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REACH Water Security in Fragile Environments Observatory

Baseline report of groundwater development in pilot watersheds Amhara, Ethiopia

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Supporting water sanitation and hygiene services for life

This Baseline Report has been produced as part of a research activity for the Water Security in Fragile Environments observatory of the REACH programme. REACH is financed by DFID through Oxford University with this activity implemented under the auspices of the Water and Land Resource Centre (WLRC) of Addis Ababa University. The research is being undertaken in two watersheds (Aba Gerima and Debre Yacob) in two districts (Bahirdar Zuria and Mecha) of Amhara National Regional State of Ethiopia.

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REACH Water Security in Fragile Environments Observatory

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Abbreviations

CBT	Compartment Bag Test
DFID	Department for International Development, Government of the UK
EC	Electric Conductivity
MPN	Most Probable Number
KII	Key Informant Interview
ppm	Parts per million
SLM	Sustainable Land Management
WLRC	Water and Land Resource Centre

Executive summary

The aim of the REACH Fragile Environments Observatory is to evaluate the contribution of Sustainable Land Management (SLM) practices to water security in fragile ecosystems and to share results for evidence-based up-scaling. The REACH project is financed by DFID and implemented by the University of Oxford. The Water and Land Resource Centre (WLRC) of Addis Ababa University is the lead implementing partner in Ethiopia and the SLM-focused activity is implemented in two learning watersheds (Aba Gerima and Debreyacob) located in two districts (Bahirdar Zuria and Mecha) of the Amhara National Regional State.

In the two selected learning watersheds, IRC is supporting the WLRC to further understand the groundwater component of the water balance by investigating the following:

1. What are the drivers behind investment in groundwater facilities by families for agriculture (household irrigation) and domestic (self-supply) uses?
2. What are the existing water quality risks and how effective are low-cost interventions?
3. What are the existing water quantity risks due to unregulated or uncontrolled utilisation of the groundwater resource at the watershed level?
4. What is the potential for participatory monitoring of groundwater and the development of Water Safety Plans in Learning Watersheds?
5. What are the potential cost-effective, locally-appropriate, labour and time-saving technologies for well construction, water lifting and water application for irrigation?
6. How can the supply chain of selected low-cost technology options be improved to provide products and services needed to construct and upgrade wells in these watersheds?

This report presents the baseline information from May 2017. A total of 799 wells (758 family wells and 41 community wells) and information was captured in questionnaires using the smartphone-based application Akvo FLOW. Additional information was collected using Key Informant Interviews (KIIs) with selected community members and Development Agents. Furthermore, 41 water samples were taken from 23 family wells and 18 community wells, testing salinity, pH and faecal coliform (using Compartment Bag Test (CBT) method).

The following results have been found:

1) Most survey respondents (>65%) have no formal education:
2) Frequently users have more than one well, in (>51%) of well-owners in Aba Gerima even moe than 51%
3) Most wells constructed after 2006, peaking in 2013-14, with Most of the poorer well-owners constructed wells only after 2010
4) Most additional wells are constructed for irrigation:
5) More family well-owners irrigated around 0.2 hectares of land using their wells
6) Most respondents drink water without any treatment:
7) Significant numbers (24-50%) of the households do not have toilets and defecate in the open

Which have lead to the following conclusions:

A. **The poor are late entrants into the well-owning class**: In both the Aba Gerima and Debre Yacob Catchments, most of the poorest-third of households surveyed had constructed their wells after 2010 – over 80% in Aba Gerima and 100% in Debre Yacob, whereas the richer categories already had wells before that time.

B. **There are significant water quality risks to family dug-wells used for drinking**. More than 90% family wells used for drinking tested had unsafe levels of faecal coliform bacteria.

C. **There are significant water quality risks to community water sources using dug-wells**. Half of all dug-well-based community water sources that were tested showed unsafe levels of faecal coliform bacteria.

D. **Threats to water quantity in family dug wells and community water sources are relatively small currently but could increase in future**. Currently there is hardly any motorized pumping of wells (though there is some pumping of surface water) and water lifting devices used on these family wells are low capacity. But increased demand for water in the future could see (competitive) water drilling and groundwater abstraction for irrigation – which could also affect drinking water wells.

E. **Comparison against the Control Watersheds is problematic, since there are statistically significant differences with the Learning Watersheds.** The 'Control' should be similar to the 'Treatment' set in all respects except for the Treatment being considered.

F. **For experiments it may be better to re-select 'control' wells from among the same wells surveyed in the learning watersheds but to disguise the subsequent 'treatment'.** The surveyed family wells in the same Learning Watersheds can be randomly designated as 'Control' and 'Treatment' wells, as in a randomized control trial, and water quality (and quantity) risk and threat reducing treatment provided to only designated 'Treatment' wells.

These findings and conclusions shape the follow-up research and will form the reference against which future developments can be compared.

Chapter 1 Introduction

1.1 Project background

The aim of the REACH Fragile Environments Observatory is to evaluate the contribution of Sustainable Land Management (SLM) practices to water security in fragile ecosystems and to share results for evidence-based up-scaling. The REACH research program is financed by DFID and led by the University of Oxford. The Water and Land Resource Centre (WLRC) of Addis Ababa University is the lead implementing partner in Ethiopia. The SLM-focused activity is implemented in two learning watersheds (Aba Gerima and Debreyacob) located in two districts (Bahirdar Zuria and Mecha) of the Amhara National Regional State.

To date, there has been limited assessment of the groundwater resources within the learning watersheds or understanding of the dynamics of groundwater utilization. However, groundwater development forms a critical component of government policies and strategies in both agriculture (e.g. the household irrigation programme) and rural water supply. In the two selected learning watersheds, where existing development of shallow groundwater is substantial, IRC is supporting the WLRC to further understand the groundwater component of the water balance, investigate the pattern of investments and benefits derived from groundwater, monitor groundwater levels, quality and utilization, and test the effectiveness of key potential interventions (e.g. low cost well protection, water safety planning) that may reduce risks and enhance benefits derived from groundwater by the rural poor.

1.2 Research Questions and Survey Objectives

The research investigates six main research questions:

- What are the drivers behind investment in groundwater facilities by families for agriculture (household irrigation) and domestic (self-supply) uses? What is the current performance of these facilities and what are the patterns of sharing of benefits within households?

This is an important research question in both watersheds. In Aba Gerima, groundwater development by households is mainly for agriculture, crop cultivation and livestock purposes, while in Debre Yacob, it is also for domestic use and backyard cultivation. Understanding the factors that influence households' choice of type of use, obstacles and opportunities for investment, and how benefits are shared within the household is expected to help to identify and promote interventions that enable optimum development of groundwater for multiple uses, with the benefits equitably shared within the household.

- What are the existing water quality risks related to using unprotected-or semi-protected water sources at household level and how effective are low-cost interventions (e.g., improved well head protection and lifting devices) in reducing water-related risks associated with family wells?

Water quality issues are likely to be more relevant in the Debre Yacob catchment where most of the wells are known to be used for drinking and other domestic uses. Most of these wells are open wells with no protection. Following a water quality monitoring survey to assess the level of risk, the effectiveness of low-cost upgrading techniques (such as improving well lining, well head protection, and lifting devices) in reducing risk and water quality from family wells will be tested. These findings will be used to generate lessons on how family wells can provide safe water through low-cost upgrading and as a result receive better attention in water supply planning and monitoring. The baseline survey of wells in Aba Gerima was intended to determine whether drinking water use is significant in scale and whether water quality assessments and upgrading to improve quality are relevant in this watershed.

- What are the existing water quantity risks due to unregulated or uncontrolled utilisation of the groundwater resource at the watershed level?

In the Aba Gerima catchment, intensive groundwater development is related to khat production. Over 200 wells were identified in the watershed during the first visit. Households commonly own multiple wells. The research will quantify the rate of groundwater abstraction and compare it to the current potential. Water balance estimations will be developed, and trends of development identified, including future risks and scenarios. Participatory groundwater monitoring will be conducted to collect additional information on groundwater levels and abstraction, and to develop a better understanding of this resource within the community. The research will be conducted in partnership with woreda-level water and agriculture government offices, and the information will be used to develop a Water Use Plan for the woreda and to inform discussions on groundwater management at regional and national levels.

- What is the potential for participatory monitoring of groundwater and the development of Water Safety Plans in Learning Watersheds (using existing national guidelines for climate-resilient water safety plans) to manage groundwater utilization risks?

Participatory groundwater monitoring and water safety plans could raise awareness within the community on groundwater development and risks. The extent to which on-going sustainable land management activities influence the management of water resources by communities in the watersheds is uncertain. Action research aims to test the potential utility of participatory monitoring and water safety plans and develop recommendations on how existing national guidelines on water safety planning can be incorporated into sustainable land management interventions.

Based on discussions with woreda-level officials and farmers two additional action research questions have been developed to meet the needs of local stakeholders.

- What are the potential cost-effective, locally-appropriate, labour and time-saving technologies for well construction, water lifting and water application for irrigation?

Farmers face problems of collapsing wells in some parts of both Debre Yacob and Aba Gerima watersheds. The effectiveness of low-cost techniques for well lining to prevent collapse will be tested with selected 'champion' farmers. The effectiveness of various water lifting technologies that save labour and time will also be tested including how they can be used in combination with other irrigation water saving techniques. In addition, the effectiveness of technologies such as well-deepening to increase well water quantities will be tested.

- How can the supply chain of selected low-cost technology options be improved to provide products and services needed to construct and upgrade wells in these watersheds?

While suppliers and service providers for well construction were encountered in both districts of Bahirdar and Mecha, households reported challenges to the supply of products and services. Available supply chains will therefore be examined, gaps identified, and solutions for improvement tested.

The objective of the baseline study was to map family wells and their existing characteristics, performance, use and risks. This includes understanding the investments made by rural households, patterns of sharing of wells, and the risks associated with abstraction (both quantity and quality).

1.3 Study area

Both catchments are in the Amhara National Regional State (Figure 1). Aba Gerima learning watershed is in Bahirdar Zuria woreda of West Gojam Zone, and is spread across the three kebeles of Laguna Debretsion, Gonbat and Robit. The learning watershed covers an area of 900 ha and is about 15 km from Bahirdar. Debre Yacob watershed is in West Gojam zone of Mecha woreda and spreads over two kebeles: Sirabetegibar and Felegehiwot. Debre Yacob learning watershed is located in Koga watershed and it covers an area of 325 ha. Debre Yacob is located at about 72km by road from Bahirdar.

Figure 1: Location of the study area

In both Aba Gerima and Debre Yacob watersheds there are small perennial streams where flow gauging equipment has been established. In Aba Gerima, there are three stream flow gauging stations and two in Debre Yacob. In addition, there are meteorological stations for measurements such as temperature and rainfall.

In both watersheds, weathered volcanic rock (mainly basalt) forms multilayer aquifer systems bearing shallow and deep groundwater. There is no abstraction of deep groundwater in the watersheds. Shallow groundwater is the main resource exploited for domestic and irrigation use.

Chapter 2 Survey Design and Methods

2.1 Survey Design

The baseline survey was conducted in the two learning watersheds and their associated two control watersheds. In all watersheds a complete inventory of family wells was conducted. Each family well was visited, and the well-owner or another member of the family interviewed. A total of 113 family wells were surveyed in the Debre Yacob watershed area, and 645 family wells in the Aba Gerima watershed area, totalling 758 family wells. A total of 23 water samples were collected from these 758 family wells and tested for the faecal coliform indicator bacteria *escherica coli (E. coli).*

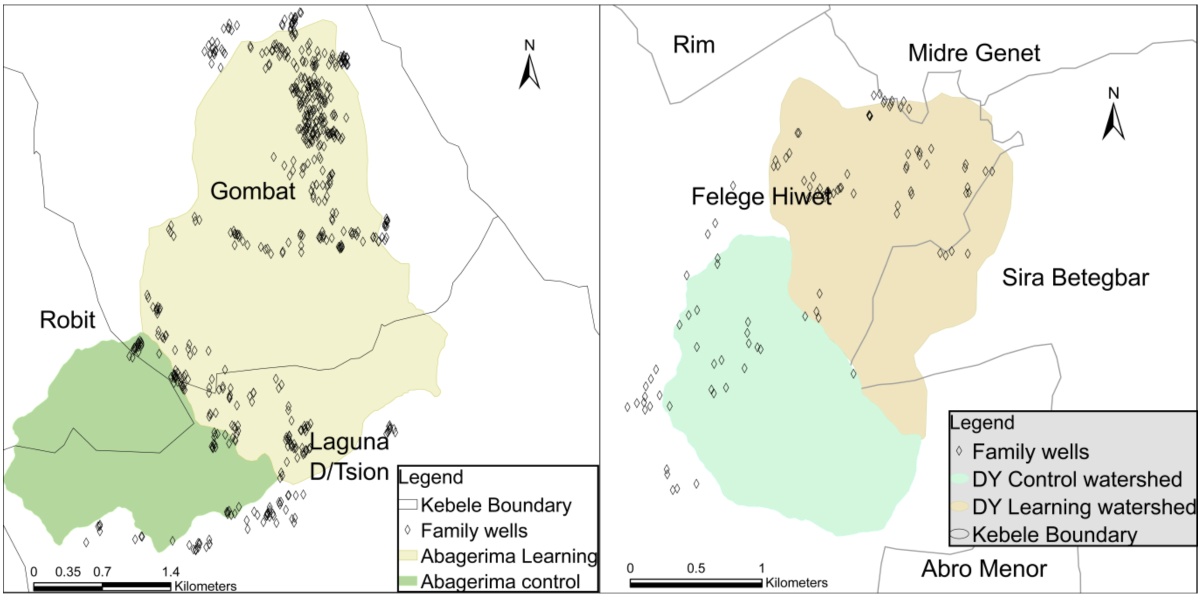

Figure 2: Distribution of all surveyed family wells in the learning and control watersheds

In addition, a community water supply inventory was conducted in these four watersheds and adjacent areas. A total of 41 community water schemes were surveyed in both Aba Gerima and Debre Yacob watershed areas and 18 water samples were collected and analysed for *e-coli*.

2.2 Data collection tools

Information on groundwater and related infrastructure was collected using two questionnaires; one for households owning and using 'Family Wells', and a second on community water supply managers responsible for 'Community Wells'. Key Informant Interviews (KIIs) were also conducted with selected community members and Development Agents appointed by the government. The questionnaires contained the following forms:

- The *Family Wells Inventory* had three forms:
  - Well owner basic details – including age, education level, number of family members and area farmed.
  - Well survey details – including well characteristics e.g. depth to water level, well depth, technologies used in well construction and water lifting, reliability, use and satisfaction, sanitation around the well, and hygiene in handling water.
  - Well water quality – tested for a sample of wells.
- The *Community Water Supply Inventory* had three forms:
  - Community basic details – including responsibility for operation & maintenance.
  - Community repeat survey - includes depth, reliability, and functionality.
  - Water quality – tested for a sample of community water supply sources.

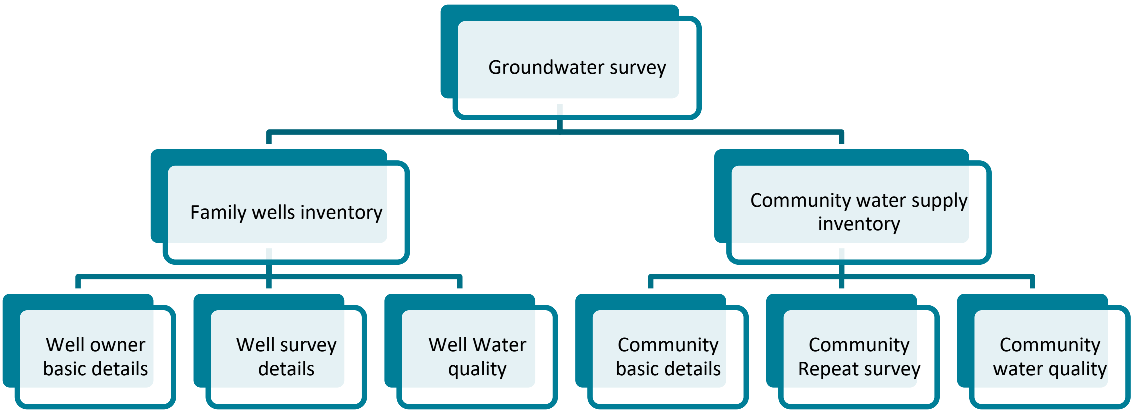

Figure 3: Types of Survey Forms Used.

KIIs were conducted with selected households owning family wells and with Development Agents to (1) verify the household survey responses and (2) to capture additional information. The KIIs covered:

- Family well ownership
- Investments made in the well
- Uses of the well
- Source of funds, and labour for well construction (e.g., own/ family labour or hired)
- Current prices of well digging (if undertaken through payment)
- Availability of service providers

2.3 Enumerator training and supervision

Potential enumerators for data collection were identified both from Mecha and Bahirdar zuria woredas through discussions with Agriculture and Water Officers of the woredas. In both woredas, government staff from woreda and kebele levels and field technicians of WLRC were selected as enumerators and given a two-day training in Bahirdar; one day on theory and the second day on practical aspects of the survey. The theoretical training covered the following aspects:

- REACH Project background and objective of the survey.
- Content of the survey questions.
  - Each survey question was discussed.
  - Key water infrastructure terms (e.g., well components, lifting devices) were explained with sketches/drawings.
- Survey team setup and approach of the data collection.
- Duration and logistics required for the survey including the roles and responsibilities of enumerators and supervisors.
- How to operate the data collection application software (AkvoFlow) using smart phones.

Practical training involved a joint survey (with the supervisor) of households having multiple family wells. The Supervisor conducted the first survey, while trainees observed how to approach households, ask the questions and enter responses. The trainees then split into sub-teams to conduct similar surveys with other households. At the end of the day, all the team members gathered to discuss their findings and experiences, clarify doubts, and adjust their approaches. Survey questionnaires were modified based on this feedback.

Trainees also practised taking different measurements (e.g., depth to water level using a dip meter). Two enumerators from the Aba Gerima and Debre Yacob teams were selected to work with the supervisor on the community water supply survey and water sampling (both from family wells and community water supply) and analysis. The two enumerators were separately oriented on different procedures of water sampling and analysis, including some physical parameter measurements such as pH and electric conductivity (EC).

Each survey team was led by the WLRC field officers from Aba Gerima and Debre Yacob catchments, and the two team leaders were supported by the Survey Supervisor (Figure 4).

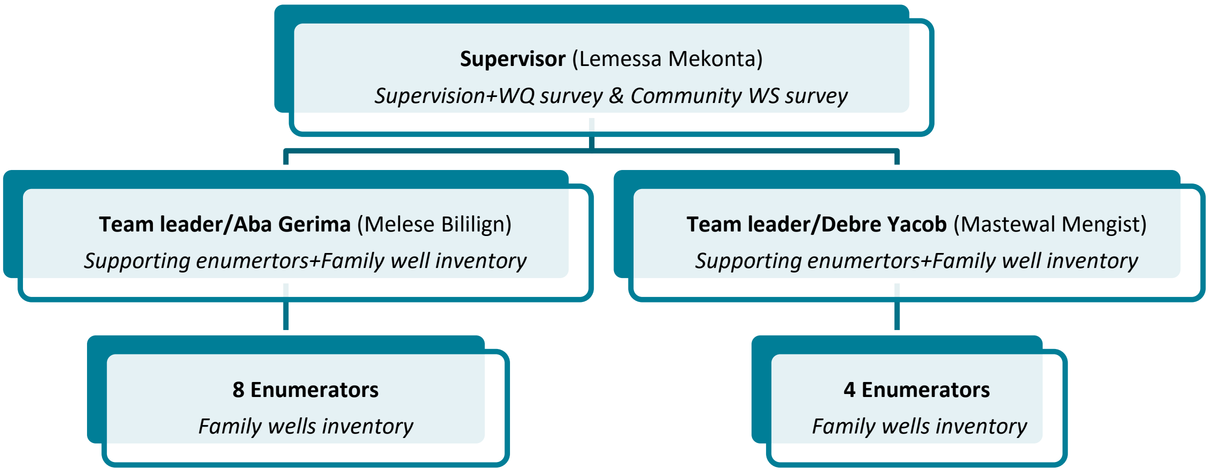

Figure 4: Survey Team setup and responsibilities

Each enumerator had a smart phone for data collection. Since multiple-well ownership is common in Aba Gerima, it was ensured that a single household (with all its wells) was surveyed by the same enumerator.

2.4 Data collection and analysis

Data were collected during 24 - 31 May 2017. Surveys made on 23 May 2017 for practical training were also included in the sample. Both family wells and community water supplies in the watersheds were inventoried. Survey information was entered via the smartphone-based application Akvo FLOW and analysed using Microsoft Excel. Water samples were collected from a sample of wells and analysed onsite for salinity (using electrical conductivity tests) and pH. Samples were also tested using the Compartment Bag Test (CBT) method (after incubation for at least 18 hours) for faecal coliform indicator bacteria *e-coli*. A total of 422 well-owning households were surveyed in Control and Learning watersheds in the Aba Gerima and Debre Yacob learning watersheds (Table 1).

Table 1: Number of well-owners surveyed

	Number of well-owning households surveyed	% in Control and Learning Watersheds	% wells surveyed in the Catchment
Aba Gerima (Control)	51	15%	100%
Aba Gerima (Learning)	279	85%	
Debre Yacob (Control)	34	37%	100%
Debre Yacob (Learning)	58	63%	
Total	**422**		

These 422 households owned a total of 681 family wells. However, there were 77 family wells owned by 49 households that were surveyed but excluded from the analysis as they were outside of both the learning and control watersheds boundary. Analysis was further restricted to the 592 wells that were operational (Table 2). The 41 community water sources surveyed also reduced to 35 after verifying the watershed boundaries on a map, and then to 33 since one source was not operational and another was an unprotected spring and therefore not considered for further analysis.

Table 2: Number of operational wells analysed

Watershed	Total wells surveyed	Operational wells	% Operational to Total Wells
Aba Gerima Control	75	67	89%
Aba Gerima Learning	502	435	87%
Debre Yacob Control	36	30	83%
Debre Yacob Learning	68	60	88%
TOTAL	**681**	**592**	**87%**

The 246 family wells that owners reportedly use for drinking water represent 36% of all family wells surveyed and 41% of operational family wells. They are classified as “wells used for drinking”. All these wells are multiple-use wells and are classified as water wells used for drinking if they are reported to be used as drinking water sources. Not because they are *exclusively* drinking water sources.

Chapter 3 Findings

3.1 Family wells: Socio-economic characteristics of survey respondents

Most survey respondents have no formal education: More than 65% of respondents (from family well-owning households) had no formal education (i.e. did not go to a regular government or private school). This applied to more women than men (Table 3). The difference between numbers of women without formal education in Debre Yacob control and learning watersheds is statistically significant (at 95% level of confidence)[1] as tested using Chi square.

Table 3: Education level of respondents.

	Total # of surveyed well owners	Males without formal education	Females without formal education
Aba Gerima (Control)	51	65%	80%
Aba Gerima (Learning)	279	73%	86%
Debre Yacob (Control)	34	74%	91%*
Debre Yacob (Learning)	58	66%	74%*

Average family size is between 5 and 6: Average family size is larger in the Debre Yacob watershed areas (6.0 and 5.4) than in Aba Gerima watershed areas (5.6 and 5.0), with 71% of households in the Debre Yacob control watershed having more than 6 members (Table 4).

Table 4: Family size of surveyed households.

	Total # of surveyed well owners	Family size			
		Average	<4 members	4-6 members	>6 members
Aba Gerima (Control)	51	5.6	18%	27%	55%
Aba Gerima (Learning)	279	5.0	25%	32%	43%
Debre Yacob (Control)	34	6.0	12%	18%	71%
Debre Yacob (Learning)	58	5.4	10%	45%	45%

[1] This basically means that It can be said with 95% confidence that the two data sets being compared (here, the number of women without formal education in two watersheds) came from two distinct distributions (i.e., distributions with a different mean) – and not from different parts of the same distribution (with the same mean). This is the interpretation of all references in this report to 'statistically-significant differences', at a certain 'confidence level' (90%, 95% or 99%).

Most households are in the 'middle third' wealth category: Indicators for wealth categories (basically asset ownership) were taken from woreda Agriculture offices; poorest-third, middle-third, and richest third. More than three quarters of the surveyed households reported being in the middle-third wealth category (Table 5).

Table 5: Wealth distribution of surveyed households.

	Total # of surveyed well owners	Poorest third	Middle third	Richest third
Aba Gerima (Control)	51	6%	78%	16%
Aba Gerima (Learning)	279	7%	77%	16%
Debre Yacob (Control)	34	6%	79%	15%
Debre Yacob (Learning)	58	17%	76%	7%

Less than 10% of wells owned by women-headed households: Only 30 out of 422 well-owning households surveyed were women-headed households (7%). More of these households were in Aba Gerima Learning watershed but the Debre Yacob learning watershed had the largest proportion of women-headed households out of surveyed households (Table 6).

Table 6: Family well-owning women headed households

	Women headed households (#)	% of total households surveyed
Aba Gerima (Control)	1	2%
Aba Gerima (Learning)	21	8%
Debre Yacob (Control)	1	3%
Debre Yacob (Learning)	7	12%

Most respondents are married males: While 86% of the family well survey respondents were male, 91% of the well owners are married.

3.2 Family Wells: Ownership and Construction

Majority of well-owners in Aba Gerima Learning watershed has more than one well: 51% of those surveyed in the Aba Gerima Learning Watershed had at least a second well (the maximum being 8 wells), and 27% of those in the Aba Gerima Control Watershed had at least 2 wells. No well-owning household surveyed in the Debre Yacob Control Watershed had a second well (Figure 5).

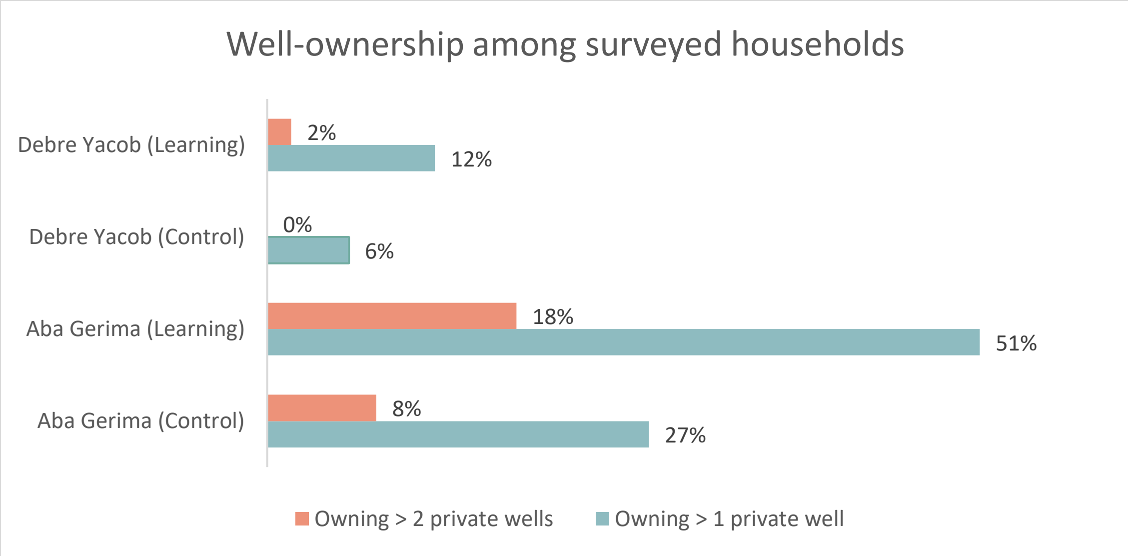

Figure 5: Well-ownership among surveyed households.

The difference between numbers of households with more than 1 well in Control and Learning watersheds in the Aba Gerima catchment is statistically significant (at the 99% confidence level). Multiple well ownership is lower in the Control watershed.

Most wells were constructed after 2006, peaking in 2013-14: Although the earliest wells date back to around 1970 and 1992 in Aba Gerima and Debre yacob catchments respectively, well numbers began to increase from 2003, most likely linked to the national campaign on family well construction (and rainwater harvesting through farm ponds). The number of wells constructed per year peaked around 2013-14 and declined thereafter in both catchments (Table7; Figures 6 & 7).

Table 7: Periods of well construction.

	# of surveyed operational weels	Proportion of wells constructed per time period			
		Before 2006	**2006-2013**	**After 2014**	**Total**
Aba Gerima (Control)	67	13%	60%	27%	100%
Aba Gerima (Learning)	435	15%	61%	24%	100%
Debre Yacob (Control)	30	17%	57%	27%	100%
Debre Yacob (Learning)	60	18%	55%	27%	100%

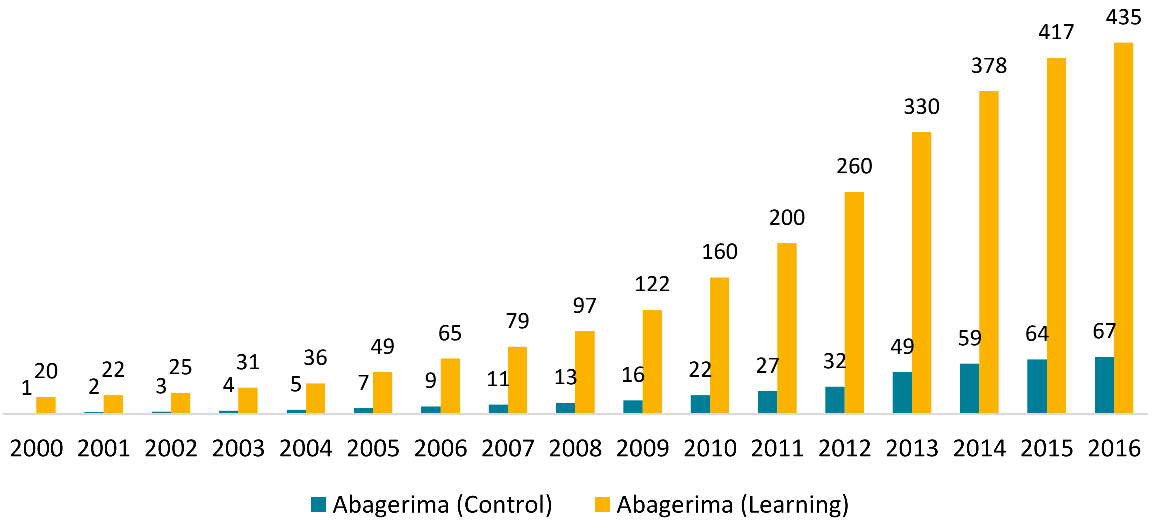

Figure 6: Cumulative number of wells constructed, 2000-2016, Aba Gerima

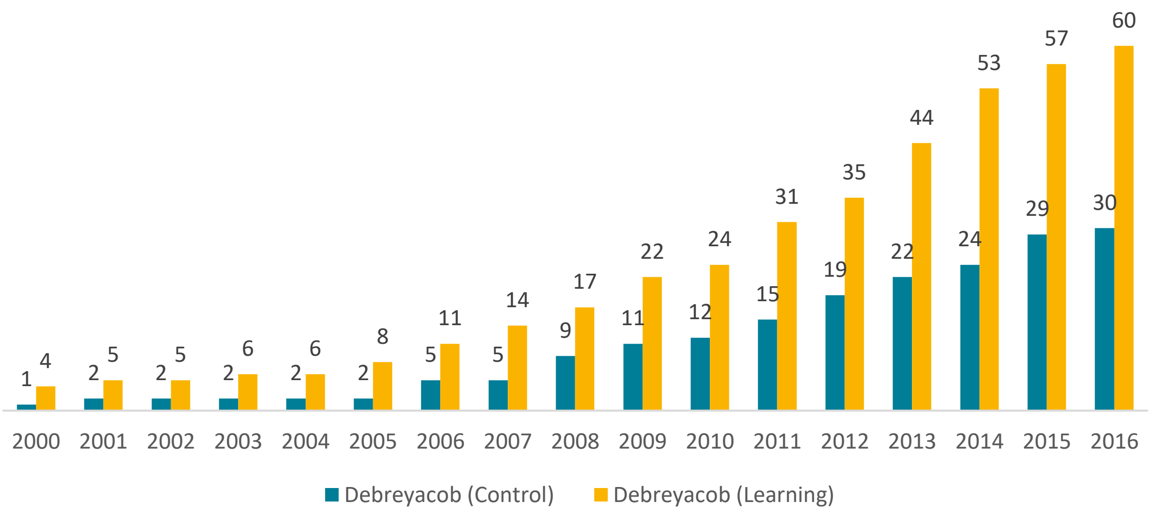

Figure 7: Cumulative number of wells constructed, 2000-2016, Debre Yacob

Most of the poorer well-owners constructed wells only after 2010: The poor are late-entrants into well-ownership: over 80% of the poorest-third households constructed wells after 2010 in the Aba Gerima Catchment, while 100% did so in Debre Yacob Catchment (Table 8, Figures 8 and 9). On the other hand, about half (49%) of the richest third constructed their wells by 2010 in Aba Gerima catchment.

Table 8: Well construction distribution based on wealth categories, Aba Gerima and Debre Yacob Learning and Control watersheds.

	Time period	Poorest Third	Middle Third	Richest Third
Aba Gerima Learning and Control watersheds	Before 2000	0%	5%	3%
	2000-2010	19%	30%	46%
	2011-2014	56%	54%	39%
	2015-2016	26%	12%	13%
	Total	100%	100%	100%
Debre Yacob Learning and Control watersheds	Before 2000	0%	1%	20%
	2000-2010	0%	41%	27%
	2011-2014	83%	43%	40%
	2015-2016	17%	14%	13%
	Total	100%	100%	100%

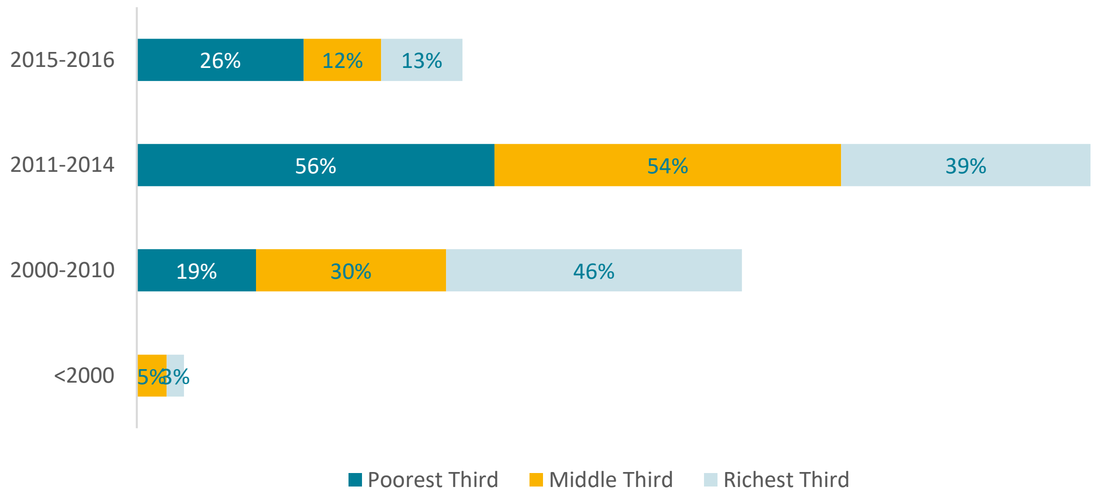

Figure 8: Well construction by wealth category, Aba Gerima (Learning & Control watersheds). n. = 502

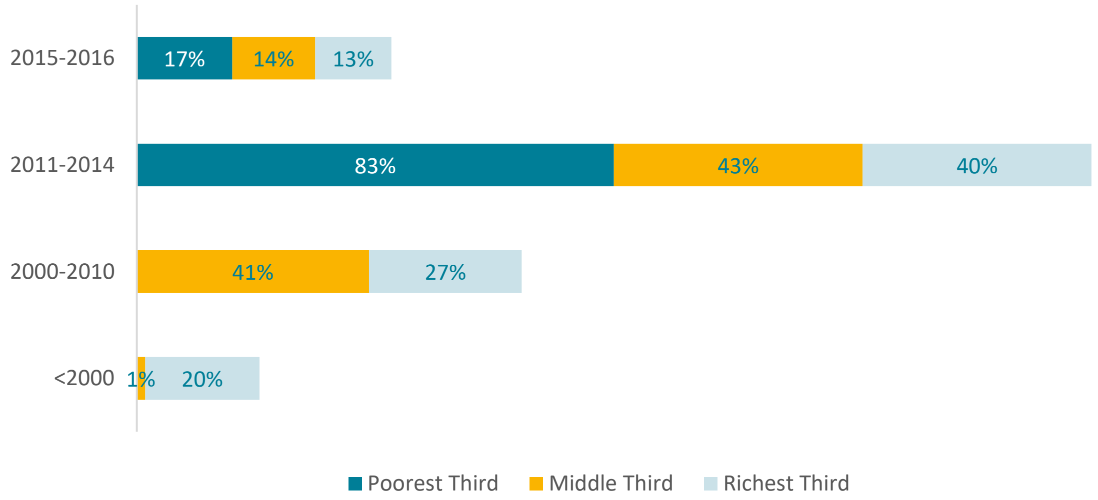

Figure 9: Well construction by wealth category, Debre Yacob Learning & Control watershed. n. = 90

Most additional wells constructed for irrigation: Irrigation was the most frequent reason mentioned for constructing additional wells, followed by providing water for livestock, while only a few mentioned constructing an additional well to replace an abandoned well (Figure 10). The supply of domestic water is not a main driver of family well construction especially in Aba Gerima.

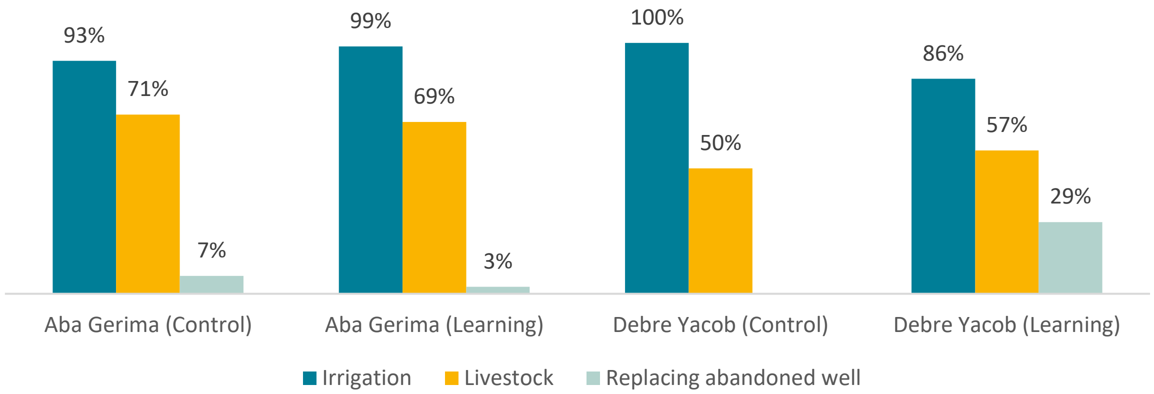

Figure 10: Reasons given by surveyed households for constructing additional wells.

Most family well owners irrigated around 0.2 hectares of land using their wells: The average irrigated land reported by well-owners was 0.2 hectares, although the Debre Yacob Control watershed had an average of only 0.13 hectares (Table 9).

Table 9: Area irrigated by well per catchment and distribution of land holding size. n. = 422

	Average (ha)	Proportion of surveyed households owning wells		
		Less than 0.2 ha	0.2 to 0.4 ha	More than 0.4 ha
Aba Gerima (Control)	0.19	65%	24%	12%
Aba Gerima (Learning)	0.20	59%	31%	10%
Debre Yacob (Control)	0.13	76%	21%	3%
Debre Yacob (Learning)	0.19	62%	24%	14%

More households in Aba Gerima than in Debre Yacob aspire for more wells: When asked whether they aspired to have more wells, 92-98% of households surveyed in the Aba Gerima catchment said yes. Only 56-66% of those surveyed in Debre Yacob said so (Table 10).

Table 10: Aspiration to develop additional wells.

	Surveyed Households	Yes, I would like more wells
Aba Gerima (Control)	51	98%
Aba Gerima (Learning)	279	92%
Debre Yacob (Control)	34	56%
Debre Yacob (Learning)	58	66%

Differences between responses from Aba Gerima and Debre Yacob watersheds are statistically significant (at the 99% level).

Male household heads usually decide whether to construct wells, and construction is by family members or neighbours without payment (though rope, pulleys and buckets are purchased locally): Most households (75%) reported that the male head of the household takes the lead in deciding about family wells construction, while 18% reported that it was the female head of the household, and the rest said it was a joint decision. Paying for someone to dig the well is not common in these areas, they said, and it is done by family members with neighbours: the men usually do the digging while women remove the soil from the hole. About 82% of the well owners said they either use own labour or neighbours without payment to construct their own wells (paying for service is minimal); however, nearly 99% have paid for products. Rope is the main product purchased (reported by 93%) followed by pulleys (64%) and buckets (60%). The woreda centre is a common place to buy these products.

Box 1 Investment and paying for well digging services

Key informants were interviewed on family well ownership, level of investment, and how the wells were constructed (own labour or paying for the services) and used. In general, paying for service is not common in both Watersheds (Aba Gerima and Debre Yacob). Rather, households mobilize either neighbours and friends labour or own labour to dig or construct their wells. The number of private well diggers/artisans varies from kebele to kebele ranging between 4 and 6 per kebele. They have no training on well digging and construction but learn by doing. The well diggers do not rely on well digging only for their livelihood but have farm land. and provide well digging services as an alternative source of income during low agricultural season. A given artisan can get a maximum contract of two wells digging per year as one informant from Sirabetegibar kebele mentioned. This illustrates the small market for well digging services in the area. Well digging prices vary depending on location (from watershed to watershed), soil type (soft or hard rock) and season (peak or low farming season). There are three modes of contracting for well digging: lump sum (full contract irrespective of depth until water is available), unit price (per meter) and daily rate. Soil removal and meals for well diggers are covered by the well owner. There are different reasons for not having one's own well including lack of suitable land for well digging (rocky, no water at shallow depth, etc.), well collapse/drying up, and lack of interest.

Key Informant	Key summary
GM	• 32 years old and has family with four children • Has family well and use it with his mother and brothers • The well was dug by artisan; took 8- 10 days to complete the well digging • The well has a depth of 13 meters • Uses for drinking and other domestic uses as well for livestock watering • Well digging in the kebele costs 2500 ETB (soil) and 3000 ETB (rocky) excluding meal provision and soil removal • Main reasons for not having own well by others in the kebele is collapse and drying up
AA	• Has a family size of eight • Had been using communal HDW installed with rope pump, which was constructed 15 years ago • Since three years has constructed his own well of depth 7.5 meters deep; mainly for plant nursery at the beginning but now used for drinking as well as irrigation • Shared by 4 households including the owner • Stopped digging due to hard stone • Paid 300ETB for well digging; used his family's labour for soil removal • Took five days to complete well digging • The well has never dried so far • Not disinfected since construction • Current well price about 1500ETB irrespective of depth excluding soil removal; but if at unit rate 60ETB per meter excluding soil removal • Negligence and hard rock are the main reasons for not having wells for many households in the area
MT	• Has four wells • Lump sum price/contract for HDWs of any depth is 3000- 4000ETB; if abandoned 50% of the total contract amount is paid by the owner. However, if the well digging is on daily basis, 100ETB/day is charged; soil removal is covered by the well owner; the contract value also depends on the soil type
AD	• 65, and married with seven children • Has one well-constructed 12 years ago; 18-meter depth • Had tried seven dried wells before having the productive ones • Use the well for livestock and irrigation only after community water supply construction in the area • Plan to deepen the well as the well has limited water during April and May • The owner is WASHCO member; and he has estimated two privates well diggers per village • Reason for not having own well by some households are lack of suitable land for well digging and carelessness

3.3 Family Wells: Water Use and Sanitation Practices

About 37% and 41% of the surveyed households use their own family well as the main sources of drinking water during wet and dry seasons respectively, – the rest use community sources: About 37% and 41% of survey respondents said that they use their own family wells as main sources of drinking water in wet and dry seasons respectively, with the proportion of users being lowest (21% and 18% in dry and wet season respectively) in the Debre Yacob Control Watershed (Figure 12). These proportions rise to around 70% and 64% for dry and wet season respectively when considering the 246 family wells (instead of surveyed households) that households said they use for drinking (Figure 11). The rest reported using community sources for drinking water, perhaps because many family wells are located far away from the house in the fields. The use of private (own) wells as a main sources of drinking water is more common for richest third households (27%) than for middle third households (22%). Only 12% of the poorest third family well owners use own well as a main sources of drinking water during dry season. The trend is similar for wet season too: 29%, 22% and 12% of the richest third, middle third and the poorest third well owners respectively are using their private wells as a main sources of drinking water.

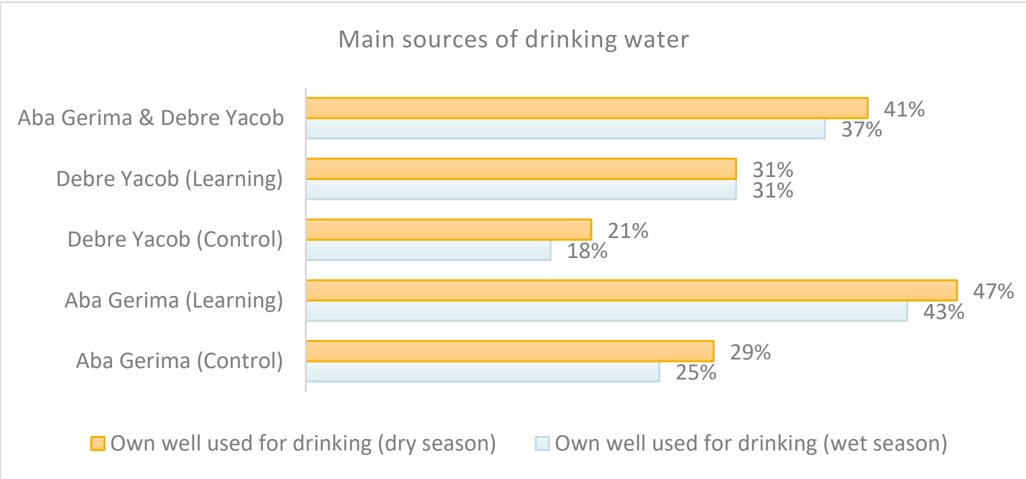

Figure 11: Main sources of drinking water from private/family wells, wet and dry seasons.

Most respondents drink water without any treatment: Out of those who are using their own wells for drinking, between 65% and 78% of them in both Aba Gerima and Debre Yacob catchments (Learning and Control watersheds) said that they drink the water from their own wells without any further treatment, while the rest reported some treatment such as filtering with a cloth, leaving it stand before using, using a filter or chlorination (Figure 12).

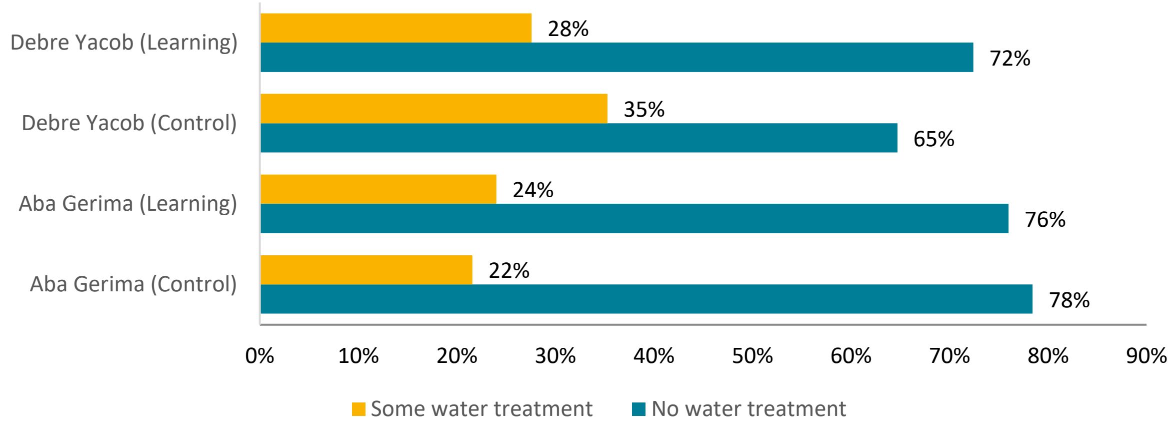

Figure 12: Well-owners who drink water from own wells with and without treatment.

Significant numbers of households do not have toilets and defecate in the open: More than 50% of surveyed households in Aba Gerima Learning Watershed reported not having toilets, and proportions in the other watersheds ranged from 24-35%, nearly all these households also reported defecating in the open (Figure 13). The difference in numbers of households with their own toilets in Aba Gerima Control and Learning watersheds is statistically significant (99% confidence level).

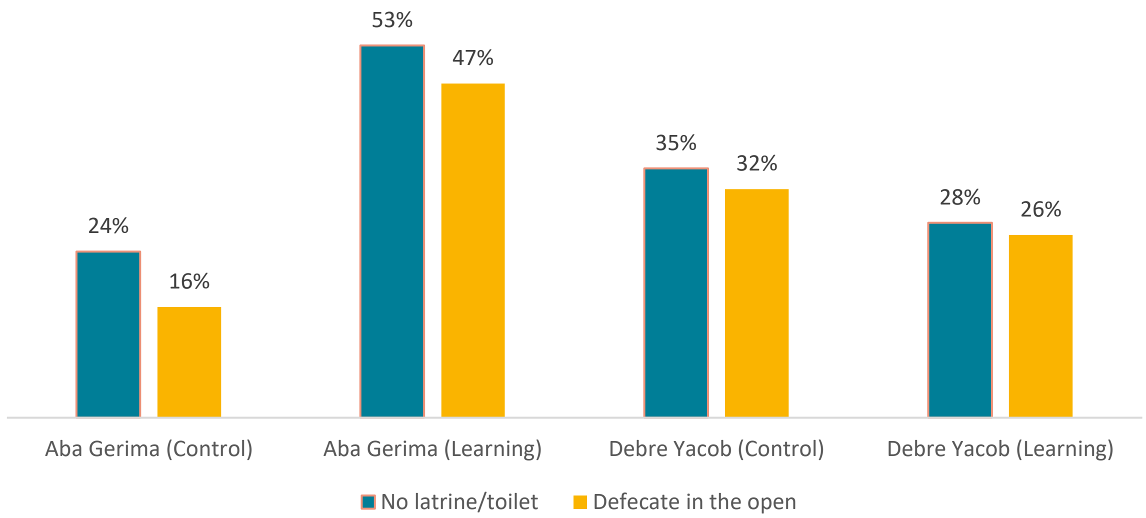

Figure 13: Well-owning households that do not have toilets and that defecate in the open.

3.4 Family Wells: Water Quality Risks

The risks to water quality that were assessed included potential contamination of well water from solid waste, faecal matter and wastewater. The factors assessed included whether the mouth of the well was level with the ground (or below ground level), whether wells had adequate physical measures to protect from contamination (e.g., aprons, soakaways, drainage channels, internal lining and parapets), and whether sources of contamination were observed near the wells (e.g., toilets, solid or faecal waste and stagnant water during rains).

Note that only the operational wells were assessed, which were 87% of all wells surveyed. The others had been abandoned.[2] These factors were also assessed separately for the 246 operational drinking water wells.

Most well mouths are level with or below the ground: While 73-85% of wells surveyed in the two catchments had mouths that were level with the ground, 8-20% had mouths that were below ground level (Figure 14). Taken together, these represented 91-100% of all operational wells surveyed in each of these Learning and Control watersheds. Runoff is likely to enter such wells when it rains.

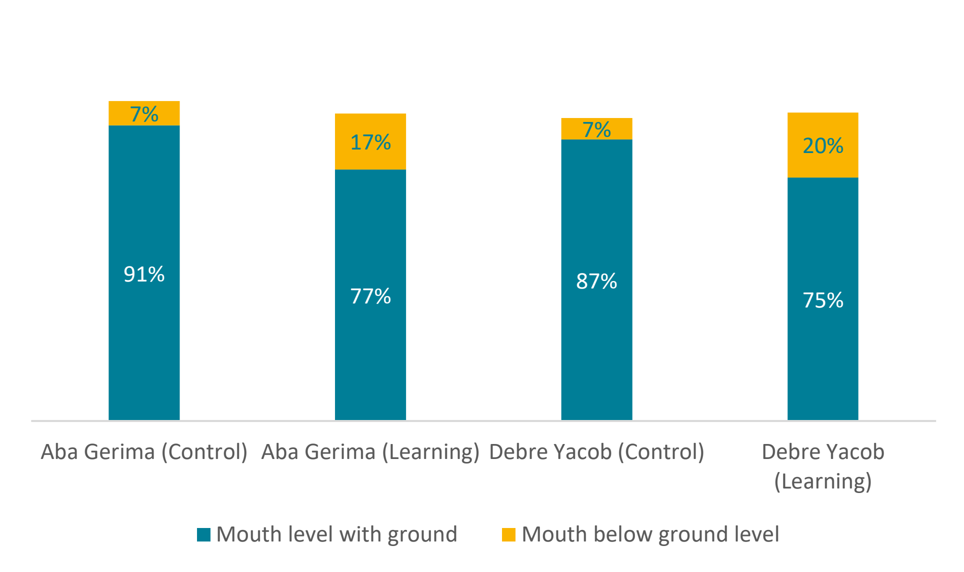

Figure 14: Family wells with mouths level with or below the ground.

The situation was similar for the 246 family wells used for drinking (Table 11).

Table 11: Family wells used for drinking water with mouths level with or below the ground.

Mouth	Operational Wells used for drinking	Mouth level with ground	Mouth below ground level	Mouth level with Or below ground
Aba Gerima (Control)	24	83%	8%	91%
Aba Gerima (Learning)	179	79%	15%	94%
Debre Yacob (Control)	13	85%	15%	100%
Debre Yacob (Learning)	30	73%	20%	93%

Most wells do not have effective covering to keep debris out: While 40-60% of operational wells surveyed in both catchments did not have covers, 30-50% had covers that were not effective in keeping out debris, e.g., loose fitting sheet or planks of wood or plastic or metal structures with gaps, cracks or holes that will allow debris

[2] Well collapse followed by drying-up is the main reason given for abandoning wells. Only about 39% of the abandoned wells are refilled; 45% are left open, while 16% are used as latrines.

to enter the well (Figure 15). Adding numbers of wells with no cover and those with ineffective covers gives a figure of 80-90% of wells that are not effective in keeping out debris from entering the well.

A similar situation was reported for family wells used for domestic purposes, where 80-92% of wells allowed debris to enter the well (Table 12).

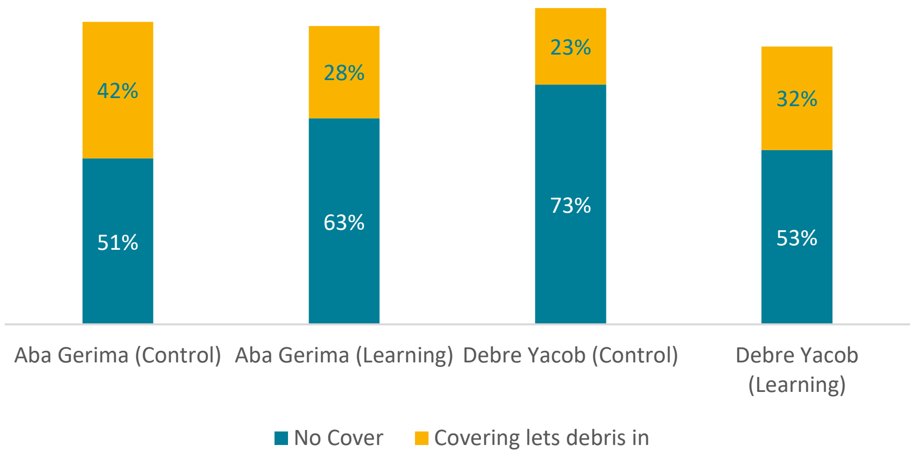

Figure 15: Family wells without effective covering to keep debris out.

Table 12: Water wells used for drinking: covering of well mouths.

Covering	Operational wells	Wells with no cover	Wells with ineffective cover	Wells that let debris in
Aba Gerima (Control)	24	42%	50%	92%
Aba Gerima (Learning)	179	46%	45%	91%
Debre Yacob (Control)	13	62%	31%	92%
Debre Yacob (Learning)	30	40%	40%	80%

Most wells do not have aprons, soakaways or drainage channels: While 90-100% of family wells in Learning and Control Watersheds in Aba Gerima and Debre Yacob did not have drainage channels, 70-80% of these wells did not have aprons and 85-100% had no soakaways (Figure 16). The difference in numbers of wells without drainage channels in Learning and Control Watersheds in Debre Yacob was statistically significant (90% confidence level).

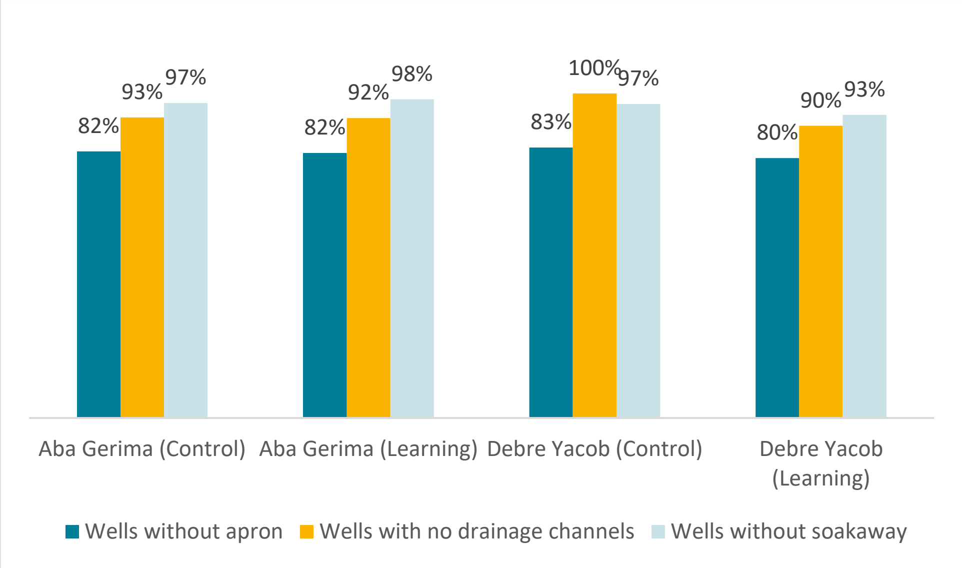

Figure 16: Family wells without aprons, drainage channels or soakaways.

The situation was similar with family wells used for drinking water (Table 13).

Table 13: Water wells used for drinking: without aprons, drainage channels or soakaways.

	Operational Wells used for drinking	Wells without apron	Wells without drainage channels	Wells without Soakaway
Aba Gerima (Control)	24	75%	92%	100%
Aba Gerima (Learning)	179	75%	89%	95%
Debre Yacob (Control)	13	69%	100%	85%
Debre Yacob (Learning)	30	83%	90%	93%

Two thirds of wells do not have lining, parapets and seals and around 20% have stagnant water around the well during rains: Between 50 and 70% of family wells surveyed in the two watersheds (both learning and control) did not have lining, parapet and seal, and 17-31% were reported to have standing water within 5 metres of the well during the rainy season (Figure 17).

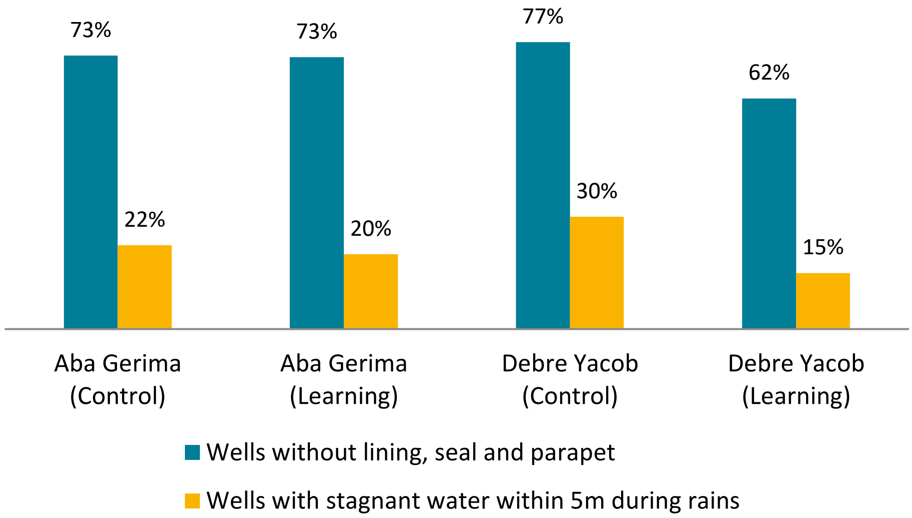

Figure 17: Family wells without lining, seal and parapet, and stagnant water during rains.

The situation is similar for drinking water wells (Table 15).

Table 14: Wells used for drinking that are without lining, seal & parapet, and stagnant water during rains.

	Operational Drinking water Wells	Wells without lining, seal and parapet	Wells with stagnant water within 5m during rains
Aba Gerima (Control)	24	67%	21%
Aba Gerima (Learning)	179	62%	21%
Debre Yacob (Control)	13	69%	31%
Debre Yacob (Learning)	30	57%	17%

Most family wells have solid/faecal waste within 5m of the well, while around 10% have a latrine close by or upstream: Around 70-90% of family wells surveyed in both Learning and Control watersheds in the two catchments were observed to have solid/faecal waste within 5 metres of the well, while 10-25% had a latrine either within 30 metres of the well or upstream of the well (Figure 18). Differences between numbers in Aba Gerima Control and Learning Watersheds are statistically significant (99% confidence level).

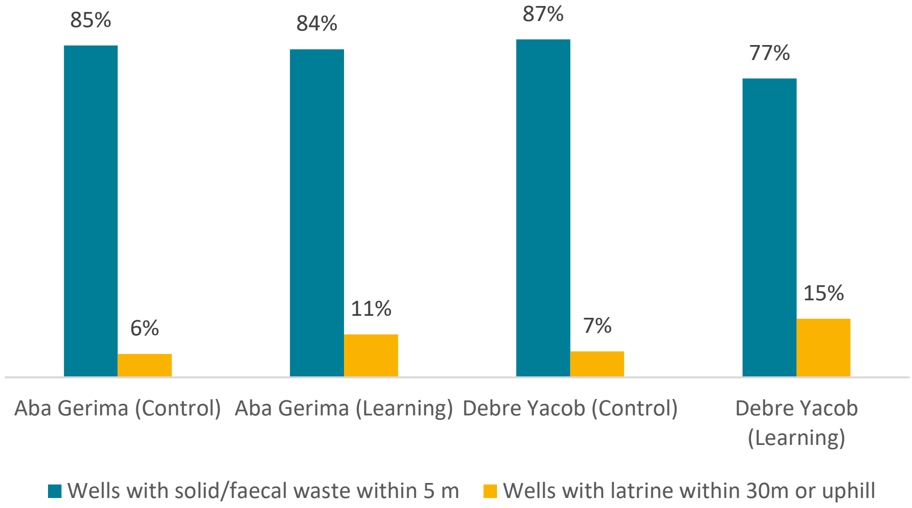

Figure 18: Family wells with solid/faecal waste and latrines within 30m.

The situation was similar for those wells used for drinking although a slightly larger proportion were located close to latrines compared to family wells in general (Table 15).

Table 15: Wells used for drinking with solid/faecal waste and latrines within 30m.

	Operational used for drinking wells	Wells with solid/faecal waste within 5 m	Wells with latrine within 30m or uphill
Aba Gerima (Control)	24	92%	17%
Aba Gerima (Learning)	179	80%	10%
Debre Yacob (Control)	13	69%	23%
Debre Yacob (Learning)	30	77%	17%

Nearly all wells used for drinking water had unsafe levels of contamination by faecal coliform bacteria: Microbiological water quality testing showed that 91% of the water samples (20 out of the 22) from operational family wells surveyed used for drinking in the Learning and Control watersheds had elevated levels (>10 MPN/100 ml) of *e-coli*, indicating contamination by faecal coliform bacteria (Table 16). Further, 14 out of the 20 (70%) wells that were found contaminated with unsafe levels of coliform bacteria had levels of over 100 MPN.

Table 16: Family wells with unsafe levels of faecal coliform bacteria.

	Tested	Unsafe (>10 MPN/100 ml)	> 10-50 MPN/100 ml	> 100 MPN/ 100 ml
Aba Gerima control	1	1		1
Aba Gerima Learning	14	13	4	9
Debre Yacob control	3	3		3
Debre Yacob learning	4	3	2	1
Total	**22**	**20**	**6**	**14**
% to total		*91%*		

3.5 Family Wells: Water Quantity Threats

The threats to water quantity include insufficient water in the well for year-round supply or for irrigation, low water levels in wells, perceived decreases in water availability, and the low levels of use of own wells for self-supplied water for domestic uses, especially in the context of wells whose waters are shared between neighbouring households. The satisfaction levels with well-owners with their wells can also be perceived as an indicator of threats to water quantity. As in the case of water quality risks, only data from operational family wells have been analysed and presented.

Around 12% of family wells do not provide year-round water, and around a third were reported to be inadequate for irrigation: Owners said that 12% of the 592 operational family wells surveyed did not yield water through all 12 months in a year, with Aba Gerima Control watershed being the worst affected (19% of wells surveyed), while 28% of these 592 wells were reported to have insufficient water for irrigation and mostly (37%) in Aba Gerima Control watershed (Figure 19).

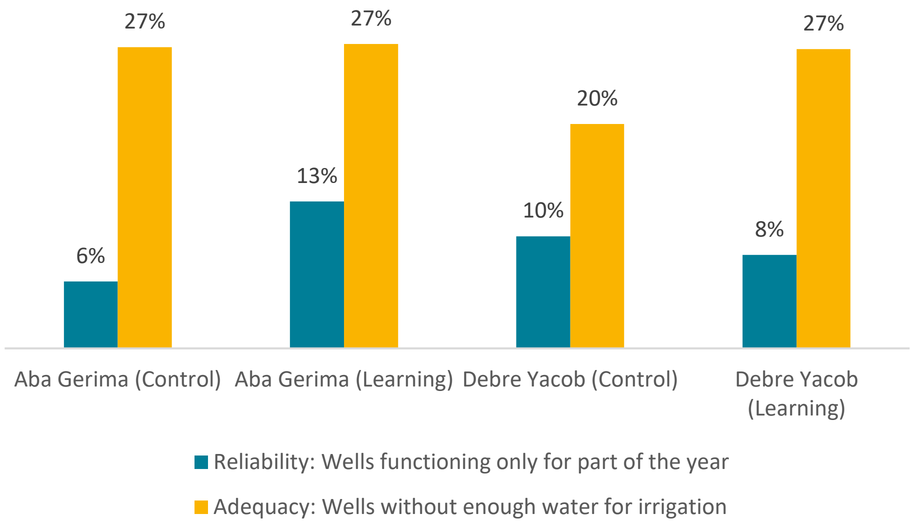

Figure 19: Adequacy of operational family wells surveyed.

The differences in well numbers in Aba Gerima Control and Learning Watersheds found inadequate for irrigation, and without year-round water supply, are statistically significant (both at the 95% confidence level).

More drinking water wells had problems of adequacy: While 16% of 246 operational wells used for drinking surveyed did not have year-round water availability, 30% of these 246 wells were said to be inadequate for irrigation (Figure 20). Once again, such wells are more in the Aba Gerima Control watershed. The differences in numbers of wells in Aba Gerima Control and Learning Watersheds that were reported to be not functioning all year around, and inadequate for irrigation, are statistically significant (at 95% and 90% confidence levels, respectively).

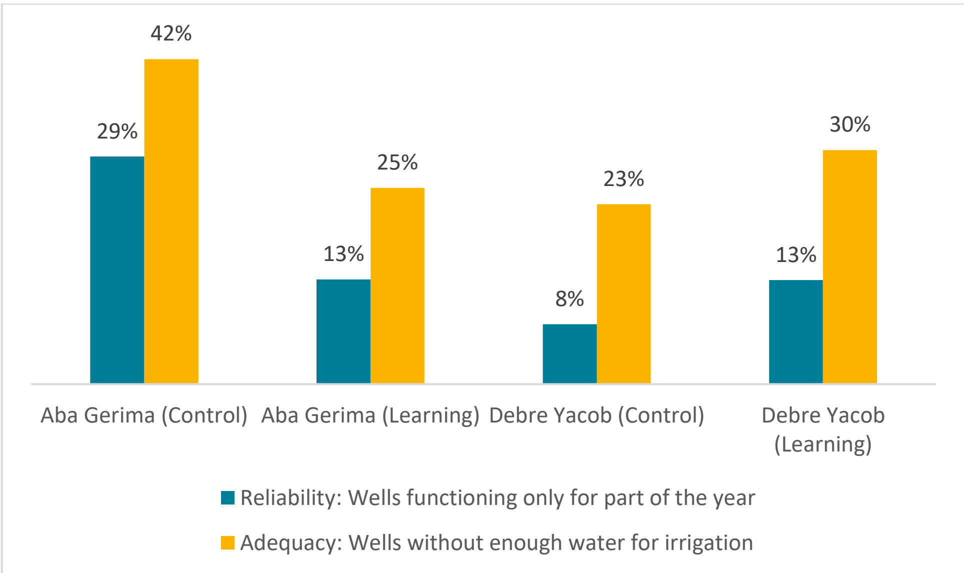

Figure 20: Adequacy of operational wells used for drinking.

Water column less than 1 metre in 25% of wells; and water levels perceived to have fallen in around 15% of wells: The morphology of surveyed family wells is similar, being cylindrical and around one metre in diameter.

The average depth from ground level to water level in the wells is around 13 metres (14.4 metres in Debre Yacob, and 12.5 metres in Aba Gerima). Using the measured depth from the ground-level to the water level in the well, and the owner-reported depth of the well (from construction design), the water column in the well was estimated. Since the survey was conducted during the end of the driest season of the year in the area (May), the highest depth to water level and least water column in the wells are expected.

Although this can be considered a threat only after calculating the number of uses and users (and hence per capita or per hectare availability), the perception of well-owners that water levels have fallen in their well is also an indicator of (perceived) threats to water quantities. A majority of well owners across the Learning and Control watersheds felt that water levels have *risen* due to watershed management work undertaken, while a small but significant proportion of 10-15% of well-owners felt that water levels had fallen in their wells (Figure 21). According to water column measurements, the column in 10-18% of wells was less than 1 metre (Figure 21).

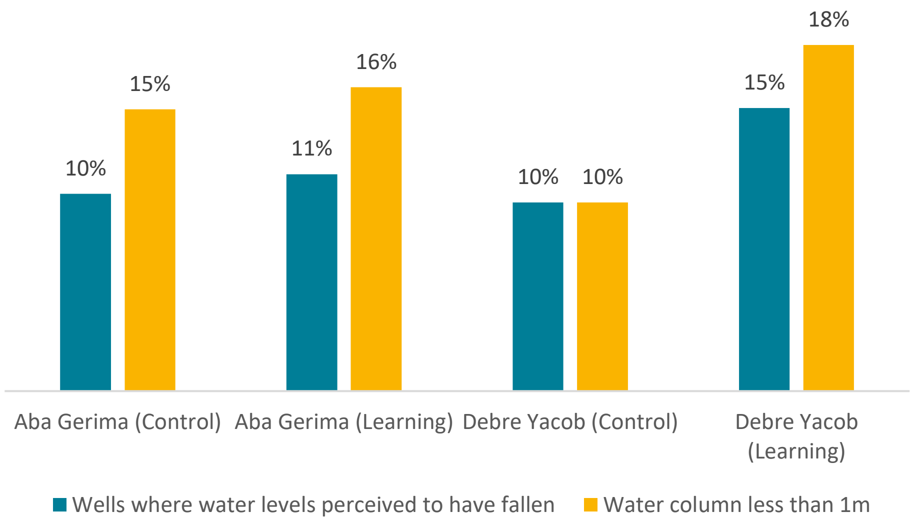

Figure 21: Family wells with perceived water level decreases & water column below 1m.

The situation was slightly worse in drinking water wells: 8-21% of well owners perceived a fall in water levels, while 17-31% of wells had water columns of less than 1 metre (Table 17).

Table 17: Drinking water wells with perceived water levels decreases and <1m water column.

	Operational Wells	Wells where water levels perceived to have fallen	Wells with water column less than 1m
Aba Gerima (Control)	24	21%	25%
Aba Gerima (Learning)	179	10%	21%
Debre Yacob (Control)	13	8%	31%
Debre Yacob (Learning)	30	17%	17%

Around 40% of the family wells are shared with neighbouring families, mostly for drinking: Well owners reported that 99 out of 246 (40%) operational wells used for drinking were shared with neighbours, nearly 80% for drinking, and 40% of these wells are shared with 3 or more families (Table 18).

Table 18: Details of 99 drinking water wells shared with neighbours.

	Shared wells	Shared for drinking	Shared with 3 or more families
Aba Gerima (Control)	6	83%	33%
Aba Gerima (Learning)	74	84%	43%
Debre Yacob (Control)	7	57%	29%
Debre Yacob (Learning)	12	92%	58%
Total/*Average*	**99**	***79%***	***40%***

While sharing of well water is generally benevolent and beneficial, sharing also implies that the contamination of these wells, and reduction in available water quantities, could threaten a larger number of users than just the well-owners and their families.

Most water well-owners used for drinking are satisfied with family well, but around 15-35% are not: More than 50% of the respondents at the 246 operational drinking water wells surveyed in the four Control and Learning watersheds reported being satisfied with their self-supply water facility, but a small minority ranging from 13% to 27% of well survey-respondents are either 'not satisfied' or 'strongly not satisfied' (Figure 22).

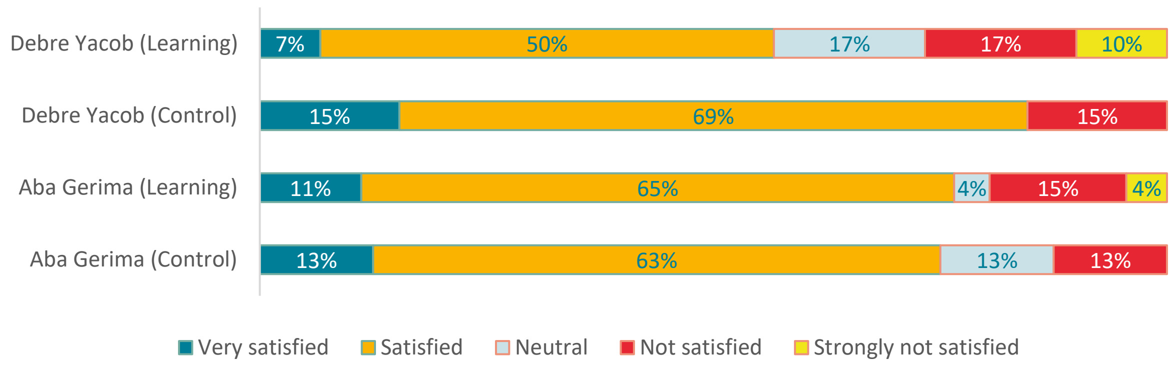

Figure 22: Satisfaction levels of family well owners (wells used for drinking).

When analysed based on the level of poverty, the rich households are the most strongly not satisfied (13%) followed by the middle third of households (3%), fig 23.

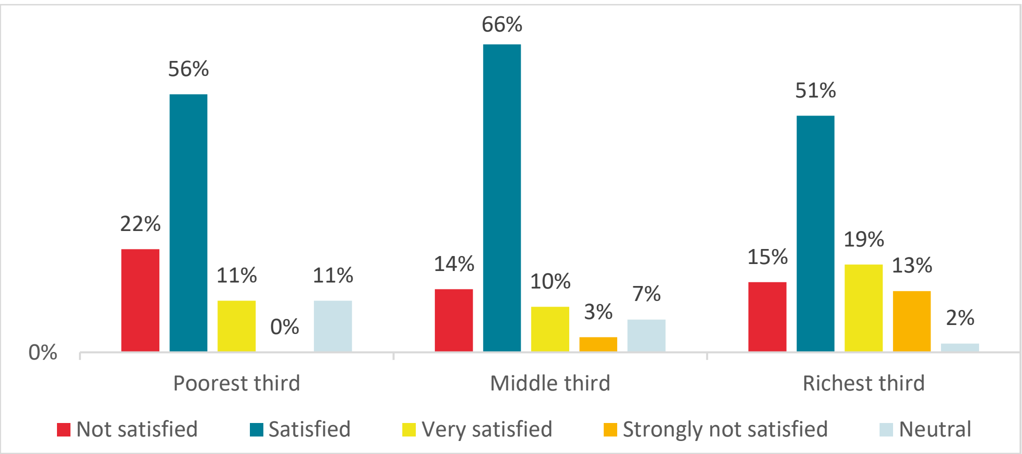

Figure 23: Satisfaction levels of family well owners (used for drinking) based on poverty level.

The level of satisfaction, however, is a subjective term capturing a range of issues – including the fact that most of them have built wells relatively recently, that well-owners consider themselves better off with a well than without one, and that these wells are perceived to be functional and useful for a range of purposes.

3.6 Community wells: Risks and Threats

Although a total of 41 community water sources were visited, 6 were later found to be outside the watershed boundary and were excluded from analysis, while 1 dug well was non-functional and one source was a spring, leaving a total of 33 dug wells and bore wells as functional community water sources (Table 19). All the boreholes are in the Control Watersheds, and the Learning Watersheds depend on dug wells.

Table 19: Community water sources in Aba Gerima and Debre Yacob watersheds

	Community Water Sources Surveyed	Operational Sources			Comments
		Bore Holes	Dug wells	Total	
Aba Gerima Control	9	8	0	8	1 dug well not working (3 years)
Aba Gerima Learning	12	0	12	12	
Debre Yacob Control	7	1	5	6	1 source is a spring
Debre Yacob Learning	7	0	7	7	
Total	**35**	**9**	**24**	**33**	

Threats to water quantities were assessed in terms of the depth of wells, functionality problems reported and consequent reliability (in terms of number of days per year the source was not functional). Water quality risks were assessed by testing the water for coliform bacteria.

Water quantity threats: Dug wells are deeper in Debre Yacob Watersheds: Average and median depths of bore wells and dug wells are more in Debre Yacob Learning and Control Watersheds than in the Aba Gerima Learning Watershed (its Control Watershed does not have an operational dug-well based community water supply) (Table 20). Greater well depths suggest that the water table is lower and so, in response to future water shortages, deepening existing bore wells or constructing new ones in Debre Yacob, may be relatively more expensive.

Table 20: Average and median well depths in Aba Gerima and Debre Yacob Watersheds

	Average depth below ground level (metres)		Median depth below ground level (metres)	
	Bore holes	Dug wells	Bore holes	Dug wells
Aba Gerima control	56		60	
Aba Gerima Learning	0	9	0	8
Debre Yacob control	80	16	80	14
Debre Yacob learning	0	10	0	9

Water quantity threats: Only dug wells reported functionality problems, with hand pumps or the source drying up or both: No problems were reported from the 9 bore wells surveyed in both Control watersheds, but

63% (15 out of 25) dug wells reported problems (including the non-operational dug well in Aba Gerima Control watershed). Most of these had to do with the handpump fixed on the dug well (10 out of 15, including the one well in the Aba Gerima control watershed), while few (3 out of 15) had problems of drying up of the source and still fewer (2 out of 15) reported problems with both hand pump and water shortage (Table 21).

Table21: Problems reported with dug wells

	Hand pump	Drying up	Hand pump + shortage	Total
Aba Gerima control				
Aba Gerima Learning	9	2	2	12
Debre Yacob control	0	0	0	0
Debre Yacob learning	1	1	0	2
Total	**10**	**3**	**2**	**15**
% to total	*67%*	*13%*	*20%*	*100%*

Water quantity threats: Most dug-well related problems disrupted community water supply for more than 90 days: The failed hand dug well in the Aba Gerima control watershed has not been operational for more than three years due to a problem with the hand pump. While this is an extreme case, most dug wells had problems that disrupted supply either for more than 90 days (47%) or for less than 10 days (27%), with the rest having problems of either 10-30 days or 30-90 days (Table 22).

Table 22: Days of disrupted community water supply due to dug well problems

	Less than 10 days	10-30 days	30-90 days	More than 90 days	Total
Aba Gerima control					
Aba Gerima Learning	4	2	2	5	13
Debre Yacob control	0	0	0	0	0
Debre Yacob learning	0	0	0	2	2
Total	**4**	**2**	**2**	**7**	**15**
% to total	*27%*	*13%*	*13%*	*47%*	*100%*

Most cases of disruptions of more than 90 days (6 out of 7 cases) were because of problems with the hand pump, but one case was due to the source drying up, reported from Debre Yacob (where dug wells and bore wells are generally deeper than in the Aba Gerima watersheds).

Water quality: Nearly 40% of the tested wells were found unsafe for consumption: Of the 13 community water sources in the two catchments that were tested for *e-coli* contamination, 5 sources were found to have high levels (>10 MPN) of contamination and therefore unsafe for consumption (Table 23).

Table 23: Community water sources contaminated by faecal coliform

	Bore wells		Dug wells	
	Tested	Found Unsafe	Tested	Found Unsafe
Aba Gerima control	3	0		
Aba Gerima Learning			5	2
Debre Yacob control			1	0
Debre Yacob learning			4	3
Total	**3**	**0**	**10**	**5**
% to total	*100%*	*0%*	*100%*	*50%*

Notably, all these unsafe sources were dug-wells, and mostly in Debre Yacob Learning watershed (3 out of 4).

Chapter 4 Conclusions

The major conclusions from the baseline survey are the following:

- **The poor are late entrants into the well-owning class**: In both the Aba Gerima and Debre Yacob Catchments, most of the poorest-third of households surveyed had constructed their wells after 2010 – over 80% in Aba Gerima and 100% in Debre Yacob.

- **There are significant water quality risks to family dug-wells used for drinking**. More than 90% family wells used for drinking tested had unsafe levels of faecal coliform bacteria. This is most likely due to a combination of poor protection from contamination (parapets, seals, lining, apron, etc.) and the close presence of solid and faecal waste from open defecation and nearby toilets, and stagnant water during rains. The population at risk is larger than the well-owning households given that most of the drinking water wells are shared with neighbouring families

- **There are significant water quality risks to community water sources using dug-wells**. Half of all dug-well-based community water sources that were tested showed unsafe levels of faecal coliform bacteria. Again, there are significant populations dependent on these sources, including some households owning family wells who prefer community sources for their drinking water needs – either because of convenience (i.e., family wells being relatively far away from houses and located in farm land) or perceptions of quality (i.e., water from family wells being used for domestic purposes but not for drinking).

- **Threats to water quantity in family dug wells and community water sources are relatively small currently but could increase in future**. Currently there is hardly any motorized pumping of wells (though there is some pumping of surface water) and water lifting devices used on these family wells are low capacity. But increased demand for water in the future could see (competitive) water drilling and groundwater abstraction for irrigation – which could also affect wells used for drinking.

- **Results of the baseline indicate significant differences between the Control and Learning watersheds.** The differences of key parameters are such that the approach of the Control watersheds in the continued research may need to be reconsidered altogether. The control watersheds were selected from neighbouring watersheds with similar characteristics. The assumption was that the 'Control' would be like the 'Learning' in most characteristics. However, in Aba Gerima Control and Learning Watersheds, statistically significant differences were found between numbers of:

    - Family wells used for drinking where water was not adequate even for irrigation
    - Family wells where water was not adequate even for irrigation
    - Family wells used for drinking that were not functioning all year round,
    - Family wells that were not functioning all year round,
    - Family wells with solid/faecal waste within 5 metres,
    - Households owning more than one well
    - Households with their own latrine or toilet

    In the Control and Learning Watersheds in Debre Yacob, there were statistically significant differences in numbers of:

    - Senior-most women in surveyed households without formal education
    - Family wells with drainage channels

- **For experiments it may be better to re-select 'control' wells from among the same wells surveyed in the learning watersheds but to disguise the subsequent 'treatment'.** The surveyed family wells in the same

Learning Watersheds can be randomly designated as 'Control' and 'Treatment' wells, as in a randomized control trial, and water quality (and quantity) risk and threat reducing treatment provided to only designate 'Treatment' wells. Such treatment could be provided as part of a more general package that also includes certain un-related elements (e.g., hand-washing and personal hygiene), it may better disguise the treatment and reduce potentially-biased reporting of false positives due to project interventions.

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