional irrigation schemes. The Government of Ethiopia has instituted several policies and strategies to support agricultural development and water resources development, including the Rural Development Strategy, the Water Resources Management Policy and the Water Sector Policy. These initiatives aim to enhance the efficient, equitable and optimal utilization of water resources for sustainable agricultural and socioeconomic development, and place small-scale irrigation as a key priority. However, despite the pro-AWM policies and the commensurate demand among farmers for AWM solutions, water resources remain poorly developed and the utilization of existing AWM schemes, including small-scale AWM, is inefficient. Field assessments in small-scale irrigation projects indicate that some irrigation schemes are not functioning due to a shortage of water, damaged structures and poor water management.

The Agwater Solutions Project mapped the potential for AWM to improve the livelihoods of smallholder farmers in Ethiopia and found that just over 38 million people (56% of the rural population) could benefit from AWM (Figure 1).

AWM Investment Opportunities in Ethiopia

Within the existing, positive policy environment, a range of AWM options already exist in different parts of the country (Box 1) that could support the realization of the estimate that just over 38 million people could benefit from AWM. Based on this long list, the researchers from the AgWater Solutions Project identified, in consultation with stakeholders, several options deemed to be technically feasible, affordable and practical for smallholder farmers. Further research determined how many smallholder farmers could potentially use these options and a series of recommendations were made on how to increase adoption and sustained use (Table 1).

Box 1. Existing AWM technologies and techniques in Ethiopia.

River and stream diversions are the most common practices in the midlands and highlands wherever there are rivers. Traditional diversions are used for small plots. Those developed by the government or NGOs are for community managed irrigation. Diversions are generally less costly than other AWM solutions.

Micro-dams or reservoirs are concentrated where river or stream diversions are not possible, but the topography is suitable for small dams and reservoirs (the midlands, highlands and areas of the Southern Nations, Nationalities, and People's Region (SNNPR)). Micro-dams are showing promise in Tigray and Amhara. Dams are usually made of earth and stone often with water-lifting devices to irrigate 100-200 ha. Investment costs can be high. Silting, seepage and waterlogging are problematic.

(Continued)

Box 1. Existing AWM technologies and techniques in Ethiopia (Continued).

Groundwater and hand-dug wells provide ample water in the midlands and highlands of the SNNPR, Oromia, East Hararghe and parts of Amhara. In the Raya and Kobo valleys in northern Ethiopia, farmers fit wells with pressurized pumps to irrigate large areas.

Lake and river pumping is common where there are lakes (Zeway, Awash, Koka, Abaya and Hawassa) and rivers (Kelafo, Mustahil, Ferfer, Dolo, Cherati, Hargel, Teji and Baro). Farmers who have good access to markets often use motorized pumps to grow horticultural crops, but price fluctuations are a constraint. Over-abstraction and water quality are causing some concern.

Rainwater harvesting in traditional ponds (*birka*) are used for livestock in dryland areas, such as Somali, and in the agro-pastoral communities of southern Tigray, Afar and Borena. The government has been implementing schemes since 2002. There have been encouraging signs of adoption in Tigray, SNNPR, and in the East and Hararghe zones of Oromia and Somali. However, the full potential of water catchments was not considered in the design stage of existing ponds leading to water loss.

Spate irrigation is a common practice in which farmers collect and divert floodwater from upstream catchments to irrigate downstream areas via simple furrow systems. Spate irrigation is mainly practiced on lowland plains (Raya Valley of Tigray, Kobo area of Amhara Region, in the Afar escarpment and in the lowlands of the South Omo Zone in SNNPR).

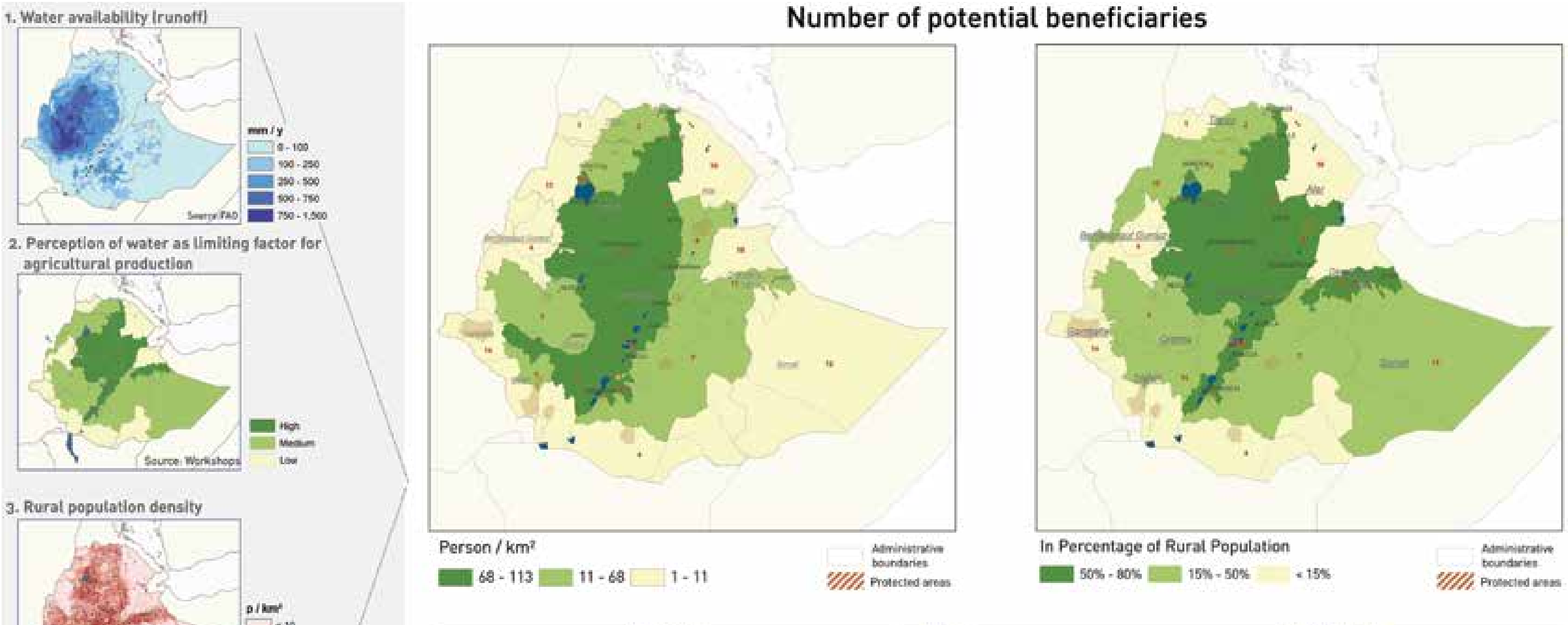
Soil and water conservation activities, such as gully reclamation, are supported by the Productive Safety Net Program (PSNP). These practices are designed to reclaim eroded areas and gullies. Government or NGO support is critical to scaling out this promising program.

Motorized pumps are often used to lift water from rivers, lakes, ponds or wells, typically for irrigating high-value crops in Hararghe and Oromia. Householders are adopting pumps across the country because they are easy to operate. Adoption is encouraged through the Water Sector Development Program of 2003. The government has imported thousands of pumps free of duty and tax, and is selling them through cooperative associations for ETB 6,500 (USD 640). This may be less efficient than encouraging private operators, and maintenance and support may be insufficient.

Other irrigation systems. Sprinkler systems were recently introduced in Tigray and Amhara. Farmers are adopting drip irrigation, treadle pumps, rope-and-washer pumps, and windmills in some areas, particularly in Oromia Region and in SNNPR. Good quality systems are not widely available yet in local markets, and the technical and financial feasibility of these solutions needs further research.

Source: AgWater Solutions Project 2010.

FIGURE 1. Potential beneficiaries of agricultural water management.



Livelihood zone		Water availability: IRWR/cp (m³/p/y)	Rural population			Perception of water as limiting factor for agricultural production	Potential beneficiaries	
No	Name		Total (,000)	Density (p/km²)	% poor (underweight)		Person (,000)	In % of rural population
1	Lowland mixed - Sesame livelihood system	1,085	522	30	48.4	low	78	15%
2	Northern mixed midlands livelihood system	406	2,397	112	48.0	medium	1,199	50%
3	Northern cereal pulse mixed livelihood system	1,286	2,194	100	51.5	medium	1,097	50%
4	North West lowland Sorghum/Sesame mixed livelihood system	16,379	729	19	43.4	low	109	15%
5	Western Coffee/Maize livelihood system	3,822	7,262	97	44.2	high	3,631	50%
6	Southern pastoral livelihood system	2,517	1,601	13	44.9	low	240	15%
7	Eastern highland mixed livelihood system	1,379	7,371	56	43.5	medium	3,686	50%
8	Awash pastoral/agricultural system	787	889	25	50.4	high	705	79%
9	Weher/Belg transition livelihood system	492	4,318	117	50.6	high	2,705	63%
10	North-Eastern pastoral livelihood system	843	814	10	50.3	low	122	15%
11	Eastern Chat/Sorghum highland mixed livelihood system	184	3,809	179	42.2	high	1,173	31%
12	"Ogaden" pastoral livelihood system	1,178	2,612	12	43.2	medium	1,306	50%
13	Highland mixed -Teff livelihood system	2,069	17,294	137	48.2	high	13,835	80%
14	Horticultural (Enset/cereal) mixed livelihood complex	994	9,166	187	51.1	medium	4,583	50%
15	Rift Valley livelihood system	468	5,391	186	46.0	high	3,278	61%
16	Gambella agro-pastoral livelihood system	6,645	470	10	43.8	low	70	15%
17	Northern pastoral livelihood systems	6,223	951	22	49.0	medium	475	50%

Source: FAO 2012a.

TABLE 1. Review of AWM options, recommendations and potential beneficiaries.

AWM solution	Solution statement	Beneficiary households (% of rural households)*	Area in hectares (% of total agricultural land)*	Estimated investment costs (USD)
Water-lifting technologies (low-cost motor pumps)	Encouraging enterprises that combine the supply of pumps, technical support to farmers and markets for produce could greatly improve the use of water-lifting technologies and bring economic benefits to farmers.	1.1-2.2 million (8.89-16.9%)	0.9-1.8 million (3-5.7%)	400/household
Groundwater for agriculture	Ethiopia has large reserves of groundwater that could be used to drive agricultural growth. Better hydrogeological mapping, changes to existing policy and capacity building are needed to harness this untapped resource.		Not calculated	
Manual well drilling	Establishing private manual well drilling enterprises to provide low-cost access to groundwater would expand the irrigated farm production area and offers potential to improve the livelihoods of millions of smallholder farmers.		Not calculated	
Community-based watershed management	Community-based watershed management would be a significant factor in helping the government achieve its aim of making agriculture the driving force of economic development in Ethiopia.		Not calculated	
On-farm water storage	Large irrigation schemes cannot always supply enough water at the right times. Storing water in farm ponds lets farmers irrigate when they need to. Farmers can then supplement rainfed crops or can grow and sell seasonal high-value crops.		Not calculated	
Small reservoirs	For investors in small reservoirs, the challenge lies in coordinating and integrating multiple uses and social groups around a common resource while limiting costs through improved procedures and financial management.	244,000-894,000 (1.9-6.9%)	244,000-894,000 (0.8-2.9%)	750,000/cubic meters (m^3) of water stored

Source: This study; all data: FAO 2012a.

Note: * Figures assume that out of the total potential beneficiary households calculated, 50% adopt the AWM option.

Details of the approach and related studies undertaken to arrive at these conclusions are given in Box 2 and elaborated in subsequent chapters. Further information, including case studies and mapping data, can be found on the project website (http://awm-solutions.iwmi.org).

Box 2. AgWater Solutions Project approach.

Situation analysis and selection of AWM options: An initial analysis was undertaken of the conditions in each country and the AWM practices already being undertaken. These were reviewed with stakeholders and some of the most promising practices were selected.

Field-scale and community-level case studies: Researchers used a participatory opportunity and constraint analysis and methodology to understand the complex interaction among social, economic and physical factors that influence the uptake and success of AWM options, and to identify technologies appropriate to different contexts in each of the project countries.

Watershed-level case studies: Researchers used a multi-disciplinary approach to look at how the natural resource base impacts on, and is impacted by, AWM in four watersheds in Tanzania, Burkina Faso, West Bengal (India) and Zambia. The analysis concentrated on the hydrological impact of current and potential AWM interventions; the current resource-based livelihoods and dependencies on sources of water and water management practices; an impact assessment of potential AWM scenarios; and a review of formal and informal institutional capacity to deal with AWM interventions and potential emerging externalities.

National AWM mapping: Maps were developed to help assess where AWM will have the greatest impact within a country or state, and where specific interventions will be most viable. The steps followed were to use a participatory process in which experts defined the main livelihood zones based on farming typologies and rural livelihood strategies, and the main water-related constraints and needs in the different rural livelihood contexts. Using this, the potential for investment in water to support rural populations could be mapped based on demand and availability of water. A further step was to map the suitability and demand for specific AWM interventions, such as motor pumps or small reservoirs, and to estimate the potential number of beneficiaries, application area and investment costs. These allow investors to choose entry points and prioritize investments in AWM that will have the most beneficial impacts on rural livelihoods.

Regional AWM analysis: Researchers used geographic information system (GIS)-analysis, crop mix optimization tools and predictive modeling techniques to assess the regional potential for the 'best-bet' AWM technologies in South Asia and sub-Saharan Africa in terms of: potential application area (in hectares), number of people reached, net revenue derived and water consumption. Scenarios were also developed to factor in climate change and potential changes in irrigation costs.

(Continued)

Box 2. AgWater Solutions Project approach (Continued).

Stakeholder engagement and dialogue: An integral part of the entire project was the engagement of stakeholders from the initial assessment of AWM opportunities through to the identification of possible implementation pathways. The dialogue process was used to ensure that project results reflected stakeholder perceptions and addressed their concerns. National consultations, dialogues, surveys and interviews were fed into all stages of the project.

AWM OPTIONS REVIEWED

Water-lifting Technologies[2]

Encouraging enterprises that combine the supply of pumps, technical support to farmers and markets for produce could greatly improve the use of water-lifting technologies and bring economic benefits to farmers.

Where the opportunity lies

In their Growth and Transformation Plan, the Government of Ethiopia discusses greater use of groundwater by helping farming households invest in private hand-dug wells and water-lifting technologies. The total number of pumps already in use in Ethiopia is not known, but the Regional Bureaus of Water Resources have supplied over 70,000 pumps and the total could be much higher.

The research

Researchers from the AgWater Solutions Project set out to identify factors that influenced the adoption of water-lifting technologies by smallholder farmers, particularly motorized pumps, in four regions: Amhara, Oromia, SNNPR and Tigray. Data was collected from 800 randomly selected farm households (200 sample households in each region). Researchers stratified the sample according to data on water-lifting technologies from the Regional Bureaus of Water Resources, and considered various physical and economic factors.

Motor pump adoption

Adoption rates

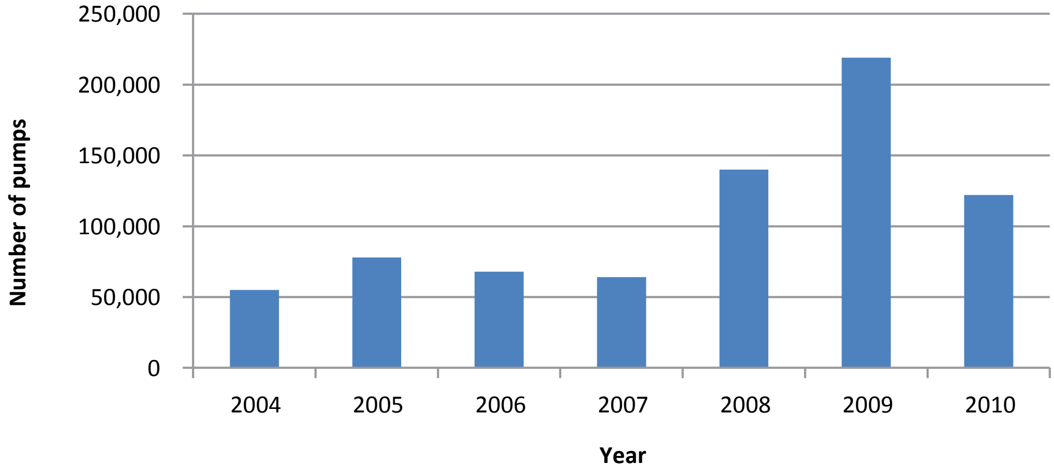
Thirty-percent of the farmers interviewed had adopted petrol or diesel pumps, 3% used electric pumps and 1% used treadle pumps. Petrol and diesel pump use was almost evenly distributed across the regions studied.

[2] Based on Gebrehaweria 2011; and AgWater Solutions Project 2011a.

Households with a higher number of adult males were more likely to adopt water-lifting technologies. Female-headed households were less likely to adopt water-lifting technologies - they made up only 3% of the adopters but 21% of the non-adopters.

The number of pumps imported into Ethiopia steadily increased up to 2009 (Figure 2).

FIGURE 2. Pumps imported into Ethiopia.



Source: Gebrehaweria 2011.

Factors affecting adoption

The survey found that a large number of farm households are aware of water-lifting technologies (WLTs), and that extension services and radio may have contributed to this high level of awareness among farmers. However, only a small percentage of farmers invest in WLTs (Table 2). Further analysis found that although information is a contributing factor for adoption it is not sufficient on its own.

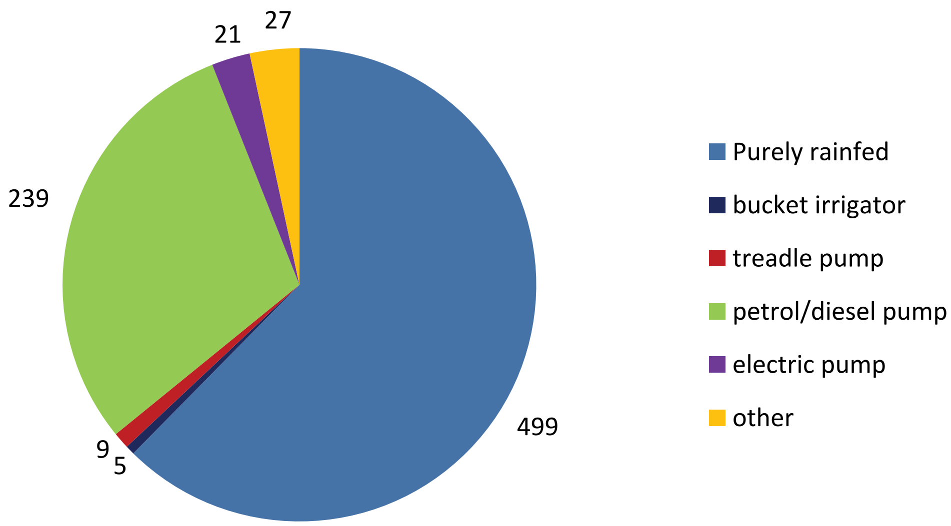
TABLE 2. Awareness of water-lifting technologies.

Type of pump	Number of farmers aware of this technology	Percentage of farmers who have ever used this technology (%)	Percentage of farmers who are still using this technology (%)
Treadle	25	8	4
Rope-and-washer	134	14	7
Petrol	510	39	33
Diesel	368	17	12
Electric	148	18	11
Wind	61	2	0
Solar	13	0	0

Source: Gebrehaweria 2011.

Motorized pumps are clearly the favored technology when adoption does take place (Figure 3). In 82% of the cases studied, farmers use motor pumps to irrigate in the dry season. The source (surface water or groundwater) does not influence adoption rates, but the size of the landholding does. Farmers with the largest landholdings tend to adopt cheaper forms of irrigation, such as gravity fed systems, those with small landholdings use manual methods (buckets and treadle pumps) and those with medium-sized landholdings adopt motorized pumping. A great many farmers still depend entirely on rainfall (Figure 3).

FIGURE 3. Comparison between farmers that use available water-lifting technologies and those that depend entirely on rainfall.



Source: Gebrehaweria 2011.

The cost associated with water-lifting technologies influences their adoption. Prices of pumps are considerably higher for motorized pumps than for manual devices (Table 3). Import taxes account for 37% of the cost of motor pumps. The running costs also vary considerably and is a factor that affect farmers' decisions to adopt the technology, although it was found that household labor was not considered an important factor.

TABLE 3. Typical cost of pumps.

Type of pump	Capital costs (ETB)		Maintenance costs (ETB)	
	WLT	Accessories	2010	To date
Treadle	3,650	4,000	375	517
Rope-and-washer	2,593	200	0	0
Petrol	4,751	1,872	953	1,420
Diesel	7,246	1,971	1,792	2,527
Electric	5,000	1,929	13,000	0

Source: Gebrehaweria 2011.

Note: USD 1 = ETB 17.8; ETB = Ethiopian Birr

Access to fuel, mechanical parts and support services were also cited by farmers as being reasons for not adopting a water-lifting technology. They feel that there are insufficient spare parts and support services for repairs and maintenance. Machinery frequently breaks down and the farmers' lack of technical knowledge to maintain these devices can lead to dissatisfaction and slow adoption by other farmers who witness these problems.

How farmers would benefit

Most farmers who invest in water-lifting technologies want to irrigate in the dry season to earn additional household income. Incidence and depth of poverty were found to be lower for households with access to irrigation.

Where to invest: Encouraging adoption

The research revealed a number of strategies that would encourage wider adoption of water-lifting technologies, particularly motorized pumps:

- Help support businesses that sell a range of pumps and provide after-sales service and parts. This could take the form of training dealers in the technical aspects of the products they sell, marketing and after-sales services, and helping them set up demonstration plots. Pump maintenance and repair manuals in local languages would help boost sales and improve farmers' capacity.
- Provide 'pro-poor' support in terms of start-up capital and tax exemptions. Support might take the form of credit arrangements and supportive policies that enable farmers to purchase water-lifting technologies using alternate forms of collateral (e.g., group guarantees and projections of future income).
- Strengthen the knowledge and skills of extension service workers to provide practical advice on the use of water-lifting technologies and irrigated agriculture, and incorporate experience-sharing farm visits.
- Explore ways and means to create pump rental markets. Many farmers are able and willing to rent pumps but there are few available. More pumps could be made available for rent using an 'irrigation service provider' model in which small entrepreneurs rent out pumps on a short-term basis. The service provider takes care of maintenance of the pumps, and offers technical and agricultural advice (Box 3).
- Develop information campaigns for broadcast on radio.

Box 3. Irrigation service providers.

Irrigation service providers are private entrepreneurs who rent out small pumps and offer support services to farmers who want to irrigate dry-season crops.

(Continued)

Box 3. Irrigation service providers (Continued).

In many sub-Saharan countries, millions of smallholder farmers earn extra cash income from irrigated vegetable cultivation during the dry season. Most use simple hand-watering methods which are time consuming and limit the area they can cultivate. Some farmers use small pumps to expand their cultivated area and with it their profit, but only relatively well-off farmers can afford the initial investment costs and have the means to run and maintain a pump. Women farmers, in particular, face trouble accessing motorized pumps. An alternative is to hire a pump for the time required to irrigate.

An irrigation service provider owns one or more portable motorized pumps along with hoses, pipes and other accessories. The service provider rents a pump set to an individual or a group of farmers for a fixed period of time, and takes care of the running costs, and operation and maintenance of the pump set. Farmers pay a fixed rate per hour that covers all costs and leaves a profit for the service provider. Depending on the need and the level of skill and motivation of service providers, they can extend their services to offering loans for agricultural inputs, agronomic advice and credit.

Benefits:

- For local entrepreneurs: a profitable business opportunity.
- For farmers: affordable access to motorized pumping as individuals (no need to organize into a collective); potentially related services (agronomic and marketing advice, and credit); and higher profits from vegetable farming due to larger areas and better water supply.

Stakeholder feedback.

Water availability

- Often there isn't enough water in ponds for motor pump use.
- There is competition for water between farmers in the upper and lower parts of watersheds.
- Sometimes the only available water is too far from our land or in places that are hard to pump from.

Pumps

- Frequent breakdowns, no reliable supply of spare parts, and poor repair and maintenance services.
- Mismatch between the number of pumps imported into the country and adoption rates, probably due to illegal, unregistered imports from Sudan.

(Continued)

Stakeholder feedback (Continued).

- Prices are high. Initial subsidies could help until local manufacturing is established.
- Reduce import taxes but only as an interim measure to avoid discouraging local manufacturers.

Enterprises

- Support existing institutions rather than establishing new ones.
- Beware of monopoly practices.

Source: FAO 2012b.

Who benefits and where

Physical suitability for small pumps was assessed on the basis of travel time to markets (defined as population centers of 20,000 inhabitants or more), which was considered 'highly suitable' if the travel time was less than 4 hours and 'unsuitable' if the travel time was over 8 hours; proximity to surface water; and the occurrence of soils with shallow groundwater potential (fluvisols, gleysols and gleyic sub-units). This was combined with demand, which was assumed to be more favorable in zones with a higher prevalence of market-oriented smallholder farmers, high population density and landholdings of less than 2 ha.

Based on these conditions it was calculated that, if 50% of the total potential motor pump users were to adopt the technology around 1.1 to 2.2 million households could benefit (amounting to 8.8 to 16.9% of the rural population). The potential application area is 0.9 to 1.8 Mha or 3 to 5.7% of the total agricultural land area (Figure 4).

Groundwater for Agriculture[3]

Ethiopia has large reserves of groundwater that could be used to drive agricultural growth. Better hydrogeological mapping, changes to existing policy and capacity building are needed to harness this untapped resource.

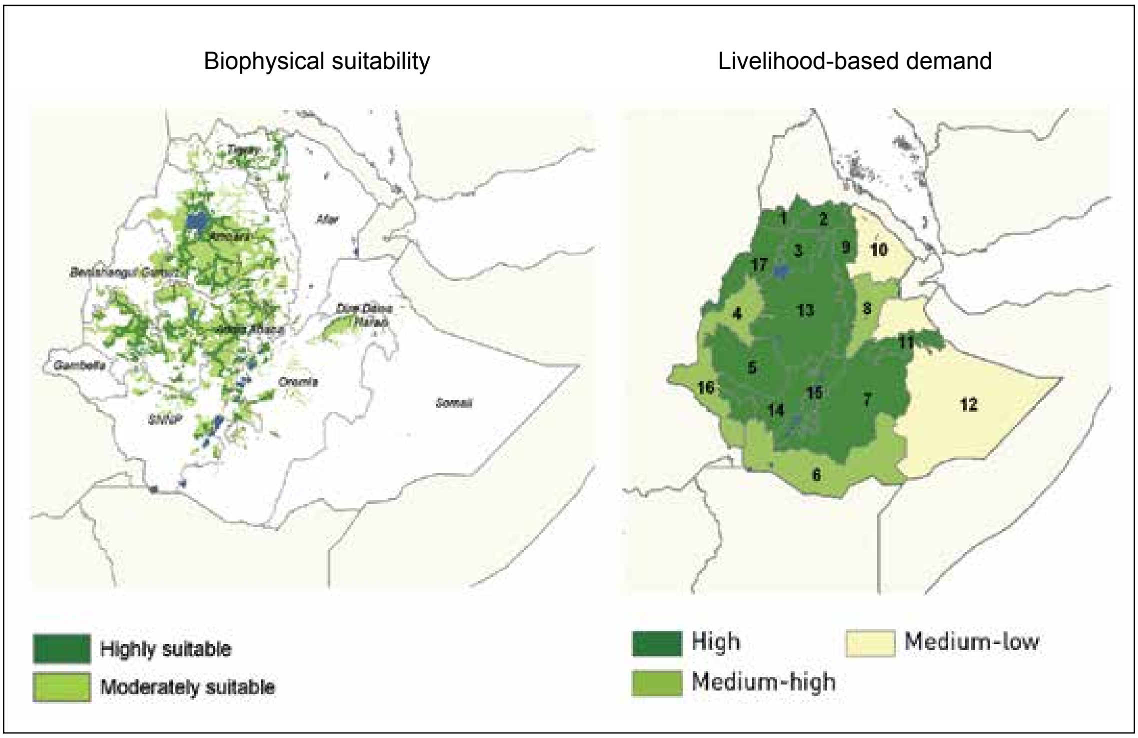
Where the opportunity lies

The Ethiopian Government plans to implement nine irrigation projects. In the coming five years, 8,000 ha will be developed as a pilot study using groundwater. The Directorate of Groundwater Development Studies and Management, Ministry of Water and Energy, will drill more than 90,000 test wells, 28,000 monitoring wells and 370,000 meters (m) of production wells. This ambitious effort will require institutional and human capacity development, technology procurement and transfer, and more up-to-date and reliable hydrogeological data and maps.

[3] Based on Gebrehaweria 2012a; and AgWater Solutions Project 2012a.

Investment in irrigation, particularly in small-scale and household-level irrigation, has been identified as a core strategy to unlink agricultural production in Ethiopia from uncertain rainfall, improve crop production and induce the use of inputs which further enhance agricultural productivity. With more smallholder farmers using motorized pumps to irrigate, groundwater will play an increasingly important role in achieving these goals.

FIGURE 4. Potential for motor pumps to improve livelihoods.



Source: FAO 2012a.

The research

Researchers from the AgWater Solutions Project undertook a comprehensive review of past and current literature and data available on groundwater from regional and state water bureaus. They determined a number of factors affecting groundwater exploitation:

Groundwater use: Agricultural use of groundwater is low. Data from 8,000 boreholes indicate that over 80% of groundwater use is for domestic purposes. Most wells are shallow and have low yields of less than 10 liters per second.

Groundwater reserves: Groundwater reserves may be greater than the commonly used estimate of 2.5 billion cubic meters (BCM). Studies in Kobo, Raya and Adaa Bechoo suggest that regional aquifers are deep and water movement crosses basins. The groundwater reserve is estimated to be 2.5 BCM in Kobo Girana Valley alone, 7.2 BCM in Raya and 965 million cubic meters (MCM) in Adaa Bechoo.

Data: The coverage and scale of the available geological and hydrogeological data and maps are not adequate for managing groundwater. The available groundwater database is not widely used by experts and institutions. A new groundwater database known as ENGWIS is under development.

Capacity to drill wells: Capacity for deep well drilling is hampered by the lack of reliable hydrogeological data, high cost of equipment and drilling, poor quality installations, and shortages of skilled and experienced personnel.

Human resources: Human resources for management and development of groundwater in regional and state water bureaus are insufficient. One-third of the available positions are vacant. The capacity gap widens at local levels of administration. There is a severe shortage of qualified well-drillers and a high demand for hydrogeologists, electricians, mechanics, water supply engineers and hydrologists.

Where to invest: Solutions to enhance groundwater use

Better groundwater data: Groundwater studies should focus first on the conceptualization of the groundwater system before making estimates based on local information. Studies are needed to understand the regional groundwater system in terms of flow hydraulics and the subsurface geological system. Government and donor agencies need to cooperate to establish and promote the use of a single source of data and information.

Capacity building: Public universities offering geology degrees (e.g., Addis Ababa University and Mekelle University) could accommodate more hydrogeology courses in their curricula. Vocational training institutions need support to meet the emerging demand for skilled labor in the drilling industry.

Institutional framework for managing groundwater: Development strategies and policies, such as the Sustainable Development and Poverty Reduction Programme and the Ethiopian Water Sector Policy, include managed groundwater development to contribute to national growth and development. However, the institutional framework for governing groundwater requires further elaboration and clarification.

Finance drilling: The government currently allows private and public well drilling companies to import drilling rigs tax free. However, the capital cost of a drilling rig can be USD 800,000 and there is a chronic shortage of spare parts. Government-backed loans, in-country parts depots and public-private partnerships would provide a much-needed stimulus to a struggling industry.

A pilot of Manual Well Drilling Businesses by iDE, together with the AgWater Solutions Project, has provided more information to support some of these recommendations, including the need for better training and financial support (for details, see the section, *Manual Well Drilling*).

Stakeholder feedback.

- We do not have enough information about where groundwater is available. Mapping potential areas will facilitate groundwater use.
- Intensive irrigation is causing salinity problems in some areas (e.g., in Abraha Atsbeha watershed in Tigray). More research is needed in these locations.

Source: FAO 2012b.

Manual Well Drilling[4]

Establishing private manual well drilling enterprises to provide low-cost access to groundwater would expand the irrigated farm production area and offers potential to improve the livelihoods of millions of smallholder farmers.

Where the opportunity lies

Establishing an industry for manual well drilling to access shallow groundwater for irrigation would benefit all stakeholders.

For low-income, smallholder farmers, it could improve their access to groundwater, lengthen the crop growing season, expand crop options to higher-value crops and increase incomes. Women farmers with wells spend significantly less time walking long distances for water.

For well drilling enterprises, it could provide a healthy return on investment and create employment.

For supply chain actors, it could increase profits along the chain.

For the financial services sector, it could stimulate demand for financial products and services throughout the value chain.

Overcoming constraints

Manual well drilling (Box 4) is feasible only in specific hydrogeologic conditions. In carefully selected test areas, a pilot drilling program conducted by iDE had an 80% success rate. Maps showing more detailed and accurate soil, hydrogeology and water resources data would help determine suitable locations and reduce exploration costs.

[4] Based on Weight et al. 2012; and AgWater Solutions Project 2011b.

Box 4. What is manual well drilling?

Teams use manual labor and simple technologies to tap shallow groundwater. In many Asian countries, it is an established business.

In Africa, manual well drilling is prevalent in Sudan, Chad, Nigeria and Niger. In Nigeria, more than 100,000 wells have been manually drilled and, in Niger, 42 private sector drilling teams have drilled more than 18,000 wells.

Once a well is drilled, farmers have a range of water-lifting, storage and application options.

Source: Weight et al. 2012; AgWater Solutions Project 2011b.

The pilot: Testing manual well drilling

In 2009, iDE initiated a manual well drilling pilot program in three locations in Ethiopia to determine the technical and financial feasibility of establishing a niche in the private sector industry for manual well drillers. The goal was to catalyze widespread private-sector, low-cost manual well drilling by creating an industry of private well drillers that were skilled in:

- drilling techniques suitable for Ethiopia's challenging geologic conditions;
- mapping areas with potential for manual well drilling;
- raising awareness among farmers and building their capacity for irrigating higher-value crops; and
- establishing market chains that link equipment suppliers, drillers, farmers and consumers.

Main findings

The pilot well drilling program in lakes Zeway, Betcho and Tana areas demonstrated the high potential demand among farmers for more access to groundwater. For every well drilled, an additional three farmers expressed interest in a well. The key constraints were the institutional obstacles to obtaining investment capital and the lack of skilled well drillers.

There are many areas with shallow groundwater and permeable soil layers with high potential for manual well drilling, but the geology in Ethiopia makes drilling a challenge. To achieve an acceptable drilling success rate, accurate groundwater maps and a database of geological conditions are essential.

A separate analysis by IWMI researchers showed that while there are alternatives such as hand digging and machine drilling, manual well drilling is the most economic option.

Where to invest: Solutions to catalyze the manual well drilling business

Researchers from the AgWater Solutions Project developed a detailed model outlining how investments in water resource mapping, driller training, warehousing inputs, awareness and value chain linking would stimulate the market for input suppliers, well drilling enterprises, small farmers and markets.

Investments refer to initial financing by donors and governments to spur private sector industry. An initial feasibility assessment is estimated to cost approximately USD 5 million. Once mobilized, private industry would become self-sustaining and expand through financial returns without further external investments (Box 5; Figure 5).

This investment model recommends simultaneous investments over a period of three to five years in driller training and certification, creating supply chains for drilling equipment and supplies, increasing demand among farmers, building farmers' capacity for irrigated agriculture, and linking farmers to processing, storage and market opportunities for higher-value farm produce.

Box 5. Establishing a manual well drilling industry.

- Produce maps showing where manual well drilling is most likely to find water and the potential number of farmers who could benefit.
- Monitor environmental risks and set up a national database on water resource availability, quality and drilling conditions.
- Set up a program to train and certify manual well drillers and help them set up businesses.
- Support private sector supply chains for spare parts, drilling equipment and pumps.
- Develop financial products and services to support the value chain.
- Raise awareness among smallholder farmers to create more demand for wells.
- Train smallholder farmers in high-value irrigated crop production and marketing.
- Facilitate smallholder farmers' access to water-lifting technologies.

Source: Weight et al. 2012.

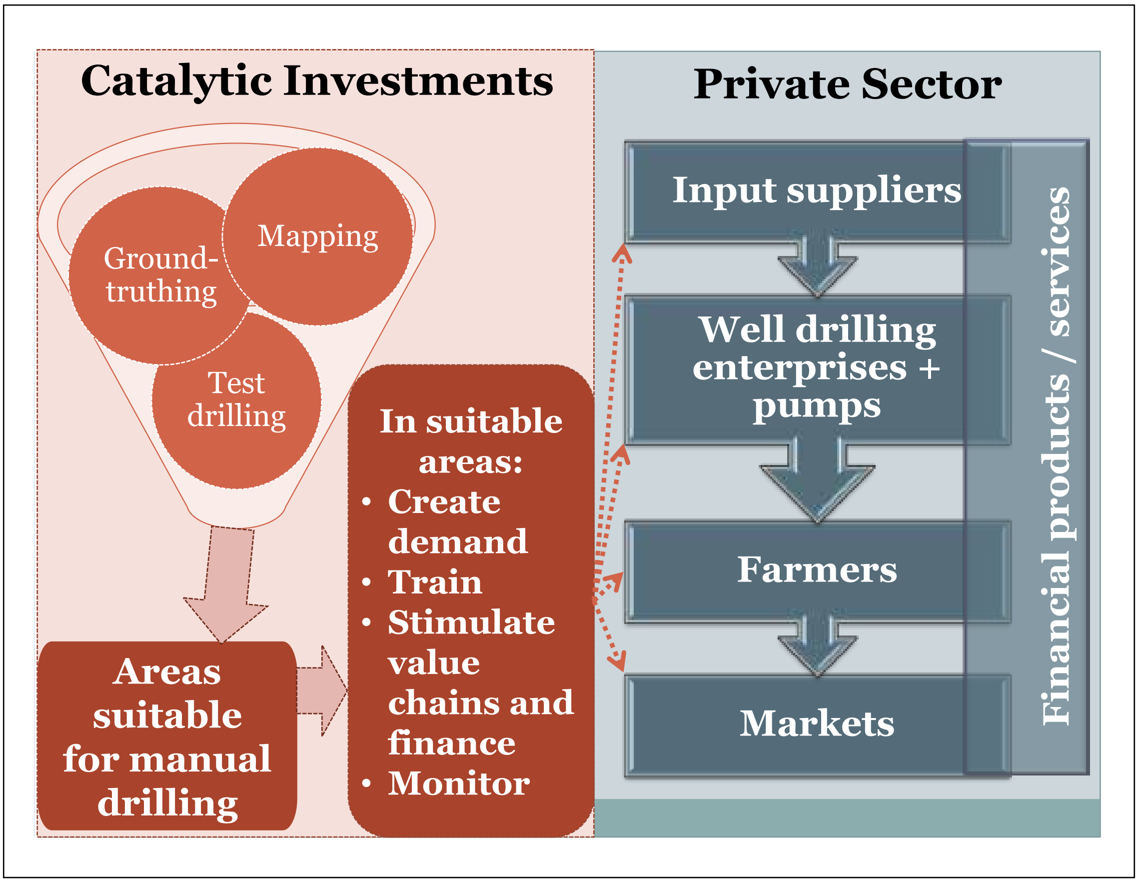
Who benefits: How farmers, drillers and suppliers would benefit

The estimated net annual additional income to farmers using a drilled well and treadle pump to irrigate a 700-square meter (m^2) plot is USD 490 per year. In addition to their cash investment, farmers would need to participate in training or extension programs to build their capacity for irrigated production and marketing of high-value crops.

Certified well drillers operating their own small business could expect to earn up to USD 1,500 per year. A certified training program for well drillers graduating up to 200 drillers per year could result in nearly 400,000 wells over ten years. Initial investment required by farmers and well drillers is USD 156 and USD 1,247, respectively (Table 4).

Suppliers of drilling equipment and materials benefit as the number of drillers multiplies and drillers scale up their operations.

FIGURE 5. How a private sector well drilling industry would work.



Source: Weight et al. 2012.

TABLE 4. Potential investment cost and financial benefits from manual well drilling.

Player in the manual well drilling business	Initial investment (USD)	Potential income (USD/year)
Farmers (irrigating a 700-m^2 plot)	156	490
Certified drillers	1,247	1,500

Community-based Watershed Management[5]

Community-based watershed management could be a significant factor in helping the government achieve its aim of making agriculture the driving force of economic development in Ethiopia.

Where the opportunity lies

Ethiopia has 12 major river basins and 17 livelihood zones. Over 80% of the population live in the regions of Oromia, Amhara and SNNPR, which together with Tigray are known as the

[5] Based on Gebrehaweria 2012b; and AgWater Solutions Project 2012b.

major regions. Given the current favorable policy framework and the government's aim to make agriculture the driver of economic development, community-based watershed management offers a promising solution.

Watershed management programs have been implemented in Ethiopia for the past four decades. New initiatives based on lessons learned over this period offer opportunities to:

- reduce farmers' dependence on rainfed, low-productivity subsistence agriculture;
- reverse land degradation;
- address flooding and sedimentation;
- tackle water shortages and moisture stress;
- generate grazing land and fodder crops for animals; and
- increase local participation in water management.

The challenge is not to 'find' solutions but to negotiate solutions that are inclusive and equitable, and steer the country towards its goal of making rural agriculture the basis of economic growth.

There is now a supportive policy and legal framework facilitating decentralized and participatory development, institutional arrangements that encourage public agencies at all levels to work together, and an approach to natural resources that reflects local legislation and tenure practices.

The research

Watershed development activities were assessed in six study sites in Tigray, Amhara and Oromia to see how management efforts can be scaled up across the country. The watersheds in each region were chosen to represent one successful and another less successful watershed. The watersheds are located to the east, where moisture is a limiting factor and watershed degradation is high.

Main findings

- Watershed size and hydrogeology play a critical role. Macro-watersheds (e.g., Abraha Atsbeha) performed better on all indicators than smaller watersheds.
- Improvement of groundwater was more pronounced in watersheds with permeable geological formations (e.g., sandstone and colluvial deposits of Abraha Atsbeha).
- Land and crop productivity and area for cultivation increased over the years as a result of land rehabilitation, water availability for supplementary or full-scale irrigation and new agronomic practices.

Socioeconomic benefits

The productivity gains on farms in the upstream areas are mainly from rainwater conservation, while farmers downstream have increased access to irrigation, particularly from groundwater (Table 5). In the lower reaches, farmers can cultivate two or more times a year because of greater water availability during the dry season.

Farm income increased, on average, by 50% and households reported food security to have increased from 20 to 90%, and access to health and education services had increased by 20 to 50% and 50%, respectively.

TABLE 5. Productivity gains from watershed management.

Watershed	Average farm size of households (ha)	Percentage reduction in soil loss (%)	Increased production area (%)	Crop production and productivity increment	Improvement of fodder availability (%)
Abraha Atsbeha	0.75	80	20-50	300%	100
Gereb Shilina	0.75	50	5	5-20%	80
Becheti	0.4	60	5-20	250%	50
Goha Cheri	0.36	75	5-20	20-50%	60
Karaba	0.25	90	20-50	20%	95
Bedesa Kela	0.5	35	5-20	5-20%	50

Where to invest: Solutions to enhance watershed management

Site-specific development: Various land rehabilitation and conservation measures are being employed (soil and water conservation structures, reforestation, gully treatment and area enclosures) along with rainwater harvesting, rural water supply and income diversification. Since a 'one-size-fits-all' approach does not work, site-specific watershed development solutions need to be identified that take into consideration local situations.

Capacity building: Managing watershed externalities within and outside a watershed requires cooperation among stakeholders to build and strengthen institutions, social norms and regulations, and to develop systems of sharing responsibilities and benefits.

Land tenure: Ethiopia's watershed management policy needs revision to address land tenure and community rights issues.

Stakeholder feedback.

Discussions around the Mekelle University study on watershed management programmes showed that participants agree that community-based initiatives work best, and that water allocation responsibilities should be devolved to avoid conflict and ensure fair sharing of surface water and groundwater.

Source: FAO 2012b.

On-farm Water Storage[6]

Large irrigation schemes cannot always supply enough water at the right times. Storing water in farm ponds allows farmers to irrigate when they need to. Farmers can then supplement rainfed crops or grow and sell seasonal high-value crops.

Where the opportunity lies

A pilot study by iDE in the Shopa Irrigation Scheme, Oromia Region, Ethiopia, showed that farmers could gain considerable benefit from on-farm ponds, including higher yields and greater incomes. The government is already promoting on-farm ponds, but this is usually to store rainfall in dry areas to supplement rainfed crops. The program could be extended to underperforming irrigation schemes.

The pilot study

iDE built four on-farm water storage demonstration ponds in the Shopa Irrigation Scheme (located within the Shopa Bultum Peasant Association), reviewed the water management and agronomic practices of local farmers, and asked them about their incomes and profits. Irrigation extension officers and development officers were also interviewed about current practices and the potential for these new AWM options.

Existing irrigation and crop choice

- Managers of the Shopa Irrigation Scheme provide water to farmers for two hours every two weeks. Farmers grow wheat, maize and potatoes, and some grow onions and cabbages.
- Maize and wheat yields are high at 4.0 tonnes per hectare (t/ha) and 2.8 t/ha, respectively. Potato, onion and cabbage yields are below potential for the area.
- Landholdings range in size from 0.5 to 5 ha with an average of 2.5 ha. Land is owned, leased or sharecropped. The total land area is 200 ha, of which 140 ha is irrigated. The irrigation regime sometimes leads to conflict and farmers are limited in the crops they can grow because they have no control over when and how much water they can use. Farmers practice flood irrigation, which wastes water and erodes the soil.

On-farm ponds

The ponds used in the scheme range in size from 14 to 40 m^2. A 28-m^2 pond can be filled in half an hour and can irrigate up to a quarter of a hectare twice a week. By storing water, farmers can irrigate between the official water supply times. Ponds are lined with a geo-membrane, concrete or clay.

Farmers also need to lift the water and iDE has been supplying treadle pumps at a 50% subsidy rate. The farmer pays ETB 170 (USD 1 = ETB 17.8). Local entrepreneurs and youth

[6] Based on Tadesse 2009.

groups are making treadle pumps. There is a tradition of group labor in the area, so digging the ponds has not been difficult.

How farmers could benefit

Farmers could use the ponds for more than supplementary irrigation. For example, cabbage production using on-farm water storage is a lucrative business. Net returns are around 1,410 USD/ha – about USD 350 more than from canal irrigation. The benefit-cost ratio shows that an investment of ETB 1 on cabbage production using on-farm ponds and treadle pumps would cover the cost and generate an additional ETB 2.90, which is high for a poor farmer.

The benefit-cost ratio for canal and flood irrigation (Table 6) is higher than the pond system because no capital is required. Without pond and pump irrigation, it would not be possible to grow cabbages, hence no additional income. The pond system also reduces nutrient depletion, a long-term benefit not included in the calculation.

TABLE 6. Benefit-cost analysis of cabbage production.

Costs and benefits of cabbage production (area 0.25 ha)	Pond and treadle pump	Canal flood irrigation
Benefits		
Production of cabbage (one cycle) (t)	8.0	5.5
Price (ETB/t)	750	750
Gross revenue from sales (ETB)	6,000	4,125
Costs (ETB)		
Total labor input (ETB 15/day)	510	420
Seed	70	85
Fertilizer	200	150
Oxen power	120	120
Depreciation on treadle pump	142	0
Depreciation of geo-membrane	500	0
Total cost	1,542	775
Net benefit (revenue less costs)	**4,458**	**3,350**
Benefit-to-cost ratio	**3.90**	**5.32**

Source: Tadesse 2009.

Markets, limits and solutions

There is ample demand for farm products. The Shopa Irrigation Scheme is close to market centers and trading routes.

One limitation is that farmers have little experience selling vegetables and are easily taken advantage of by brokers and merchants. iDE is organizing 'Producer and Marketing Groups' for farmers. The groups are legal entities that will help farmers get better access to inputs and micro-finance institutions, and improve their bargaining position.

Where to invest

- Promote AWM options in other irrigation schemes. The government could combine this approach with its current rainwater harvesting program.
- Geo-membrane linings are currently hard to acquire. A useful investment would be in making them more widely available. One way to do this would be to support local manufacturers. Other options such as concrete and clay could be improved.
- Strengthen cooperatives to help farmers get better access to markets and negotiate better prices for crops.
- Improve management of the irrigation scheme to ensure water continues to be available.
- Provide training on improved agronomic practices and irrigation of new high-value crops, such as vegetables.

Small Reservoirs[7]

For investors in small reservoirs, the challenge lies in coordinating and integrating multiple users and social groups around a common resource. Limiting costs through improved procedures and financial management is also critical.

Where the opportunity lies

In sub-Saharan Africa, the term 'small reservoir' refers to the water stored behind an earthen or cement dam less than 7.5 m high. They can store up to 1 MCM of water and sometimes have a downstream irrigation area of up to 50 ha. Capital investment is, generally, externally driven and community management is the norm.

A well-designed reservoir can sustain multiple uses including livestock, fisheries, domestic needs and small businesses. Small reservoirs support soil and water conservation, drought proofing and small-scale community irrigation. In many cases, small reservoirs are assets in which significant investments have already been made by governments, donors, NGOs and communities. They are in high demand, fit with national strategies and policies, and attract funding from international development agencies. In many cases, they perform below expectations for irrigation but have multiple-use benefits that are often unaccounted for.

The Research

Studies were conducted on four small reservoirs in Hintalo Wejerat, Tigray: Gum Selassa, Miella, Shilanat 4 and Hizaeti Wedicheber. The approach to analyze the performance of reservoirs used qualitative evaluation based on the ranking of respondents. The rankings related to four main indicators: the status and functioning of dam infrastructure; effectiveness of management of the reservoir; benefits of the reservoir to users; and equity in the institutional arrangements for the use and management of the reservoir.

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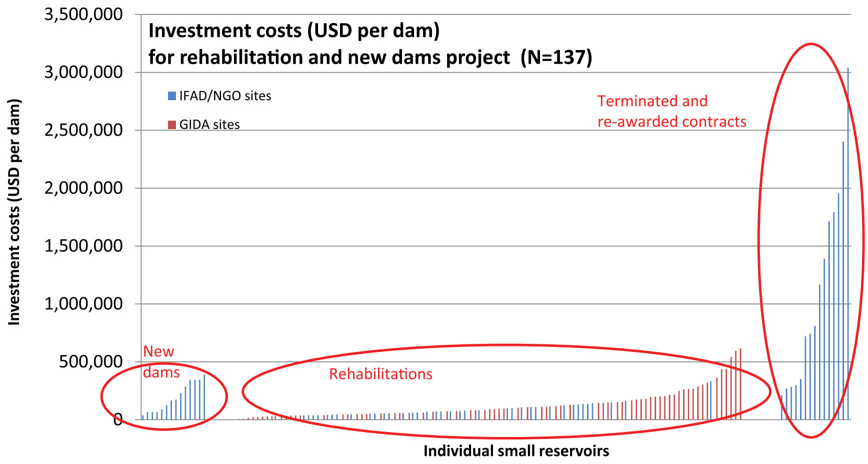
[7] Based on Venot 2011; and AgWater Solutions Project 2011c.

Main findings

Controlling costs

Storing surface water is an expensive way to invest in AWM, but is sometimes the only way to provide people in rural communities with water. High costs can often be traced back to poor design, construction and management (Figure 6). Investment costs can be controlled by improving procedures, more detailed feasibility studies and strict accountability to decision makers.

FIGURE 6. Investment costs of dams and reservoirs with flaws in the design, procurement and construction stages are a costly venture.



Source: Venot 2011.

Account for all uses

To effectively evaluate small reservoirs and to compare them to other AWM interventions, a cost-benefit analysis needs to be considered per capita and for the entire lifetime of the project. If managed well, then costs are comparable to investments in other types of AWM interventions. Benefits are greatest when multiple uses, existing farming systems, water recharge and direct pumping are taken into account.

Effective management

To be effective at providing livelihood benefits, small reservoirs also need a strong and inclusive institutional component. Water user associations (WUAs), for example, tend to ignore de facto or planned multiple uses other than irrigation. There needs to be multiple organizational options for communities, and coordination with traditional and local authorities.

Where to invest

There are a number of promising approaches to improving the use and efficiency of small reservoirs.

- Coordinate and integrate multiple users 'spatially' around the small reservoir/watershed and 'temporally' throughout the project cycle.

- Facilitate multiple institutional arrangements.
- Strengthen existing policies, procedures and links within organizations.
- Introduce a step-wise approach to assess feasibility and needs when planning rehabilitation or new construction.
- Establish pre-qualification standards for contractors and better compliance with existing procedures for awarding contracts.
- Develop guidelines for contractors on the design of multiple-use reservoirs.
- Build capacity for extension workers, especially regarding multiple-use systems and social aspects.

Who benefits and where

Better information generally leads to more effective decision making. Improved planning processes would reduce investment costs with a positive impact on performance as will adopting a multiple-use perspective for monitoring. Overall, there would be a better return on investment.

A 'suitable' area for small reservoirs is defined as an agricultural area where the Aridity Index (yearly precipitation divided by yearly reference evapotranspiration) is between 0.2 and 0.65, i.e., semi-arid to dry sub-humid. A higher livestock density is assumed to be correlated with enhanced multiple uses of small dams. Using these criteria, research carried out by the AgWater Solutions Project estimates that if 50% of the households that could potentially benefit from small reservoirs were to begin using these, this could amount to 244,000 to 894,000 households in Ethiopia (1.9 to 6.9% of rural households). The potential application area is 244,000 to 894,000 ha or approximately 0.8 to 2.9% of total agricultural land (Figure 7).

Taking river basin hydrology, environmental constraints, yield improvements, costs of the investment and price impacts of expanding crop production into account, the potential area expansion for small reservoirs in East Africa is 5 Mha and 100 million people (or 19 million households) (IFPRI 2012).

CONCLUSIONS[8]

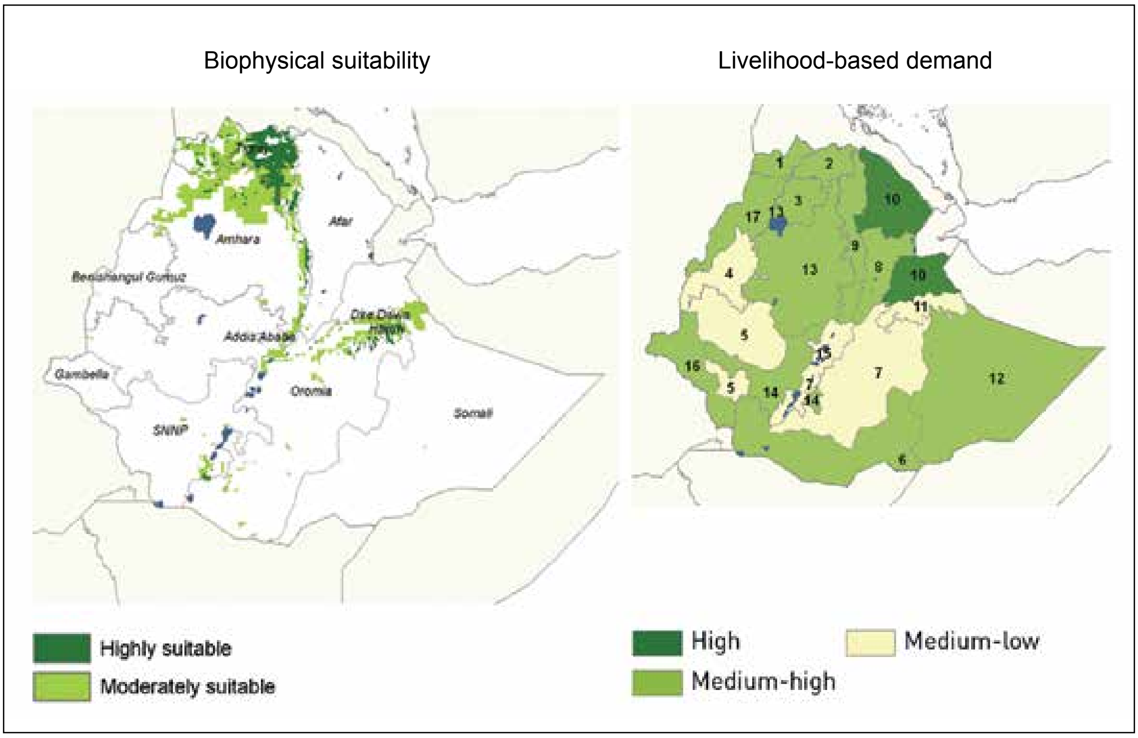
Ethiopia has a wealth of opportunities to increase irrigation and food production. At present, most farmers are smallholders cultivating for subsistence purposes usually on rainfed land or grazing livestock. The Government of Ethiopia has made a commitment to increase irrigation. The AgWater Solutions Project reviewed a number of AWM options and has made a series of recommendations:

Water-lifting technologies could benefit around 1-2 million households at an investment cost of up to USD 884 million. The financial barriers to entry must be lowered by supporting pump supply businesses, and by reducing taxes and subsidies. Improving after-sales services, access to spare parts and extension services, and providing manuals in local languages could extend the life of pumps and prevent abandonment. Pump rental markets should also be explored, including credit arrangements to stimulate their development.

[8] All figures provided in this section assume that 50% of the total potential users adopt the AWM option. All figures are taken from FAO 2012a.

The use of **groundwater** and the development of **manual well drilling** will only be feasible if there is more information about the resource. Investments should be made in mapping groundwater, developing a national database, facilitating information sharing and developing a pool of skilled labor for well drilling. An improved institutional framework and groundwater policy are also required.

FIGURE 7. Potential for small reservoirs to improve livelihoods.



Source: FAO 2012a.

Community-based watershed management has many proven socioeconomic benefits but interventions must be developed and implemented with watershed users, and must take account of local conditions and needs. Institutional development, land tenure and user rights will be critical.

Small reservoirs could benefit some 200,000-900,000 households at a total maximum investment cost of USD 3,272 million. The advantage of small reservoirs and **on-farm water storage ponds** is that they provide multiple benefits as well as allowing farmers to grow high-value dry-season crops. Keeping costs down during the planning, implementation and use of small reservoirs is the challenge.

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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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