AgWater Solutions Project
Case Study

Water Lifting Irrigation Technology Adoption in Ethiopia: Challenges and Opportunities

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The AWM Project
The AgWater Solutions project was implemented in five countries in Africa and two states in India between 2008 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 small-scale farmers.

The leading implementing institutions were the International Water Management Institute (IWMI), the Stockholm Environment Institute (SEI), the Food and Agriculture Organization of the United Nations (FAO), the International Food Policy Research Institute (IFPRI), International Development Enterprises (iDE) and CH2MHill.

For more information on the project or detailed reports please visit the project website http://awm-solutions.iwmi.org/home-page.aspx.

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Contents

INTRODUCTION

Smallholder agriculture is the main source of income and employment in developing countries where Ethiopia is not an exception. Agriculture dominated by smallholder rainfed farming system is the mainstay of the Ethiopian economy, while, low and erratic rainfall causes severe drought that threatens the livelihoods of the rural poor. Land scarcity due to high population density makes the expansion of agricultural land increasingly difficult, leading to small landholdings. These problems are particularly serious in the densely populated highland areas of Ethiopia, where low agricultural productivity due to severe land degradation and low soil fertility is a critical problem (Pender and Gebremedhin, 2004).

Agricultural production remains below one ton per hectare, where most rural households subsist on incomes of less than a dollar a day (Pender and Gebremedhin, 2007). Poverty is a persistent and widespread problem and has been aggravated by the recent worldwide high food prices, which have severely affected less developed countries and the poor implying there is a need for production of more food.

In general, heavy reliance on rainfed agriculture, especially when rainfall is highly variable, severely affects the performance of agriculture leading to recurrent droughts and adverse effects on the economy. The World Bank (2006 cited in Hagos *t al.* 2009), for example, estimated that hydrological variability costs the Ethiopian economy over one-third of its growth potential and has led to a 25% increase in poverty rates.

Ironically, Ethiopia is one of the abundant water-receiving countries in the east African region (Makombe *et al.*, 2007); which has approximately 12 river basins with an annual runoff of 122 billion m^3 and with 2.6 billion m^3 of ground water (Awulachew *et al.*, 2006). With all this potential, however, the country fails to produce enough food to feed its population. The country’s perennial dependence on food aid has been then attributed largely to an over-reliance on rainfed smallholder agriculture. For example, only 5-6% of the 4.25 million hectares of irrigable land is currently developed through traditional, small-, medium-, and large-scale irrigation schemes (Awulachew *et al.*, 2007).

The good news this is at least the problem has been well recognized in the country’s development policy. For example, in its Growth and Transformation Plan (GTP) the Ethiopian government has recognized that among the major challenges encountered during the past five years (2005/06-2009/10) of PASDEP implementation were delayed entrance of rainy seasons; early withdrawal and poor distribution of rain (MoFED, 2010).

In general, poverty reduction is at the center of the development agenda of the Ethiopian government in general and the regional governments in particular. In line with this, there has been a general consensus that increases in agricultural production and poverty reduction should come mainly from improved agricultural productivity rather than agricultural land expansion. To this end, investment in irrigation development has been considered one of the viable strategies for achieving food security. Intensive community-based soil and water conservation programs have been carried out to reduce soil degradation and improve agricultural productivity (Hagos, 2003; Hagos *et al*., 1999). Investment in irrigation, particularly in small-scale irrigation development, has been identified as one of the core strategies to delink agricultural performance from rainfall and then to ensure sustainable growth and development (World Bank 2006; MoWR 2002; MoFED 2006).

In line with this, expansion of small-, medium- and large-scale irrigation has been emphasized in the five year GTP (2011-2015) (MoFED, 2010). Although scheme level irrigation is still important, it is capital intensive and limited in land coverage, implying that it cannot fully exploit available opportunities that can be adopted and used at household level, while smallholder irrigation is seen as cost effective compared to scheme level irrigation projects. For example, Rydzewski (1990) argued that well managed smallholder irrigation can be more cost effective than large-scale irrigation in Africa. Experience from Zimbabwe also revealed that small-scale private irrigations are more likely to bring higher returns per hectare as compared to large-scale irrigation schemes (Takeshima *et al.* 2010), because small-scale private irrigation technology allows irrigation schedules to be adjusted to provide farmers the right amount of water at the right time (Dauda *t al.* 2009). A study in Nigeria demonstrated that small-scale irrigation technology gives flexibility to respond to localized events, such as erratic rainfall, which is one of the critical factors is missing in large-scale irrigation schemes (Takeshima *t al.* 2010). A study in Ethiopia (Kloos, 1991) showed that large-scale irrigation schemes have increasingly experienced financial deficits and ecological problems related to poor drainage, water logging and salinization due to poor management, which promotes a shift to peasant-based small-scale irrigation in the late 1980s and early 1p90s. The multi-dimensional benefits that farmers can reap from successful adoption of smallholder irrigation technologies may justify such a shift.

In general, adoption of smallholder irrigation technology leads to higher profitability (Yaro, 2004) and production of food in the dry season. It also enables smallholders to irrigate and produce backyard vegetables and undertake micro-enterprises (Westby *t al.* 2005). Experience from Sub-Saharan African countries show that adoption of smallholder irrigation technology has been the driving force behind the expansion of irrigated land (Takeshima *t al.* 2010) from which Ethiopia can learn how effective public support can promote farmers' investment in smallholder irrigation technology. But, effective public support needs to be based on understanding the nature of farmers' demands for smallholder irrigation technology and the challenges they face. For example, adoption of appropriate technology and farming systems suitable to different agro-ecologies may help smallholders more effectively use available resources to increase their production and productivity.

Given the surface and ground water potential of the country, promoting groundwater use and adoption of household level irrigation technologies is crucial for improved production and food security at household level. It seems that among the fundamental policy directions that the GTP focuses is to improve the productivity of labor and land. Through smallholder farmers' use of water resource as an entry point, smallholders can make use of various water resources depending on the nature of their farming systems, landholdings, livelihoods and their proximity to the source of water.

The extent water can contribute to sustainable livelihoods depends not only on the availability, but on the nature of property rights, access to water, management systems and the type of technology, because property rights and institutional setups are crucial for sustainable use of water resources. Moreover, the specific relationship between water and improved livelihoods may determine the type of technology and farmers' willingness to invest in the technology. However, successful adoption of new technologies takes considerable time before all have adopted and learned to use new technologies efficiently.

Improved water use and expansion of household level irrigation through natural resources conservation and development of both ground and surface water has been identified among the focus areas of the next five year GTP (MoFED, 2010). The same document emphasized that due attention has been given to support farm households to have alternative water sources and water lifting technologies so they can use available water resources for food production (ibid). However, as existing studies are limited, there is a knowledge gap in relation to what type of technology and to what extent they are adopted and the factors that affect farm households' adoption decisions. For example, national data on imported motorized pumps shows only the number of imported motor pumps, while information on how many of these have reached the smallholder and what challenges farmers face in their adoption process is not known.

Most studies and policy documents on the Ethiopian irrigation sector laud community level irrigation such as small-, medium- and large-scale irrigation schemes for their role to improve agricultural productivity and food security. As emphasized in the Five Year Growth and Transformation Plan (GTP) (MoFED, 2010), even though scheme level irrigation is still important, it is capital intensive and limited in land coverage implying that scheme/community level irrigation projects cannot fully exploit available irrigation opportunities that can be implemented at household level.

Although water lifting technologies have the potential to improve the efficiency of water use; the experience of water lifting technology adoption in Ethiopia is not sufficient. A combination of technical and socio-economic factors such as high investment cost, high operating costs and lack of support services (maintenance and spare parts) may contribute to the low rate of adoption. For example, empirical evidence from Tigray shows that significant number of farm households have adopted motorized and treadle pumps, but lack of maintenance service and supply of spare parts is the main challenge **(**Tadesse, 2008). The same study documented that farmers often complain about frequent breakdown of pumps, lack of technical skills and maintenance services leading to delayed production activity. For instance, during a motor pump breakdown, farmers have to take their motor pumps to the nearest big town (mainly to the zonal and regional capital) which are about 50 to 70 kilometers away at considerable cost in time and money.

The risk due to low and fluctuating market prices has been cited as an impeding factor. Most smallholders produce in small quantities and lack affordable means of transport, restricting them to local markets where buyers act monopolistically to set prices. For this reason, the smallholder producers have little bargaining power as they lack information on market prices and have no storage facilities. In general, rural markets are thin and transaction costs of marketing are high due to lack of communication and transport infrastructure leading to an information asymmetry. Therefore, high costs of marketing and associated risks are likely to limit farmers' benefits of technology adoption. Likewise, lack of improved inputs such as seed and extension services are among the challenges that limit the adoption of agricultural technology in general and motor pumps in particular. Moreover, the successful use of smallholder agricultural water management technologies is likely to depend on farm households' access to suitable and affordable water lifting technologies. Nevertheless, there has been no attempt to study the challenges that affect household technology adoption.

The objective of this paper is, therefore, to study the adoption status of motor pumps and factors influencing farm household adoption decisions in four regions (Amhara, Oromia, SNNP and Tigray) of Ethiopia using primary data collected from 800 randomly selected farm households (200 from each region). Since the outcome variable is a discrete choice (1=adopt and 0=not adopt) a binomial logit model is employed to identify factors affecting farm household water lifting technology (motor pump) choice.

A range of factors (physical, economic and instructional) can affect the adoption of motor pumps. The physical characteristics may include the type of water source, land size and soil fertility. There are also cite specific factors, while economic and institutional factors may include the whole demand and supply chain, such as access to extension service and access to credit. The effects of household characteristics such as education level, gender, age, and labor endowment are among the other factors to be examined. The output of this study will contribute to a better understanding of the factors that influence the adoption of water lifting technologies and to more informed policy making.

Background

In past 12 years, the average rate of irrigation development in Sub-Saharan Africa was about 1150 ha/year with a slightly higher rate (2000 ha/year) in Tanzania, Nigeria, Niger, Zimbabwe and South Africa (FAO, 2001). Despite its ground and surface water potential, Ethiopia has used only about 5% of its water resources to irrigate about 5% of its irrigation potential (World Bank, 2006 and FAO, 2005). Paradoxically, the smallholder agriculture that supports about 80% of the population suffered from erratic and unpredictable weather condition leading to recurrent droughts that result in abject poverty where about 38.7% of the population living below the poverty line.[1]

Like in other Sub-Saharan African countries, the majority of farmers in Ethiopia are smallholder rainfed cultivators with small landholdings (on average about 1 ha in the highlands). The Ethiopian highlands, where the majority of the population are settled, has experienced substantial agriculture production risk due to the critical problems of land degradation, soil nutrient depletion and erratic rainfall (Berg and Ruben, 2006; Hagos, 2003; Pender and Gebremedhin, 2004). The situation is aggravated by a low level of agricultural technology adoption and input use. The population is growing at an alarming rate leading to high demand for food, while the cultivable land has reached its frontier, which calls for the expansion of irrigation and agricultural intensification.

Accordingly, small-scale irrigation has been recognized as a policy priority in Ethiopia for poverty alleviation and growth (MoFED, 2006) and climate adaptation (Government of Ethiopia, 2007). Ethiopia has abundant surface water resources, with 12 major river basins

[1] World Fact book, 2010 at: http://www.indexmundi.com/ethiopia/population_below_poverty_line.html

where the total annual runoff is estimated at about 122 billion cubic meters (Ministry of Water Resources, 2001, Awulachew t al. 2006). Eleven major lakes cover a total area of 750,000 ha also contribute to the country's irrigation potential (ibid). Information on groundwater potential is, however, mixed. Previous studies, for example, Awulachew (2010) estimated that Ethiopia's groundwater potential is in the order of 2.6 to 13.5 BCM, while recent assessments on groundwater occurrence in Kobo, Raya and Adda Bechoo indicated that the potential has been grossly underestimated. For example, project studies for irrigated agriculture in Kobo, Raya, and Adaa Bechoo indicated that the groundwater reserve is in the order of 2.6, 7.2 and 965 MCM, respectively (Semu, 2011)[2].


A farmer using her treadle pump in Debrekerbe watershed, Tigray (Adopted from Tadesse *et al.* 2008).

Despite its potential, the performance of irrigation in Ethiopia is hardly worth mentioning. However, rigorous efforts are now being made towards ground and surface water harvesting for smallholder irrigation. Rivers, lake pumping, ponds and shallow wells are the main sources of water commonly used for smallholder irrigation. In areas where watershed management is practiced, groundwater recharge has been improved leading to adoption of different irrigation technologies such as treadle and motor pumps. According to Tadesse *et al.* (2008), in Debrekerbe watershed (Tigray) in a small village with about 500 to 800 households, about 360 shallow, hand-dug wells were developed where the maximum depth of the wells is less than 8 meters and within less than 4 meters of the water table. This has made it possible for the smallholders, particularly women, to adopt different technologies such as treadle pumps.

In general, the adoption of water lifting technology may depend on agro-ecological, economic, institutional and risk factors.

Description of factors influencing the adoption of smallholder irrigation technology

Available evidence indicates that farm household adoption of smallholder irrigation technologies is affected by different factors, including agro-ecological, socio-economic, risk and institutional factors.

Agro-ecological factors

Agro-ecological factors include water availability, topography, climatic conditions and soil type.

[2] This is a consultant's draft report of the study on groundwater potential sponsored by IWMI as part of the AWM project

Water availability: Irrigation water comes from rivers, ponds, runoff, lakes shallow hand-dug wells and deep boreholes. The forms of water bodies are determined by rainfall, river flows, landscape, conservation activities, soil type and irrigation season. Farmer irrigation practices and adoption of water lifting technologies depend on the proximity of the source of water. Availability and cost of accessing water is an important factor for the adoption of irrigation technology. Lack of easily accessible water sources and storage structures often hampers farmers' capacity.

Climatic conditions: Climatic conditions like rainfall, temperature, humidity and length of dry season affect the type and system of irrigation (Table 1). For example, there is evidence from Ethiopia, that investment in irrigation has a positive impact on household income and poverty reduction (Hagos *t al.* 2009, Gebregziabher, 2008 and Haile, 2008), which is particularly important in the moisture deficit semi-arid regions where rainfall is erratic and highly variable. A previous study from Tigray (Gebregziabher, 2008) showed that the effect of irrigation on the probability of fertilizer use is higher in low rainfall areas than in high rainfall areas. This provides clear evidence that irrigation is of paramount importance for fertilizer and other technology adoption in low rainfall areas. Fertilizer adoption in moisture deficit and high rainfall variability areas is low. The empirical evidence makes it clear that irrigation is more important in drought prone areas than in areas with sufficient precipitation. This has policy implications for where to allocate irrigation investments, but it must be combined with overall cost-benefit analyses where investment costs, crop productivity effects and transportation costs are taken into account.

In general, in most of the Ethiopian highlands, the length of the dry season ranges up to eight months, except in areas where the short rainy season prevails, implying that the importance of smallholder irrigation and technologies is relatively high.

Topography and Soil type: Topography may affect farmer irrigation practices (Table 2, Table 3). For example, rugged mountains and gorges limit the construction of dams and then community level irrigation schemes leading to high demand for smallholder and private irrigation. Water holding and infiltration capacity of the soil also affect the type of irrigation technology to be adopted.

Table 1. General description of agro-ecological factors and technology adoption

Agro-ecological factors	Description	General situation in Ethiopia
Water availability	Source of water include surface & groundwater: Surface: river, pond, lake, runoff harvest (small dams) Groundwater: shallow and hand-dug wells, deep borehole *Type of water source determine the type water lifting technology*	• Except in the presence of big perennial rivers in some parts of the country, rivers as a source of irrigation water is seasonal • Shallow ground water exists in the order of 8 to 16 meters depth • In areas where watershed activity has been practiced, shallow well recharge has improved • Depth of shallow wells is between 4 to 8 meters, while shallow well water table is between 1 and 4 meters. Tadesse *et al.* (2008) • Unlike previous reports (Awlachew *et al.* 2006), there is substantial groundwater potential, especially in Kobo, Raya and Adaa Bechoo (Semu, 2010) • An overflow treadle pump can pump up to 6 meters depth; a pressurized treadle pump up to 10 m (TWRB) • A 3.5 HP motor pump can pump 3.7 l/s from about 28 m depth shallow groundwater; a 13 HP motor pump can pump 10l/s from about 30 m depth (TWRB)
Climate	• Diverse agro-ecology: Ethiopia is divided into 32 agro-ecologies classified into 3 primary zones (high rainfall, moisture deficit and pastoralist) • Unreliable and erratic rainfall	• Cold, cool and humid highlands: >2500 masl, annual rainfall ranges from 1200 to 2200mm; barley and wheat are dominant crops, growing season >210 days • Temperate, cool sub-humid highlands: between 1500-2500 masl, annual rainfall ranges from 800-1200 mm; growing season between 150-210 days, densely populated • Warm semi-arid lowlands: between 500-1500 masl, annual rainfall ranges from 200 to 800 mm, sorghum and corn are common crops, growing season between 91-150 days; warm year round; temperature ranges from 27 to 50°C • Hot and hyper arid: <500 masl; annual rainfall is less than 200 mm; desert type vegetation; pastoralism is the main economic activity; growing season <90 days; encompasses Denakil depression, eastern Ogaden, Blue Nile and Tekeze river valley [3]

[3] Source: USAD3 at http://www.fas.usad.gov/pecad/ and
MoA3 at: http://www.ilri.org/InfoServ/Webpub/fulldocs/X5493E/X5493E07.HTM

Topography and soil	• Topography affects the location of dam leading to high demand for smallholder private I rrigation • Vertisols dominate Ethiopian soil See Table 2	• Vertisols cover about 12 million ha, which is nearly 19% of the arable land and 22% of the currently cultivated land • Vertisols cover >25% of central, northwest and southeast regions • Improved management of vertisols may improve crop production • Vertisols occur in 1.89, 2.87, and 1.31 million ha in warm arid lowland, temperate, and cool humid highland agro-ecological zones (MoA) • Vertisol, growing season and cropping system See Table 3

Table 2. Major Ethiopian soils classified by region (in million ha)

Soil class	Zones							
	CEN	NW	W	S	SE	E	NE	N
Nitosols	0.8	3.7	8.1	1.2	0.4	0.1	0.1	-
Cambisols	1.3	0.8	0.5	3.1	1.8	1.2	1.0	2.3
Vertisols	1.6	2.7	2.0	1.6	1.6	1.2	0.3	0.9
Luvisols	0.4	2.3	0.1	1.3	0.7	0.5	0.1	0.6
Fluvisols	0.2	0.1	1.6	1.4	0.2	1.0	0.2	1.3
Xerosols	-	-	-	0.9	0.9	2.5	-	1.1
Solonchaks	0.1	-	-	0.1	-	-	-	-
Acrisols	-	0.4	1.3	0.1	-	-	-	-
Others	0.2	0.1	0.4	-	0.3	1.3	0.1	-
Total	4.6	10.1	14.0	9.7	6.1	9.0	2.9	7.2
% Vertisol	35.0	27.0	14.0	16.0	26.0	13.0	10.0	13.0

Legend: CEN=Central, NW=North-west, W=West, S=South, SE=South East, E=East, NE=North East, N=North
Source: Adapted from MoA at:
http://www.ilri.org/InfoServ/Webpub/fulldocs/X5493E/X5493E07.HTM

Table 3. The possible benefits from improved vertisol management

Agro-ecology	Area in 000 ha	Growing season	Cropping system	Production potential
Cold, cold humid and temperate highlands 1300-3000 masl[4]	5939	Long growing season 151-270 days	Rainfed cropping: maize, wheat, barley, teff, oats, haricot, linseed, rape, faba, noug, 50% suitable for improved surface water management	6m ton @2t/ha
Warm semi-arid <1300 masl	2992	Short growing season <150 days	Grazing and irrigated cropping: cotton, sugar-cane, sesame, rice, sorghum, maize) 25% can be irrigated	3 m ton @4t/ha
Temperate and warm arid	2199	Long growing period 151-270 days	Rainfed cropping: maize, sorghum, sesame, cotton, sugar-cane, sunflower 50% suitable for improved surface water management	2m ton @2t/ha
Cold, cold humid and temperate highlands 1300-3000 masl	806	Short growing season <150 days	Grazing and irrigated crops vegetables, spices, fruits, flowers, maize, 25% can be irrigated	0.8m ton @4t/ha
Total				11.8m ton

Socio-economic factors

Socio-economic factors that affect farm household adoption decisions of water lifting technologies may include input and output markets, purchase and operating costs of technologies, and transaction costs. Traditional division of labor by gender may also limit female farmers to access required capital, input and knowledge of irrigation technologies.

Output market: The nature of the output market, such as whether farmers have access to markets, whether they have capacity to negotiate for better prices and access to transport and storage facilities, affects the benefits, which in turn affects their willingness to invest and adopt irrigation technologies.

Input market: For irrigation to be profitable, a combination of complementary inputs are required (such as, fertilizers, improved seeds, fuel, credit). Investment in irrigation equipment (e.g. motor pump) requires sufficient startup capital for which access to credit is crucial. For a farm household to invest in irrigation technology it must be cost effective, otherwise farmers lack incentive to invest (Binswanger 2007). Poor maintenance service and supply of spare parts is another impeding factor, especially when frequent breakdowns of motor pumps are common. The problem becomes more serious when public support and subsidy mechanisms are weak or missing.

[4] Masl=meters above sea level

Transaction cost: High transaction costs associated with accessing information about input and output markets also affect the adoption of irrigation technologies. The transaction cost is associated with gathering information on where to find equipment and input suppliers, the types of irrigation equipment available in the market and the quality of irrigation equipment. In Ethiopia, such transaction costs are high because many farmers rely on traditional farming systems and are less familiar with modern irrigation equipment. In addition to risk associated with output markets, other factors discourage farmers to adopt motor pumps. These include: risk related to productivity of irrigation equipment, the probability that the equipment will breakdown, the volatility of the price of fuel used in operating the equipment, risks of sharing irrigation equipment with other farmers, and uncertainty in tenure security. Empirical studies in other parts of the world show that some of these risks are important determining factors of farmers' demand for irrigation technology. For example, Ogunjimi and Adekalu (2002) found that frequent pump breakdown is a serious limiting factor in Nigeria due to farmers' poor maintenance skills. However, transaction costs can vary across farmers with different characteristics such as gender, land ownership, and distance to the nearest town.

Technologies and institutional Factors

Irrigation technologies (Table 4) such as motor pumps do not stand alone. The type and source of irrigation water is important as is storage. Access to a body of water is a key factor that affects farmers' investment in irrigation technologies. Since water is generally a public good, the social benefit of detecting the source of water may be higher than the individual farmer benefit. Hence, the public sector can play an important role in providing information on the potential and location of water sources to be used by farmers, where information about potential of surface and ground water is scant.

Almost all irrigation equipment is imported and prices are extremely high with government tax contributing about 37.44% to the price. Government could provide a subsidy or tax exemption to stimulate local production to help make motor pumps affordable for the smallholder. Supporting the private sector to produce equipment locally may benefit the smallholder. As mentioned in the section on socio-economic factors, information asymmetry on both input and output markets is a limiting factor. The market is thin and buyers act monopolistically to determine prices. Public support in improving access to market information and to link smallholders with private businesses and traders and outgrowers is important.

The role of public and private sector support for farmers' adoption of irrigation technology is of paramount importance (Table 5). Institutional support includes access to credit, supply of irrigation equipment, spare parts and maintenance services, extension services, technical and institutional support from government, NGOs and farmer associations, such as water user associations (WUAs). Institutions, especially NGOs and government (public) institutions, can play an important role to support the smallholder in importing and distributing irrigation equipment as well as other inputs and facilitating credit, linking farmers to private suppliers and buyers, providing financial assistance and subsidies, especially to purchase irrigation equipment and other startup capital.

Table 4. General description of irrigation systems, water lifting technologies and sources of water

Source of water	Water lifting device/system
Surface water • River • Lakes • Ponds	• Bucket (mainly from ponds and rivers) • Treadle pump (from ponds) • Motor pumps (from rivers, lakes) • Electric pump (typically in the in the Rift Valley for lake pumping) • River diversion canals
Shallow groundwater	Treadle pump: • Can lift water from 6 m depth and is used to irrigate less than 0.25 ha Motor pump: • Can lift water from 16 m depth depending on the capacity • Can irrigate relatively large plots, but differs based on the pump capacity (e.g., a 3.5 hp can irrigate about 2ha) Buckets:
Deep Groundwater	Heavy duty electric pumps • Water table is deeper than 100 m • Practiced in the Raya-Kobo Girana Valley and in the Rift Valley (Zeway area) • Investment cost is high and not affordable by the smallholder • Potential for private investment and community level irrigation • Suitable for high value cash crop production (such as, vegetables, spices, flower farms, fruits, etc.)
Rain water harvesting: Store runoff water using ponds, soil and water conservation structures, used for supplementary irrigation when rain ceased early (before flowering).	
Spate irrigation: Divert flood water to farmland using ditches and locally available materials; practiced during rainy season mainly in Raya-Kobo valley and Afar lowlands	

Table 5. Socio-economic and characteristics of water lifting technologies

Type of technology	Functions	Technical, cost and institutional issues
Treadle pump (overflow)	• Irrigates up to 200m^2 land • Can pump up to 6m depth • Locally produced • Low discharge & flow rate • Labor intensive and time consuming • Inadequate for large are	• Costs 574 Birr (about USD 50) • Unfamiliarity and lack of technical knowledge • Frequent breakdown • Lack of spare parts and maintenance service • Credit is available from micro-finance institutions, but not subsidized • Inefficient extension service and input supply system • Lack of information about better input and output market • Low output price, hence low incentive to adopt the technology

Treadle pump (pressurized)	• Can pump from 10 m depth • Irrigates up to 0.25 ha • Cab be used with drip system • Locally produced • Labor intensive and time consuming • Inadequate for large areas	• Comparable to overflow treadle pumps • Costs about 878.40 Birr (about USD77); used without drip • Drip system costs about 930 Birr • If drip system is used with pressurized treadle pumps, price can be reduced by 50% (costs about 1,370 Birr, equivalent to about USD120) (Source: Tigray Bureau of Water resources)

Motorized pump	• High water delivery capacity relative to treadle pump
	• Irrigates relatively large size of land compared to treadle pump
	• Irrigation capacity depends on the size and power of the pump, for example:
	    ○ 3.5 hp Chinese Goshan brand can pump 3.7 l/s from 28 m depth, irrigate about 2 ha
	    ○ 13 HP USA Lambardin brand can pump 10 l/s from about 30 m depth; irrigate 10 ha, costs 54,000 Birr duty free and 90,000 Birr if tax is included (Source: TBoWR)
	• Farmers prefer motorized over treadle pumps, because treadle pumps are laborious and irrigate small plots (Source: SOS Sahel, SNNP)
	• Farmers use motorized pumps to pump from shallow aquifers, rivers, lakes
		• Motor pumps are expensive
		• Chinese 3.5 hp Goshan pump cost 12,500 Birr (USD 1,092); distributed to groups of four people, American brand 13 hp Lambardin pump costs about 90,000 Birr; mostly used by community or private investors
		• The regional bureaus of water resources promote and disseminate motor pumps on credit basis (started in 2005)
		• Credit provided by micro-finance institutions
		• High tax rate (37%)
		• Lack of subsidy, except that SOS Sahel, in SNNP has subsidized 50% of cost of pumps to its beneficiaries
		• Lack of technical know-how and less familiarity with the technology leading to frequent breakdowns
		• Lack of spare parts and maintenance service
		• Shortage of fuel and high cost of fuel
		• Weak extension services; low output price leading less incentive to adopt

Adoption status of water lifting technologies

Based on information from the regional bureaus of water resources and our survey data, the type of water lifting technologies adopted by smallholders are diverse. Although treadle pumps are locally produced and relatively low cost, they are labor intensive and can irrigate small plots, making them more suitable for households that can afford to hire labor. According to information from agricultural extension workers in the case study weredas and our survey data, there is widespread use of motorized pumps. Data from the regional bureaus of water resources also indicate the same (Table A1-A3 in Annex). Among the

19,846 water lifting technologies distributed by the Oromia regional bureau of water resources, only 162 were treadle pumps. Evidence from Tigray and Amhara regions shows the same trend. In our study area in Tigray we found no functioning treadle pumps as compared to 154 motor pumps. Similarly, despite the 14,731 of treadle pumps supplied by the Amhara Bureau of Agriculture, only 4992 (34%) were adopted by farmers. This indicates that farm households are reluctant to adopt treadle pumps. They are labor intensive, have low irrigation capacity, are of low quality, frequently breakdown, and it is difficult to find spare parts and maintenance service.

Although the total number of adopted motor pumps is not known, our sample survey shows a prevalence of motor pumps compared to other types of water lifting technologies (Table 6). Similarly, among the technologies distributed by the regional bureaus of water resources, motor pumps take the greater share where 19,338, 20,916 and 18,348 motor pumps were distributed in Oromia, Amhara and Tigray regions, respectively[5] (Table A1-A3 in Annex). The national data on imported motor pumps (Table 4) supports our data from the regions.

Table 6. Total number of motor pumps imported August 2004 to December 2010

Year	Origin of Country						Total Import (with tax)	Total Import (with and without tax)
	China	India	Japan	Germany	Italy	Rest of the world		
2004 (5 months)	722	75	139	224	650	7,64	2,574	3,620
2005	5390	21,829	4,767	1,350	6,004	5,010	44,350	78,680
2006	3,316	10,809	6,682	4,852	7,868	4,788	38,315	67,054
2007	6,601	11,665	6,802	1,303	6,296	3,034	35,701	65,334
2008	31,046	21,852	9,012	1,132	6,987	3,855	73,884	140,058
2009	10,077	11,749	5,751	1,036	81,345	8,611	118,569	219,916
2010	15,315	30,226	10,342	1,363	4,099	6,664	68,009	122,690
Total	72,467	108,205	43,495	11,260	113,249	32,726	381,402	697,352

The type (model) and capacity of motor pumps varies widely and can be related to the country of origin. According to data from Oromia and Tigray bureau of water resources, the model as well as capacity (HP) of motor pumps ranges between 3.5 and 13 HP (Table 7; Table A1 and A3 in Annex). On average, a 3.5 HP motor pump costs about 12.500 Birr and can irrigate about 2 hectares and is commonly used by a group of farmers. This indicates that prices are significantly high for the smallholder to afford. Information from the regional bureaus of water resources show that before the Ethiopian Birr was devalued by about 20% in September 2010, the average price of a motor pump was about 8,093.37 Birr. The current average price after adjustment for inflation is estimated to be about 9,712 Birr, which is equivalent to USD 590.00. Data from the Revenue and Customs Authority hand shows that the pre-devaluation average cost of a motor pump (including CIF and tax) was about

[5] we could not find the same data for SNNP

6,500.00 Birr, where tax accounts for about 37.44% of the cif value. If the price is adjusted to account for inflation and profit margin, the average selling price is high.

Table 7. Average cost and tax rate of imported water pumps

Cost Component	Average
Average CIF Value of water pump (Birr)	4668
Average tax per unit of water pump (Birr)	1832
Average purchase price/water pump (CIF+Tax) (Birr)	6500
Tax rate	37.44 (%)
• Customs duty	10%
• Value Added tax	16%
• Sur tax	8%
• Withhold tax	3%

Source: Ethiopian Customs and Revenue Authority (Author summary)

METHODOLOGY

Sampling and data

Data used in this study were obtained from a survey in four regions of Ethiopia (Tigray, Amhara, Oromia and SNNP). The study was conducted from October to December, 2010 to identify factors influencing the adoption of smallholder irrigation technologies. The data was collected as part of a comprehensive nationwide study on the Agricultural Water Management (AWM) Solutions project carried out by the International Water Management Institute (IWMI). The major components of the project included: assessment of the challenges and opportunities of the adoption of water lifting technologies, assessment of the economic feasibility of investment in groundwater based irrigation, assessment of experiences in watershed management and assessment of rain water harvesting.

This study focuses on the challenges and opportunities of the adoption of motor pumps. Data was collected from a sample of 800 farm households (200 from each region). A stratified random sampling method was employed where we used data from the regional bureaus of water resources and agriculture to identify weredas (districts) and kebles (subdistricts) with relatively high adoption rates of water lifting technologies. We then used a list of farm households in each keble to stratify into adopter and non-adopter households. Finally, we used a proportional random sampling technique where among our sample households 499 (62.38%) were found to be purely rainfed cultivators while the other 301 (37.62%) have adopted one or more type of the different water lifting technologies (Table 8).

Table 8. Number of sample households by region

Region	Sample Households		
	Purely Rainfed	Irrigating	Total
Amhara	115	85	200
Oromia	118	82	200
SNNP	120	80	200
Tigray	146	54	200
Total	499	301	800

Our data also includes information on demographics, plot level, input, production, asset holding, access to credit and extension services, and access to input and output markets. All data were recorded in local units, but family size and livestock holdings were converted into adult equivalent and Tropical Livestock Units (TLU). Farm size was recorded in a local unit (temad), but it was also converted into hectare where one temad is approximately equivalent to one-quarter of a hectare.

Most of rural households own more than one plot of land with different plot characteristics. We asked our respondents to rate their plots as fertile, moderately fertile and less fertile or 'poor'. For the purpose of analysis, we aggregated the size of each plot to get a household's landholdings where the fertility of each plot is most likely to differ. Therefore, to capture the characteristics (soil fertility) of total land owned by a household, we computed an index of land fertility (ILF) as[6]:

$$ILF = \sum_{i=n}^{n} f_i rp_i$$

Where f_i takes the value of 1, 2 and 3 for fertile, moderately fertile and less fertile (poor), respectively; and rp_i represents the ratio of each plot owned by the household to the total landholdings. Hence, the value of ILF ranges between one and three $(i.e. 1 \leq ILF \leq 3)$where the lowest values indicate better land fertility.

Secondary data on quantity, type and price of water lifting technologies was collected from the regional bureaus of water resources of Tigray, Amhara and Oromia and from SOS Sahle in SNNP. Information on imported motor pumps and prices were collected from the Federal Customs and Revenue Authority. We also have reviewed previous studies and reports in relation to groundwater, surface water and irrigation potential.

Analysis

We use both descriptive and econometric analysis. Assuming that the production system in the study area represents a multi-crop agricultural production process where land holding is fixed, the allocation of land into crop type and irrigation technology is endogenous (Negri and Brooks, 1990). The adoption decision of irrigation technology is discrete, where a farmer can decide to adopt or not to adopt, in which case the farmer faces a dichotomous decision problem to adopt or not to adopt motor pump. In our context, motor pump

[6] The same procedure was applied in Zerfu D. (2010)

adopters are those farmers who were, during the survey, using a motor pump (petrol or diesel) to irrigate part of their land, while the rest are non-adopters. The binomial logit model was used to estimate the probability of motor pump adoption i.e., $\Pr(y_i = 1|x)$ where the model is transformed into the odds as follows (Long, 1997)

$$\frac{P(y_i = 1|x)}{P(y_i = 0|x)} = \frac{\Pr(y_i = 1|x)}{1 - \Pr(y_i = 1|x)} \qquad (1)$$

The odds indicate to what extent farmers have adopted motor pump $(y = 1)$ relative to those who did not adopt $(y = 0)$. The log of the odds specified in Eq. 2 below suggests that it is linear in the logit.

$$\ln\left[\frac{P(y_i = 1|x)}{1 - P(y_i = 1|x)}\right] = x\beta_i \qquad (2)$$

which is equivalent to the logit model derived as:

$$P(y_i = 1|x) = \frac{\exp(x\beta_i)}{1 + \exp(x\beta_i)} \qquad (3)$$

where P denotes the probability that the i^{th} farmer has adopted motor pump, x_i captures household and farm level characteristics that affect household adoption of a motor pump, while β_i is a parameter to be estimated.

A binomial logit model is useful for investigating the influences of household and farm level attributes on household's technology adoption relating the probability of motor pump adoption to the underlying characteristics. The dependent variable (y) is the logarithm of the odds in favor of motor pump adoption, and the parameters are interpreted as derivatives of this logarithm with respect to the independent variables. The estimated coefficients can then be used to predict the adoption probability of a motor pump. In the logit model, like in any nonlinear regression model, the parameters are not necessarily the marginal effects (Greene 2000; Kennedy 2001), but represent changes in the natural log of odds ratio for a unit change in the explanatory variables.

RESULTS

Descriptive results

Our survey data show that among the water lifting technology adopting households, 1.66; 2.99; 79.40; 6.98 and 8.97 percent have adopted buckets, treadle pumps, diesel/petrol motor pumps, electric pumps and other types of water lifting technologies, respectively (see Table 9).

Table 9: Adoption status and type of Technology Adopted

Type of technology	Number	Adopting and non-adopting households (%)	Type of technology adopted (%)
Purely rainfed	499	62.38	
bucket irrigator	5		1.66
treadle pump	9		2.99
petrol/diesel pump	239	37.62	79.40
electric pump	21		6.98
other	27		8.97
Total	800	100.00	

Since more than two-thirds of the adopters (239 or 79.40%) have adopted motor pumps, our data limit us to focus on the adoption of motorized pumps. Unlike other water lifting technologies, the regional distribution of motorized pumps was found to be relatively evenly distributed across the regions, enabling us to make regional comparison (TableI10).

Table 10: Adopted type of technology by region

Region	Rainfed	Bucket	Treadle pump	Petrol/diesel	Electric	Other	Total
Amhara	115	0	3	61	0	21	200
Oromia	118	0	1	54	21	6	200
SNNP	120	5	5	70	0	0	200
Tigray	146	0	0	54	0	0	200
Total	499	5	9	239	21	27	800

The descriptive analysis presented in Table 11 shows that the farming system is male dominated. Female headed households constitute 21% of the non-adopters and only 3% of adopters, implying that female headed households are less likely to adopt irrigation technologies as compared to male headed households. The Chi-square test shows that the difference is statistically significant. Since female headed households are among the poor, capital constraints and lack of access to credit may explain the reason for less female adopters.

The average age of adopters and non-adapters was 42.7 and 44.6 respectively. A *t-test* shows that the difference is statistically significant. The implication is that older farmers have more farming experience but they are less likely to have formal education and tend to stick to traditional farming systems. This is consistent with literature and empirical findings in other parts of Ethiopia (Ahmed *et al.* 2002).

Average family size in adult equivalent is 4.217 persons, but when comparing adopters and non-adaptors, motor pump adaptors have significantly larger family size. Consistently, motor pump adopting households have more adult male members compared to non-adopters, while the difference in adult female members is statistically insignificant. Livestock, especially oxen ownership, is an important asset in the Ethiopian farming system. Average oxen and non-oxen livestock holding was 1.228 and 2.805 TLU respectively. Adopters own more oxen.

Household awareness of motor pumps, ownership of radios, and access to extension services were used as proxies of awareness. We found that 93.7 percent of adopters and 64 percent of non-adopters were aware of motor pumps. Ownership of radios and televisions are significantly different among adopters and non-adopters, where adopters own more radios, while non-adopters own more television sets. We assumed that ownership of television improves access to information, but the data show that those who own televisions are less likely to adopt. It possible that households who use money to buy a television have no money left to invest in a motor pump. Access to extension services, credit and fuel are positively related to adoption of a motor pump.

Table 11. Comparison of adopters and non-adopters

Variable Description	Total		Adopters		Non-adopters		t/χ^2 *test* significance
	Observation	Mean	Observation	Mean	Observation	Mean	
Gender of household head (1=male)	800	0.848	239	0.971	561	0.795	40.033‡***
Age of household head	800	44.024	239	42.720	561	44.579	1.772*
Family size in adult equivalent	800	4.217	239	4.572	561	4.065	3.113***
Adult male household member	800	1.563	239	1.753	561	1.481	3.109***
Adult female household member	800	1.491	239	1.498	561	1.488	0.127
Oxen ownership (TLU)	800	1.228	239	1.523	561	1.102	4.063***
Other than oxen livestock ownership (TLU)	800	2.805	239	3.434	561	2.537	3.508***
Farm size in ha.	800	0.82	239	0.41	561	0.73	4.248***
Household was aware of motor pump before adoption (1=yes)	800	0.730	239	0.937	561	0.642	74.264‡***
Ownership of radio	800	0.608	239	0.803	561	0.524	6.4126***
Ownership of mobile	800	0.364	239	0.519	561	0.298	1.5287
Ownership of television	800	0.073	239	0.033	561	0.089	2.689***
Average amount of remittance (Birr)	800	92.814	239	139.95	561	72.729	1.6354
Household participate in off-farm activity (1=yes)	800	0.236	239	0.213	561	0.246	0.987‡

Access to water related extension service (1=yes)	800	0.304	239	0.473	561	0.232	46.057‡***
Household uses own finance to buy technology (1=yes)	800	0.169	239	0.146	561	0.178	1.209‡
Household head assume leadership in farmer association (1=yes)	800	0.033	239	0.054	561	0.023	5.195‡**
Household head assume leadership in farmer cooperatives (1=yes)	800	0.030	239	0.021	561	0.034	0.966‡
Average expenditure on fertilizer (in Birr)	800	1781.4	239	23000.91	561	1085.98	1.912*
Total harvest (in Birr)	800	23858.26	239	55256.54	561	2885.36	3.960***
Total harvest in (Kg)	800	1431.8	239	2480.86	561	984.8859	3.638***

**significance at 10%, ** significance at 5%, ***significance at 1%, ‡= χ^2 Value*

The average farm size was 0.82 ha where the average irrigated and rainfed farm size was 0.41 and 0.73 hectare, respectively. Average fertilizer use per hectare of irrigated land was significantly higher compared to rainfed agriculture (Table 13). The difference in fertilizer use was mirrored in the production difference between irrigated and rainfed agriculture, which indicates that access to irrigation boosts fertilizer use leading to improved yield per hectare. This is in line with previous empirical findings by Gebregziabher (2008b). The same study found that that investment in irrigation in Tigray has significantly increased average income of irrigators as compared to rainfed cultivators where the difference in average income was 92% (average income was 4,933 and 2,570 Birr per irrigating and rainfed households, respectively). The head count ratio and incidence of poverty was unambiguously lower for households with access to irrigation than households without. Computing the ratio of value of harvest over expenditure on fertilizer (as a proxy of benefit-cost ratio) shows that the investment in irrigation improves the productivity and marginal product of complementary inputs.

Table 12. Average farm size, fertilizer use and production: Comparison between irrigated and rainfed agriculture

Farm size, Fertilizer use and Production	Total	B/C ratio	Irrigated	B/C ratio	Rainfed	B/C ratio
Farm size (ha)	0.82		0.41		0.73	
Fertilizer use (Birr)	1,781.44	13.39	2,300.91	24.02	1,085.98	2.66
Harvest (Birr)	23,858.26		55,256.54		2,885.36	
Fertilizer use/ha (Birr)	2,497.72	9.68	5,311.63	13.66	1,948.31	4.07
harvest/ha (Birr)	24,169.83		72,563.81		7,929.79	

Among the adopters, 82% were irrigating during the dry season implying they can produce more than one crop per year. Table 13 shows that in the study area, surface and shallow groundwater are the main sources of water for motor pump adopters.

Table 13. Water sources and availability according to respondents in the survey areas

Water source	Availability	Available throughout the year
Stream	31	19
Lake	108	93
River	274	186
Small dam	13	2
Shallow groundwater	144	112
Total	570	412

Despite the positive contribution of irrigation, the existing rate of irrigation technology adoption in sample study areas is low. We hypothesized that farmers' awareness about the technology may lead to a high adoption rate. Although 510 and 368 of our sample households were aware of petrol and diesel pumps, only 38.6% and 17.40% have ever adopted them (Table 14).

Table14. Awareness and adoption rate of farm households (petrol and diesel pump)

Type of technology	Aware of petrol/diesel pump	Ever adopted	Currently adopting
Petrol Pump	510	197	169
Diesel Pump	368	64	44

Our data shows that awareness and information are not sufficient for a farm household to adopt the technology. There may be other factors that affect adoption decision among which price and maintenance costs are important.

According to our survey data, the average price of a petrol or diesel pump and associated accessories was in the order of 6,623 and 9,217 Birr. Not only the initial investment but the maintenance costs were also considerably high (Table 15).

Table 15. Average cost of water lifting technology and associated accessories and maintenance cost

Type of technology	Average purchase price	Average price of accessories	Previous year average maintenance cost	Average maintenance cost since pump was purchase
Petrol Pump	4,751.32	1,872.00	953.00	1,420.00
Diesel Pump	7,246.319	1,971.00	1,792.00	2,527.00

Since motor pumps do not stand alone, the investment cost of related infrastructure may also hamper the adoption decision of a farm household. For instance, our data shows that average construction cost of different types of water storage structures, such as, hand-dug and shallow wells, ponds and tube wells, was in the order of 365 to ,4022 Birr[7] (Table 1*6*), which is too expensive for a poor farm household.

Table 16. Average cost of irrigation infrastructure based on farmers' response

Irrigation infrastructure	Average (mean) cost (Birr)	Maximum cost (Birr)
Tube well	365.00	550.00
Shallow well	4,021.52	15,000.00
Dug-out	9,57.98	9,450.00
Pond	1,949.63	5,000.00

Regression results

Econometric analysis to identify factors that affect the adoption of motor pumps is presented in Table 17. Among the variables included in the regression, the following were found to significantly affect the adoption of motor pumps.

Gender: The regression results confirm that male headed households are more likely to adopt motor pumps compared to female headed households. This indicates that female headed households are less likely to benefit from available irrigation opportunities and may require interventions to address the gender imbalance.

Risk and information: Results show that access to extension (contact with extension workers) and ownership of a radio are statistically significant at 1% and 5% level of significance. This is consistent with the literature (Mourdhed, 1995) that aversion to risk causes smallholder farmers anxiety towards new innovations because unfamiliar techniques can produce uncertain yields, hence farmers with limited incomes or assets are reluctant to adopt unproven technologies. Such uncertainty can be alleviated by exposure to information regarding the new technology. Evidence from Egyptian smallholder desert farmers also shows that on witnessing such proof on nearby large farmers, the smallholder

[7] Since the Ethiopian Birr was devaluated by about 20% in September 2010, current price of motorized pumps is expected to be inflated by the same proportion. The current exchange rate between Birr and USD is at about 16.75=1USD.

farmers were persuaded to adopt drip irrigation (Mourdhed, 1995). This suggests that strengthening the extension service is important. This can be done through organizing experience sharing tours to learn from nearby model farmers and then to scale up best experiences in technology adoption.

Access to input: Availability of fuel and the number of adult female and male family members were used to test whether access to inputs can affect the adoption of a motor pump. We found that access to fuel was positive and statistically significant at 1% level of significance, implying that improving the input supply chain could be an entry point to address the slow adoption of motor pumps. Adult female and male family labor was not significant, but as a motor pump is assumed to be less labor intensive compared to other types of irrigation technologies the result should not be surprising.

Farm size: The coefficient of farm size suggests a negative farm size effect on motor pump adoption, implying that farmers with larger land holdings may have an option to diversify their rainfed crops or may tend to use other irrigation systems such as gravity irrigation.

Credit and Remittance (access to finance): We hypothesized that access to credit plays an important role in technology adoption. Two dummy variables *(first, credit for input, second, whether a farm household uses their own money or credit to buy motor pump*) were included as independent variables to account for the credit effect on motor pump adoption. Although our result indicates that farmers are more likely to use their own money to invest in a motor pump, access to credit was found to positively affect motor pump adoption. This result may represent mean that a risk-averse credit provider may make be reluctant to give credit to farmers who have not yet proven to be successful. The positive effect of credit may imply that lending institutions are willing to give credit once a farmer (creditor) is successful and can pay back his loan. In this case, it is likely that liquidity constrained, mainly female headed farm households, are rationed out in the adoption process. Hence, regardless of uncertainties and risks, we suggest that carefully designed credit arrangements may help poor farm households, especially female headed households, adopt motor pumps. The positive coefficient of remittance also indicates that households who received remittances are more likely to adopt motor pump compared to their counterparts, implying that lack of finance (liquidity) is an impeding factor of motor pump adoption.

Off-farm employment: Farmers who participate in off-farm activity are less likely to adopt motor pumps. Although we can assume that participation in off-farm activity is a means to generate additional income, we know that in our study area, the Productive Safety Net Program (PNSP) is the main off-farm activity, where the poorest farm households get priority. Hence those participating in off-farm activity are more likely to be among the most capital constrained households, which are less likely to invest in motor pumps (Kassie *et al.*, 2008; Rosenzweig and Binswanger, 1993). Since low agricultural productivity causes persistent poverty, financing poor farm households to help them adopt motor pumps might be an effective poverty reduction strategy.

Physical characteristics: The type of water source often influences the type of water lifting technology. Three water source dummies, groundwater (shallow and dug wells) river and lake are included as independent variables to account for the type of water source as an influencing factor of motor pump adoption. Groundwater and rivers as a source of irrigation water were found statistically significant at 1% level of significa*nce* compared to lake pumping (the control variable). The result may imply that farmers who have access to surface water or shallow ground water are able to flood their fields by pumping water from a well. We also found that most pump owners irrigate during the dry season, suggesting that year round access to ground and surface water helps farm households produce more than one crop per year. Moreover, watershed development activity is expected to positively affect groundwater recharge, leading to a high adoption rate of water lifting technologies. Evidence from Debrekerbe watershed, Tigray (Tadesse *et al.* 2008) supports this argument.

Finally, four regional dummies, Amhara, Oromia, SNNP and Tigray were incorporated to account for regional factors influencing technology adoption. These may include both physical and socio-economic factors, such as agro-climatic, education, transportation and marketing differences. The regional dummies reflect that the log of the odds relative to Tigray, the control (omitted) region. The result indicates that some unobserved factors correlated with regional location are affecting the probability of motor pump adoption. The negative coefficients imply that the control region (Tigray) has unobserved characteristics that are more favorable for motor pump adoption compared to the other three regions.

Although we are not sure what favorable factors may exist in the control region, some of the following may explain the difference. First, the fact that Tigray in general and the Eastern Zone of Tigray (where our sample site found) in particular is a drought prone area may encourage drought risk-averse farm households to intensify their agricultural production through the use of a motor pump. For example Takeshima (2010) argued that farmers who lack resources to insure against rainfall risks raise their demand for irrigation technologies, because risk-averse farmers are generally more willing to invest in irrigation technologies. Koundouri *et al.* (2006) found that when farmers face difficulty in accessing natural sources of water due to frequent drought, they try to invest in irrigation technologies.

Second, the size of land holdings in the northern highlands in general and in Tigray in particular is small (on average not more than a hectare). Since our result indicates a negative farm scale effect, farm households may try to intensify by adopting a motor pump.

Finally, intensive soil and water conservation combined with watershed management activities in the region could have improved groundwater recharge giving the smallholder better access to shallow ground water leading to high adoption of motor pumps. Tadesse *et al*. (2008) confirmed that in Debrekerbe watershed in Tigray, about 360 shallow hand-dug wells were developed where the maximum depth and water table of a well was found to be less than 8 and 4 meters respectively.

Table 17. Regression Results: Factors that affect Adoption of Motor Pump (Logit Model)

Variable Description	Coefficient
Dependent variable: Adoption status of motor pump (1=adopt)	
Constant	-4.272***(0.893)
Gender of household head (1=male)	1.004**(0.482)
Household head age	0.011(0.013)
Male adult family labor	-0.135(0.145)
Female adult family labor	-0.068(0.142)
Shallow groundwater is source of water (1=yes)	1.390***(0.404)
River/surface water is source of water (1=yes)	2.815***(0.424)
Lake is source of water (1=yes)	Control (omitted) variable
Household is aware of petrol pump (1=yes)	1.457***(0.445)
Household is aware of diesel pump (1=yes)	0.298(0.346)
Farm size (ha)	-0.234*(0.127)
Ownership of radio	0.514*(0.274)
Ownership of mobile telephone	0.071**(0.028)
Ownership of oxen	-0.104(0.135)
Household received remittance (1=yes)	0.001***(0.000)
Household participates in off-farm activity (1=yes)	-1.080**(0.431)
Availability of fuel (1=available)	1.989***(0.431)
Household had access to extension services (1=yes)	0.967***(0.34)
Household had access to credit to buy fuel (1=yes)	2.711***(0.801)
Hired labor is available (1=yes)	-0.069(0.343)
Farmer practices dry season irrigation (1=yes)	3.506***(0.341)
Household uses own money to buy motor pump (1=yes)	0.915*(0.495)
Household uses credit to buy motor pump (1=yes)	Control (omitted) variable
Motor pump is bought from nearest town (1=yes)	-0.572(0.666)
The farmer assumes leadership role in farmer organization (1=yes)	0.050(0.505)
The farmer assumes leadership role in cooperatives (1=yes)	-1.607*(0.881)
Ownership of Television	-1.581***(0.590)
Region (1=Oromia)	-3.264***(0.645)
Region (1=SNNP)	-3.154***(0.477)
Region (1=Amhara)	-3.808***(0.638)
Region (1=Tigray)	Control region (omitted)
Log-likelihood	175.144
Number of observation	800
Wald (chi2)	266.10
Prob (chi2)	0.000
Adjusted R^2	64.10

*significant at 10%, **significant at 5%, ***significant at 1%, Figures in parenthesis are robust standard errors

CONCLUSION

Smallholder rainfed agriculture is the mainstay of the Ethiopian economy. The sector that supports 80% of the population suffers from erratic and unpredictable weather conditions leading to recurrent droughts with 38.7% of the population living below the poverty line. Heavy reliance on low, erratic and unevenly distributed rainfall affects the performance of agriculture that results in recurrent droughts and food insecurity.

Ethiopia is a water-receiving country with 12 river basins with an annual runoff of 122 billion m^3. Information on groundwater potential is mixed. Previous studies estimated that Ethiopia's groundwater potential is in the order of 2.6 to 13.5 BCM, while a recent assessment on groundwater occurrence in Kobo, Raya and Adda Bechoo indicated that the groundwater potential is in the order of 2.6, 7.2 and 965 MCM, respectively.

With all this potential, the country fails to produce enough food to feed its population. Ethiopia has uses 5% of its water resources to irrigate only 5% of its irrigation potential. Despite its irrigation potential, the Ethiopian highlands, where majority of the population are settled, has experienced substantial agriculture production risk due to adverse rainfall and other climatic conditions. The situation is aggravated by a low level of agricultural technology adoption and input use. The population growing at an alarming rate, leading to high demand for food while the cultivable land has reached its frontier. This calls for the expansion of irrigation and agricultural intensification. Irrigation has been recognized as a policy priority in Ethiopia for poverty alleviation and growth and climate adaptation.

Ethiopian irrigation development lauds community level irrigation such as small-, medium- and large-scale irrigation schemes for their role to improve agricultural productivity and food security. As emphasized in the Five Year Growth and Transformation Plan (GTP), even though scheme level irrigation is important, it is capital intensive and limited in land coverage, implying that scheme and community level irrigation projects lack to exploit available irrigation opportunities that can be implemented at household level.

Current information shows that adoption of smallholder irrigation technologies is at a low level where a combination of technical and socio-economic factors such as high investment cost and high running costs combined with weak public support contributes to the low rate of technology adoption. Based our study on motor pump adoption in four regions (Amhara, Oromia, SNNP and Tigray), the average price of a motor pump and accessories is about 6,623 to 9,217 Birr, of which 37.44% of is government tax. The average maintenance cost is also high. Investment in water storage structures is also expensive, averaging 365, 4,022, 958 and 1,950 Birr for tube wells, shallow wells, hand-dug wells, and ponds.

Female headed households adopt less often compared to male headed households. Since female headed households are among the poor, policy interventions in financing investment in motor pumps might help to scale up the adoption rate and minimize gender imbalance.

Access to information and extension services was positively related to motor pump adoption, implying that lack of information increases farmers' anxiety towards new technology because capital constrained farmers are usually reluctant to adopt unproven modern technologies. We suggest that such uncertainties can be alleviated by exposing farmers to information about the technology. Hence, strengthening the extension service and organizing formal and informal experience sharing tours to learn from nearby model farmers is of paramount importance. Improved access to input and capital are positively related with motor pump adoption, implying that finance constraint is an impeding factor. Institutional support to address farmers' capital constraint would be an important policy direction.

Our findings shows that those who participate in off-farm activity are less likely to invest in motor pumps. The reason could be because those participating in off-farm activity are among the poor who are engaged in low risk and low yield activities possibly trapped in a vicious circle of poverty. Hence, any interventions that can help the poor to get out of the trap might be used as an entry point to hedge the poor against shocks by helping them get access to credit and other financing mechanisms for motor pumps.

The type of water source often influences the type of water lifting technology. Based on our data, groundwater and rivers as a source of irrigation water were found to positively affect motor pump adoption, implying that motor pumps are suitable in ground and surface water potential areas leading to dry season irrigation and production of more than one crop per year. Watershed management and other natural resource conservation activities might have improved groundwater recharge giving the smallholder better access to shallow ground water leading to high adoption of motor pumps.

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ANNEX

Table A1 Water lifting technologies distributed by Oromia Water Resource Bureau (up to 2010)

Model	Power (HP)	Water discharge/second	Quantity	Unit price/Birr
BOSHAN HL 100CL 4''	9.6hp/3600	26.6L/S	4,300	12,000.00
BOSHAN HL 80CL 3''	7.5hp/3600	16.6L/S	3,000	9,197.00
BOSHAN HL 100CL 4''	9.6hp/3600	26.6 L/S	1,827	12,000.00
BOSHAN HL 80CL 3''	7.5hp/3600	16.6L/S	2,669	9,197.00
BOSHAN HL 50CL 2''	5.5hp/3600	11 L/S	1,516	7,936.00
BOSHANHL 100 CL	9.6hp/3600	26.6 L/S	11	12,000.00
FIRMAM 3''	5.5hP	1.6L/S	240	8,400.00
Eagle	5.5	16.6l/s	1,782	7,461.20
LUTIYA			61	
Robin PTG 307 3''	5.7 hp	16.6	2,265	3,000-7,800
Honda 3''	5.7hp	16.6	907	3,500-8,200
Lambardin 4''	11hp	26.6	206	35,000-65,000
Lambardin 3''	7.5hp	16.6	571	23,000-31,000
Electrical Pump	10HP	75m^3/hr	2	65,000
Electrical Pump	200HP	764 L/S	11	
Treadle pump			162	
Rope and washer pump			316	
Total			19,846	

Source: Oromia Water Resource Bureau

Table A2. Water Lifting Technologies Distributed by Tigray Region Water Resource Bureau (2005-2010)

Model	Power (HP)	Quantity	Unit Price/Birr
KAMA KM178 KDP30 3"	4	512	4,542.85
KAMA KM178 KDP30X 3"	5.5	144	4,594.25
KAMA KM178 KDP30 3"	5	1,116	4,063.18
LUUNTOP 170 LDP80c 2"	3.8	629	3,910.00
LUUNTOP LA178FP LDP80c 3"	4.5	1,100	4,347.00
KIPOR KM178F KDP30 3"	5.5	1,200	5,232.50
LUUNTOP LA178F LDP80c 3"	4.5	1,250	5,457.70
BOSHAN HL178FAP2 HL50CL 2"	4.2	100	9,372.37
BOSHAN HL178FAP2 HL50CL 3"	6	5,497	13,656.32
BOSHAN	3.5	6,500	12,500.00
BOSHAN	13	300	90,000.00
Total		18,348	

Source: Tigray Water Resource Bureau

Table A3. Water Lifting Technologies Distributed by Amhar Region Water Resource Bureau (2005-2010)

Zone	Motor Pump				Treadle Pump			
	Supplied	Distributed	In stock	Need maintenance	Supplied	Distributed	In stock	Need maintenance
West Gojam	3,986	1,633	2,353	0	2,057	176	1,881	0
East Gojam	3,050	1,001	2,049	67	1,648	799	849	0
Awi	1,046	833	213	0	947	183	764	0
South Gonder	3,000	681	2,319	113	767	449	318	518
North Gonder	2,000	879	1,121	0	684	640	44	0
North Wollo	1,550	335	1,215	104	150	309		0
South Wello	1,863	673	1,190	0	2,919	828	2,091	0
Wag-Hemera	562	137	425	24	382	273	109	0
North Shewa	3,000	861	2,139	432	5,144	1,302	3,842	5,762
Oromia	859	590	269	0	33	33	0	0
Total (Region)	20,916	7,623	13,293	740	14,731	4,992	9,739	6,280

Source: Amhara Water Resource Bureau