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Equity of Coverage and Utilization of Water, Sanitation, and Hygiene Infrastructure by Measures of Vulnerability: A study in rural Ethiopia

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Abstract

Equity of Coverage and Utilization of Water, Sanitation, and Hygiene Infrastructure by Measures of Vulnerability: A study in rural Ethiopia

By Jennifer Ann Vettel

Background

The health benefits of access to and behaviors associated with improved water, sanitation and hygiene (WASH) practices are well established [1-3]. The Millennium Development Goal (MDG) target for access to improved drinking water sources was met in 2010, but inequity remained a major concern [5]. The MDG target for access to improved sanitation was not met, and the most vulnerable populations did not experience the same equity to improvements as less vulnerable populations [6].

Methods

We analyzed the relationship between coverage and utilization of water, sanitation and hygiene infrastructure, as part of a countrywide WASH program, and how that relationship was altered by vulnerability factors. Households were assessed for coverage of water, sanitation, and hygiene technologies through key indicators, and those with coverage were further assessed for utilization of the infrastructure. To compare baseline and endline values in a cluster survey with categorical values, we used the population average model, which uses generalized estimating equations with a link identity, family binomial, and correlation exchangeable to determine if there was a significant change from baseline to endline. To find the difference in the change of given indicators between two unique groups, we included an interaction term between time and the group categorization to determine the difference-in-difference.

Results

We found improvements in coverage of our three outcomes of interest: improved water coverage, household latrine coverage, and household handwashing station coverage. The project succeeded at increasing utilization of two of the outcomes of interest: improved water source utilization and household latrine utilization by all family members and safe disposal of feces of children under 5. Vulnerable households differed from non-vulnerable households on two key indicators: household latrine coverage and improved water source utilization. Households in non-difficult and challenging (D&C) *kebeles* reported greater improvements on improved water coverage and utilization when compared to D&C *kebeles*, but D&C *kebeles* reported greater improvements on household handwashing station coverage.

Conclusion

Some vulnerability statuses may contribute to greater increases in coverage and utilization rates, while other vulnerability statuses hinder these increases. Differing vulnerability statuses should be considered when implementing WASH projects in similar contexts.

Equity of Coverage and Utilization of Water, Sanitation, and Hygiene Infrastructure by Measures of Vulnerability: A study in rural Ethiopia

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Introduction

The health benefits of access to and behaviors associated with improved water, sanitation and hygiene (WASH) practices are well established [1-3]. An estimated 801,000 children under the age of five died from diarrheal diseases that are preventable through improved WASH practices [4]. The Millennium Development Goal (MDG) target for access to improved drinking water sources was met in 2010, but inequity remained a major concern [5]. The MDG target for access to improved sanitation was not met, and though improvement was seen, the most vulnerable populations did not experience the same equity to improvements as less vulnerable populations [6]. The Sustainable Development Goals were developed, with thematic clusters including water and sanitation and promoting equality, to address these inequities [7].

Access to improved water and sanitation is associated with reductions in diarrheal disease [1] and research suggests that diarrhea in children under two may be linked to stunted growth, decreased IQ, and future risk of obesity [8, 9]. Combined interventions that include access to infrastructure and provision of education have been shown in multiple studies to be effective in reducing illness-related school absenteeism [10-12], which is a predictive factor of academic success in elementary school students [13]. The provision of infrastructure does not ensure it will be utilized consistently or correctly. There are few published pre-and-post studies that assess both changes in coverage and long term, sustained utilization of WASH infrastructure [2]. Behavioral factors, such as gender of head of household, wealth, perceived benefits, and social norms were found to be influential in utilization of latrines and handwashing facilities [2, 14, 15]. Coverage and

utilization of infrastructure need to both be considered to ensure that infrastructure improvements are reaching and being utilized consistently by their intended audience.

Equity is a key concern for vulnerable groups, such as the elderly, infirm, disabled, and poorest populations, who may not have the resources or ability to access improved water and sanitation facilities or practice proper hygiene. Evidence suggests that there is inequity between wealth quintiles and coverage of improved water and sanitation infrastructure [6]. Socio-economic status may predict adoption of water, sanitation, and hygiene infrastructure [2, 16, 17]. In Ethiopia specifically, there has been equitable progress across the top four wealth quintiles, but the poorest quintile has not seen the same improvements [18]. Associations have been seen between contextual factors, such as level of education, age and gender, and adoption of WASH infrastructure and behaviors [2]. There may be associations between female-headed households and outcomes including absenteeism, diarrhea and malnutrition in children, but evidence is inconclusive [13]. Little research has been conducted on vulnerability statuses other than wealth as they related to equitable coverage and utilization of WASH infrastructure.

The purpose of this study was to examine through a pre-and-post evaluation if there had been increases in coverage and utilization of key WASH infrastructure. Additionally, we examined how vulnerability status, defined as households including female heads, orphans, infirm, disabled, and poorest populations modified the coverage and proper utilization of WASH infrastructure. Finally, we looked at how living in a difficult and challenging location impacted the increases in coverage and utilization of infrastructure.

Methods

Background

We conducted a pre/post-evaluation design in 95 wards, or *kebeles* of Ethiopia. The study was nested within the Millennium Water Alliance Ethiopia program (MWA-EP). Between 2011 and 2014, five members of MWA-EP (Catholic Relief Services, CARE International, World Vision, WaterAid, and Living Water) provided water supply and sanitation services to improve the health status, standard of living, and dignity of poor people in rural Ethiopia [19]. Our evaluation focused on the project's first objective, to increase access to safe water for domestic and personal uses, improved sanitation, hygienic practices thus contributing to full water and sanitation coverage in Ethiopia. The project increased access to safe water for domestic and productive purposes by constructing new boreholes, rehabilitating existing boreholes, expansion of multi-point water schemes, and rehabilitation of multi-point water schemes. The project improved sanitation coverage by promoting household latrines through community-led total sanitation (CLTS) [19]. The goal of CLTS is to eliminate open defecation in a community, and uses facilitators to 'trigger' communities into associating open defecation with ingestion of feces. CLTS aims to shame and disgust people into changing their behaviors [20]. The project improved hygiene coverage by promoting tippy-taps, a low-cost handwashing station [19]. Each partner independently implemented the interventions in their respective *kebeles* in four of the nine regions of Ethiopia, as seen in Appendix I.

Eligibility criteria for inclusion

A household was eligible for this study if they lived in an intervention *kebele* and were on the census list obtained from the *kebele* office or they were missing from the official census list but added to the list prior to household sampling. Eligible household contained at least one person over the age 15 who was at home and willing to participate in the survey. Households that were not on the census list, but were neighboring to a sampled household that either refused to participate or did not have someone over the age of 15 available to participate were also eligible for the study.

Sampling design

Baseline data were collected between October and November of 2011, and endline data were collected between June and July of 2014. Prior to baseline data collection, we calculated the necessary sample size for the household survey using previous data from the study area to predict the expected baseline values and intra-cluster correlation. We powered the study to expected changes in three key indicators: latrine coverage, handwashing station, and use of an improved water source. Based on these assumptions, we collected a simple random sample of approximately 20 households per *kebele*, with the *kebele* as our primary sampling unit, for a sample size of approximately 1,900 households each at baseline and endline. At endline, we used the same *kebeles* as primary sampling units, but new households were randomly selected for inclusion based on the difficulty of conducting the survey in the same households as baseline.

Data collection

At baseline, a randomized two-stage cluster sampling design was used, and a random number generator in excel randomly selected intervention *kebeles* by implementing partner, using proportional stratified sampling by difficult & challenging status, to serve as the clusters, or primary sampling units. We considered a *kebele* as difficult and challenging (D&C) if it met at least one of the following criteria:

- Far from the woreda center (approximately 1 full day travel to access *kebele*)
- Challenging topography & hydrogeology (gravity spring/borehole not feasible)
- Scattered settlement
- Population includes pastoralists

We selected at least 20 *kebeles* from each of the implementing partners, and for partners only operating in 20 or fewer *kebeles*, all *kebeles* were included in the evaluation.

The following outcomes were used to assess equitable coverage and utilization of WASH hygiene infrastructure. Utilization was only measured among those households with coverage since households without coverage would be unable to utilize the infrastructure.

Desired Measure	**Household criteria**	**Indicator of interest**
Water Coverage	Self-reported improved source within 1.5 km as primary source of water year-round	Proportion of households with access to an improved source within 1.5 km of their home year round [21]
Water Utilization	Self-reported collection of over 15 liters of water per person, per day by the household from an improved source within 1.5 km	Proportion of households collecting 15 liters of water per person per day from a protected water source within 1.5 km year-round [21]

Sanitation Coverage	Observation of the presence of any type of household latrine	Proportion of households with any type of latrine in compound [19, 22]
Sanitation Utilization	Self-reported defecation in a latrine by all family members and safe disposal of feces of children under 5	Proportion of households where all members >5 are using latrine. [19, 22] Proportion of children under 60 months whose feces were disposed of safely [22]
Hygiene Coverage	Observation of a fixed place for handwashing at the household	Proportion of households with access to a fixed place for handwashing [19]
Hygiene Utilization	Observations of signs of use around handwashing station (water on ground, soap present)	Proportion of households with access to a fixed place for handwashing utilizing the station on a regular basis [19] Proportion of household with soap and water at hand washing station [22]

The household survey included questions to determine if a family was "vulnerable." In this evaluation, we considered a household as vulnerable if it met at least one of the following criteria:

- Household is in the poorest quintile
- Household is headed by a female alone
- Household consists of at least one member who is disabled,
- Household consists of at least one member who is chronically ill
- Household consists of at least one member who is an orphan

Wealth was determined using a system modeled on the standard methods for wealth assessment in Ethiopia by the World Bank [23]. This principle component analysis (PCA) method determined a single wealth metric from combined assets, including bicycles, radios, or mobile phones.

Program officers from each organization visited the government central office of each *kebele*, randomly sampled households from complete census lists using a random number list provided by us, and recorded the names and location information to contact households for surveys. The surveys were translated into Amharic and Orimifa by a Jimma University partner and MWA-ET staff. At each household, enumerators requested to speak with the female most responsible for the household. If she was not available, another member of the household over the age of 15 could respond. Informed consent was obtained from each participant, followed by the questionnaire and structure observations of latrines and handwashing materials.

Data analysis

The data were cleaned and analyzed using SAS 9.4 (SAS Institute, Cary, NC) and STATA 13 SE (StataCorp, College Station, TX). We included the 95 clusters that were surveyed at both baseline and endline in this analysis. The *kebeles* sampled, by partner, can be seen in Appendix II. The xt functions in STATA 13 SE (StataCorp, College Station, TX) were used to account for panel data and the clustering effects at the village level.

To compare baseline and endline values in a cluster survey with categorical values, we used the population average model, which uses generalized estimating equations (GEE). This model describes changes in a population mean given changes in covariates, while still accounting for the cluster level non-independence of observations. We used this model to find information on how changes in time changed the demographics of an

average household, specifically our vulnerability characteristics. Since all variables of interest were binary, we used a link identity, family binomial, and correlation exchangeable model to determine if there was a difference in demographics from baseline to endline, as described by Ukoumunne et. al. [24]. To find the difference in the change from baseline to endline of given indicators between two unique groups, we used generalized estimating equations with a link identity, family binomial, and correlation exchangeable with an interaction term between time and the group categorization of interest to determine the difference-in-difference (DiD) and *p-value* for the difference in the change of coverage and utilization of water, sanitation, and hygiene infrastructure from baseline to endline the two groups of interest.

We assessed the basic demographic and vulnerability data from baseline to endline using the basic generalized estimating equations model to determine if there were major changes in any of the variables of interest. We assessed coverage and utilization of WASH infrastructure from baseline to endline using the basic generalized estimating equations model to see if there had been an increase in coverage and utilization during the project period.

The difference-in-difference comparison using the interaction term was use to assess if the change coverage and utilization of WASH infrastructure from baseline to endline was equal between vulnerable and non-vulnerable households. Coverage and utilization were further investigated by specific vulnerability statuses (Bottom 20% SES, households with orphans, households headed by a female, household with a disabled person and

household with a chronically ill person). We assessed if households with multiple vulnerability indicators had similar coverage and utilization as households with a single vulnerability indicator. We compared the change in coverage and utilization of WASH infrastructure from baseline to endline between *kebeles* that were considered difficult and challenging (D&C) and those not considered difficult and challenging using the difference in difference methodology.

Results

Demographic data

We collected data from 1,909 households at baseline and 1,892 households at endline in 95 *kebeles*. There was no difference from baseline to endline in the proportion of households with orphans (9.4% at baseline, 8.1% at endline, p=0.13) or headed by a female with no adult male present (12.3%, 11.5% respectively, p=0.40). We saw a difference from baseline to endline in the proportion of households with a disabled person (9.1% at baseline, 6.4% at endline, p=0.002) or with a chronically ill household member (9.8%, 4.9% respectively, p<0.0001). Of all households with at least one vulnerability factor, there was a difference in the proportion of households that were classified as vulnerable (41.3% at baseline, 37.7% at endline, p=0.018). The baseline and endline characteristics of the households are presented in Table 1.

Assessment of improvements in coverage and utilization from baseline to endline

The results of the initial investigation of changes in coverage and utilization of water, sanitation and hygiene technologies are presented in Table 2. Between baseline and endline, we found a change in water coverage of 29.2% (95% CI= 26.5%, 31.9%). The

change in utilization of water was 12.3% (95% CI=7.7%, 16.9%). Between baseline and endline, we found a change in sanitation coverage of 9.6% (95% CI= 7.0%, 12.2%). The change in utilization of sanitation facilities was 14.6% (95% CI=11.2%, 18.1%). Between baseline and endline, we found a change in hygiene coverage of 20.1% (95% CI= 17.1%, 23.0%). The change in utilization of water was 0.5% (95% CI=-9.8%, 10.8%).

Assessment of coverage and utilization by vulnerability status

The results for the initial vulnerability analysis are presented in Table 3. We considered 789 households as vulnerable at baseline and 730 households as vulnerable at endline. Between baseline and endline, we found a change in water coverage of 29.0% in non-vulnerable, compared to a change of 29.8% in vulnerable households (DiD= 0.2%, 95% CI=-5.6%, 5.9%). Changes for sanitation coverage was 5.5% and 14.7%, respectively (DiD=10.1%, 95% CI=4.8%, 15.5%). Changes for hygiene coverage was 20.3% and 17.9%, respectively (DiD=-2.1%, 95% CI=-6.1%, 1.9%). Between baseline and endline among households with water coverage, we found a change in water utilization of 7.0% in non-vulnerable households, compared to a change of 18.6% in vulnerable households (DiD=11.4%, 95% CI=2.2%, 20.7%). Changes for sanitation utilization among those with coverage was 14.2% and 12.9% respectively (DiD=-0.2%, 95% CI=-7.5%, 7.1%). Changes for hygiene utilization among those with coverage was 3.3% and 10.2% respectively (DiD=0.8%, 95% CI=-17.4%, 19.0%).

The results from the secondary analyses of vulnerability can be found in Supplemental Tables 1 and 2. Few analyses revealed significant differences between groups due to low sample size, and they were not investigated further.

Assessment of coverage and utilization by difficult and challenging status

The results for the analysis of the difference between difficult and challenging *kebeles* and non-difficult and challenging *kebeles* are presented in Table 4. We considered 54 *kebeles* as not difficult and challenging (non-D&C), and 54 *kebeles* as difficult and challenging (D&C). Between baseline and endline, we found a change in water coverage of 31.4% in non-D&C *kebeles,* compared to a change of 26.3% in D&C *kebeles* (DiD= -5.1%, 95% CI=-10.7%, 0.4%). Changes for sanitation coverage was 8.0% and 11.8%, respectively (DiD=3.8%, 95% CI=-1.4%, 9.0%). Changes for hygiene coverage was 8.7% and 35.0%, respectively (DiD=26.3%, 95% CI=20.2%, 32.4%). Between baseline and endline among households with water coverage, we found a change in water utilization of 16.5% in non-D&C *kebeles,* compared to a change of 4.2% in D&C *kebeles* (DiD=-12.9%, 95% CI=-22.7%, -3.0%). Changes for sanitation utilization among those with coverage was 13.6% and 15.8% respectively (DiD=2.0%, 95% CI=-4.9%, 8.9%). There was insufficient data to consider the change in hygiene utilization.

Discussion

We analyzed the relationship between coverage and utilization of water, sanitation and hygiene infrastructure, as part of a countrywide WASH program, and how that relationship was altered by vulnerability factors. Households were first assessed for coverage of water, sanitation, and hygiene technologies through key indicators, and those who had coverage of the infrastructure of interest were further assessed for utilization of that technology. We found improvements in coverage of our three outcomes of interest:

improved water source coverage, household latrine coverage, and household handwashing station coverage. The project was successful at increasing utilization of two of the three outcomes of interest: improved water source utilization and household latrine utilization by all family members and safe disposal of feces of children under 5. Vulnerable households differed from non-vulnerable households on two key indicators: household latrine coverage and improved water source utilization. Households in non-difficult and challenging (D&C) *kebeles* reported greater improvements on improved water coverage and utilization when compared to D&C *kebeles*, but D&C *kebeles* reported greater improvements on household handwashing station coverage.

There was an increase in coverage of all three WASH technologies and utilization of two of the three technologies during the program period. The largest increase was in the proportion of households with water coverage, which grew almost 30% to an endline value of 62.6%. One explanation for the large change is that it was a community level indicator that did not rely on the households to implement. There was a small increase in latrine coverage, but the coverage was high at baseline, leaving little room for improvement. Open-defecation rates dropped, with a 14.6% increase in the proportion of households that self-reported all members of the family over 5 always used the latrine and safely disposed of feces of children under five. Community-led total sanitation (CLTS) has been shown in many settings to be effective at encouraging latrine construction, changing behaviors, and lowering open defecation rates [25-27]. Our results support this evidence. The result is promising, as open-defecation is acceptable in Ethiopian culture: as of 2014, Ethiopia had one of the highest number of open defecators

worldwide, with 38.1 million people regularly practicing open defecation [18]. At baseline, the proportion of households with a handwashing station was very small, and there was a large increase in the proportion of households with a handwashing station at endline (20.1%, $p<.0001$). We did not see an increase in the proportion of households utilizing handwashing stations. At both time points, we found utilization rates over 85%, demonstrating that most households with handwashing stations are utilizing the station on a regular basis.

We found no difference in the change of access to an improved water source within 1.5 km of the home based on vulnerability status. Since water points are typically communal, household level vulnerability did not influence a change in coverage. However, utilization of the improved source year round and collecting 15 liters of water per person per day does rely on the specific household. At baseline, non-vulnerable households had a higher proportion utilizing the improved source year round and collecting sufficient water. However, at endline, vulnerable households passed non-vulnerable households, with over 50% of those with access to an improved source within 1.5 km of their home reporting that they collected at least 15 liters per person per day from that source. To our knowledge, this is the first study to assess whether vulnerable households collect more water than non-vulnerable households. Vulnerable households had a greater change in latrine coverage from baseline to endline than non-vulnerable households. Vulnerable households had lower baseline latrine coverage than non-vulnerable households and coverage at endline was approximately equal between the two groups. We did not see a difference between vulnerable and non-vulnerable households in the increase of

utilization of household latrines from baseline to endline. This result demonstrates that CLTS is an effective strategy to be used with both vulnerable and non-vulnerable populations within communities. There was no difference between the increase in handwashing station coverage or utilization between the two groups. This result suggests that vulnerability status does not alter the uptake of handwashing facilities on the household level. These results show that vulnerable households when given access to infrastructure and knowledge on behavior change succeed at equal or higher levels than non-vulnerable households. When implementing the Sustainable Development Goals moving forward, equal provision of access is essential.

Non-difficult and challenging (non-D&C) *kebeles* had a greater increase in water coverage than difficult and challenging (D&C) *kebeles* (31.4% and 26.3% respectively). One explanation is that the criteria for difficult and challenging status in this study included difficult topography where a traditional borehole and gravity fed water system would not work. These *kebeles* were also hard to reach, requiring additional resources to bring in construction materials. D&C *kebeles* also had lower increases in water utilization than non-D&C *kebeles* (4.2% and 16.5% respectively). A possible explanation for this is that difficult topography could make trips to the water point challenging or dangerous. There was no difference in the increase of latrine coverage and utilization for D&C and non-D&C *kebeles*. As with vulnerable households, this indicates that CLTS was effectively implemented in both D&C and non-D&C households. We found that households in D&C *kebeles* had a greater change in handwashing station coverage than those in non-D&C *kebeles* (35% and 8.7% respectively). Additionally, the proportion at

endline with handwashing stations was higher for D&C *kebeles* than for non-D&C *kebeles* (38.7% and 12.2% respectively). One explanation is that since the *kebeles* were difficult for water interventions, the partner organizations instead focused resources in D&C *kebeles* towards hygiene interventions.

Strengths and Limitations

Our study was one of the first to look at the impact of vulnerability statuses on coverage and utilization of water, sanitation and hygiene in a programmatic context. We used appropriate standard indicators that are used by the Government of Ethiopia and follow many of the standards recognized by the UNICEF/WHO Joint Monitoring Program, ensuring that we were following the accepted body of knowledge at this time. Our study used generalized estimating equations, which allowed us to adjust for cluster-level effects. The estimator that we used – the difference in difference estimator – is an unbiased estimator [24].

Our study had several limitations. The variables we used were primarily self-report or observation at a single time point. Self-report is vulnerable to courtesy bias, but we would not expect differences in bias between vulnerable and non-vulnerable households. For observation variables, finding soap or water on the ground around the station does not necessarily indicate that it is always utilized by all family members, particularly at key times. There may be inconsistencies in how the intervention was implemented by each partner. Since partners collected their own data, that may have biased the data. Finally, since we designed this intervention as an adequacy evaluation, there is no control group. It is not possible to attribute the changes in the communities to the intervention alone.

Conclusions and Recommendations

Study findings show that in rural Ethiopia, there has been an increase in coverage of improved water sources, latrines, and handwashing stations, and that increased utilization has been seen for water and latrines. Vulnerable households, as defined as a household in the bottom 20% SES, with an orphan, with a disabled person, or with a chronically ill person, had greater increased in the coverage of latrines and the utilization of an improved water source. Households located in a difficult and challenging *kebele* saw a smaller increase in coverage and utilization of an improved water source when compared to non-difficult and challenging *kebeles*, but had greater increases in the coverage of handwashing stations. We conclude that some vulnerability statuses may contribute to greater increases in coverage and utilization rates, while other vulnerability statuses hinder these increases. Differing vulnerability statuses should be considered when implementing WASH projects in similar contexts.

These findings contribute to proper program planning for an effective intervention. These results can allow NGOs to develop more targeted interventions, where they can optimize their resources to make the greatest impact for the greatest number of people. The results also allow these NGOs to be aware of where there might be inequity in their projects and work to ensure those inequities are eliminated to meet the Sustainable Development goals targets for water and sanitation and equality.

To our knowledge, we are the first study to specifically examine how changes in coverage and utilization of WASH infrastructure different by vulnerability statuses. Future studies on this same subject could include the following:

- A plausibility evaluation that includes a non-randomly selected comparison group that did not receive the intervention of interest.
- A longitudinal study following the same households to determine how coverage changed in specific households over time.
- A qualitative study to understand why some households chose to invest in improved infrastructure while others did not
- A detailed investigation of household level vulnerability factors and *kebele* level difficult or challenging factors to explore what factors are most influential in encouraging or discouraging changes in coverage and utilization.

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Tables and Figures

Table 1: Demographic Characteristics at baseline and endline

Baseline and endline sample vulnerability characteristics of households

Characteristic	**Baseline (n=1909)**	**Endline (n=1892)**	***p-value***
HH with orphan [b]	178 (9.4%)	150 (8.1%)	0.13
HH headed by female [b]	229 (12.3%)	208 (11.5%)	0.40
HH with disabled person [b]	173 (9.1%)	121 (6.4%)	0.002
HH with chronically ill person [b]	185 (9.8%)	93 (4.9%)	<0.0001
All Vulnerable [b c]	789 (41.3%)	713 (37.7%)	0.018

Note: The baseline and endline tabulations were calculated using the xttab function in Stata. The *p*-value for the variable household size was obtained using generalized estimating equations with a link identity, family binomial, and correlation exchangeable..

[a] Reported mean household size and standard deviation

[b] Reported number of household and percent of households.

[c] All vulnerable includes any household meeting at least one of the vulnerability statuses (lowest 20% SES, HH with orphan, HH headed by female, HH with disabled person, HH with chronically ill person)

Table 2: Baseline and Endline Characteristics for Coverage and Utilization

The change in coverage and utilization characteristics of households from baseline to endline

Characteristic	**Baseline - n (%) (n=1909)**	**Endline - n (%) (n=1892)**	**Δ in %**	**95% CI**	***p-value***
Improved water source within 1.5 km as primary source year-round	608 (33.6%)	1176 (62.6%)	29.2%	26.5%, 31.9%	<.0001
Self-reported collection of over 15 liters of water per person per day from improved source within 1.5 km [a]	215 (35.5%)	519 (44.4%)	12.3%	7.7%, 16.9%	<.0001
Presence of a Household Latrine	1275 (67.7%)	1466 (77.5%)	9.6%	7.0%, 12.2%	<.0001
Self-reported defecation in a latrine by all family members and safe disposal of feces of children under 5 [a]	708 (55.9%)	1024 (69.9%)	14.6%	11.2%, 18.1%	<.0001
Presence of a fixed place for handwashing	56 (3.1%)	403 (23.7%)	20.1%	17.1%, 23.0%	<.0001
Signs of use around handwashing station, including water on group and soap present [a]	48 (85.7%)	387 (96.0%)	0.5%	-9.8%, 10.8%	0.93

Note: The baseline and endline tabulations were calculated using the xttab function in Stata. The change in percent from baseline to endline, the CI and the *p-value* were calculated using generalized estimating equations to account for clustering effects with a link identity, family binomial, and correlation exchangeable.

[a] Utilization is among those with coverage

Table 3: Coverage and Utilization by vulnerability status on a cluster level

Characteristic	Non-vulnerable Households			All Vulnerable Households [b]			Difference between groups	
	Baseline (n=1076) n (%)	Endline (n=1162) n (%)	Δ in %	Baseline (n=789) n (%)	Endline (n=730) n (%)	Δ in %	Difference in Difference (95% Confidence Interval)	*p-value*
Improved water source within 1.5 km as primary source year-round	360 (33.9%)	710 (60.7%)	29.0%	248 (33.1%)	466 (56.7%)	29.8%	0.2% (-5.6%, 5.9%)	0.96
Self-reported collection of over 15 liters of water per person per day from improved source within 1.5 km [a]	138 (38.4%)	286 (40.6%)	7.0%	77 (31.2%)	233 (50.2%)	18.6%	11.4% (2.2%, 20.7%)	0.016
Presence of a Household Latrine	783 (70.6%)	922 (78.2%)	5.5%	492 (63.5%)	544 (76.3%)	14.7%	10.1% (4.8%, 15.5%)	<.0001
Self-reported defecation in a latrine by all family members and safe disposal of feces of children under 5 [a]	435 (55.8%)	660 (71.6%)	14.2%	273 (55.9%)	364 (67.0%)	12.9%	-0.2% (-7.5%, 7.1%)	0.96
Presence of a fixed place for handwashing	39 (3.6%)	284 (26.3%)	20.3%	17 (2.3%)	119 (19.2%)	17.9%	-2.1% (-6.1%, 1.9%)	0.31
Signs of use around handwashing station, i.e. water on ground and soap present [a]	34 (87.2%)	273 (96.1%)	3.3%	14 (82.4%)	114 (95.8%)	10.2%	0.8% (-17.4%, 19.0%)	0.93

Note: The change in percent from baseline to endline was calculated using generalized estimating equations with a link identity, family binomial, and correlation exchangeable. The difference in difference and *p-value* were calculated accounting for the interaction term between time and vulnerability status with generalized estimating equations with a link identity, family binomial, and correlation exchangeable

[a] Utilization is among those with coverage

[b] All vulnerable includes any household meeting at least one of the vulnerability statuses (lowest 20% SES, HH with orphan, HH headed by female, HH with disabled person, HH with chronically ill person)

Table 4: Coverage and Utilization by Difficult and Challenging (D&C) status

Characteristic	Non-D&C *kebeles* (n=54)			D&C *kebeles*[b] (n=41)			Difference between groups	
	Baseline (n=1,091) n (%)	Endline (n=1,081) n (%)	Δ in %	Baseline (n=818) n (%)	Endline (n=811) n (%)	Δ in %	Difference in Difference (95% Confidence Interval)	*p-value*
Improved water source within 1.5 km as primary source year-round	403 (38.2%)	746 (69.6%)	31.4%	205 (27.1%)	430 (53.3%)	26.3%	-5.1% (-10.7%0.4%)	0.07
Self-reported collection of over 15 liters of water per person per day from improved source within 1.5 km [a]	138 (34.4%)	362 (48.9%)	16.5%	77 (37.6%)	157 (36.6%)	4.2%	-12.9% (-22.7%, -3.0%)	0.01
Presence of a Household Latrine	709 (66.0%)	804 (74.4%)	8.0%	556 (69.9%)	662 (81.6%)	11.8%	3.8% (-1.4%, 9.0%)	0.15
Self-reported defecation in a latrine by all family members and safe disposal of feces of children under 5 [a]	369 (52.3%)	524 (65.2%)	13.6%	339 (60.3%)	500 (75.6%)	15.8%	2.0% (-4.9%, 8.9%)	0.58
Presence of a fixed place for handwashing	36 (3.5%)	117 (12.2%)	8.7%	20 (2.5%)	286 (38.7%)	35.0%	26.3% (20.2%, 32.4%)	<.0001
Signs of use around handwashing station, including water on group and soap present [a]	28 (77.8%)	106 (90.6%)	-0.7%	20 (100.0%)	281 (98.3%)	--	---	---

Note: The change in percent from baseline to endline was calculated using generalized estimating equations with a link identity, family binomial, and correlation exchangeable. The difference in difference and *p-value* were calculated accounting for the interaction term between time and difficult and challenging status with generalized estimating equations with a link identity, family binomial, and correlation exchangeable.

[a] Utilization is among those with coverage

[b] Difficult and challenging status was determined at baseline if the *kebele* was far from the woreda center (approximately one full day travel to access *kebele*), had challenging topography and hydrogeology (gravity spring and borehole are not feasible), a scatter settlement, or the population included pastoralists. This status was maintained, regardless of what the *kebele* was classified as at endline.

Supplemental Table 1: Coverage and Utilization by vulnerability status

	Bottom 20% SES			
	No Δ in % BL to EL	**Yes Δ in % BL to EL**	**Difference in Difference (95% Confidence Interval)**	***p-value***
Coverage of Water	29.5%	38.6%	6.7% (-0.9%, 14.3%)	0.085
Coverage of Latrines	4.0%	24.9%	21.7% (14.5%, 29.0%)	<.0001
Coverage of Hygiene	10.5%	11.2%	3.2% (-1.4%, 7.9%)	0.17
Utilization of Water*	11.2%	24.8%	10.9% (-1.8%, 23.5%)	0.093
Utilization of Latrines*	10.1%	12.6%	6.2% (-3.8%, 16.1%)	0.23
Utilization Hygiene*	-2.8%	---	---	---

	HH with orphan				HH headed by female			
	No Δ in % BL to EL	**Yes Δ in % BL to EL**	**Difference in Difference (95% Confidence Interval)**	***p-value***	**No Δ in % BL to EL**	**Yes Δ in % BL to EL**	**Difference in Difference (95% Confidence Interval)**	***p-value***
Coverage of Water	29.5%	25.3%	-2.3% (-12.2%, 7.6%)	0.65	29.2%	29.0%	1.2% (-7.4%, 9.9%)	0.78
Coverage of Latrines	10.2%	3.5%	-6.5% (-15.8%, 2.8%)	0.17	8.3%	16.6%	7.8% (-0.9%, 16.4%)	0.079
Coverage of Hygiene	20.1%	13.2%	-5.7% (-12.5%, 1.2%)	0.11	20.0%	16.1%	-1.5% (-7.4%, 4.4%)	0.61
Utilization of Water*	12.3%	17.7%	2.5% (-12.9%, 17.8%)	0.75	10.5%	26.4%	12.7% (-0.7%, 26.1%)	0.063
Utilization of Latrines*	13.9%	20.8%	8.7% (-3.5%, 20.6%)	0.16	14.5%	17.2%	3.4% (-8.5%, 15.4%)	0.58
Utilization Hygiene*	2.6%	4.1%	-12.5% (-36.2%, 11.2%)	0.30	3.5%	---	---	---

	HH with disabled				HH with chronically ill			
	No Δ in % BL to EL	**Yes Δ in % BL to EL**	**Difference in Difference (95% Confidence Interval)**	***p-value***	**No Δ in % BL to EL**	**Yes Δ in % BL to EL**	**Difference in Difference (95% Confidence Interval)**	***p-value***
Coverage of Water	29.0%	28.7%	0.3% (-10.1%, 10.7%)	0.95	29.5%	25.9%	-4.4% (-15.7%, 6.8%)	0.44
Coverage of Latrines	9.7%	7.0%	-1.5% (-11.8%, 8.7%)	0.77	9.5%	6.1%	-1.9% (-12.6%, 8.8%)	0.73
Coverage of Hygiene	19.9%	23.7%	2.8% (-5.1%, 10.6%)	0.49	20.0%	27.9%	3.5% (-5.7%, 12.7%)	0.45
Utilization of Water*	11.8%	16.8%	5.4% (-10.8%, 21.5%)	0.52	11.7%	17.0%	8.6% (-8.4%, 25.5%)	0.32
Utilization of Latrines*	15.6%	6.2%	-9.9% (-23.3%, 3.6%)	0.15	16.1%	0.8%	-16.0% (-29.4%, -2.6%)	0.02
Utilization Hygiene*	2.0%	35.5%	11.6% (-32.7%, 55.8%)	0.61	1.7%	19.3%	7.5% (-27.0%, 41.9%)	0.67

Note: The change in percent from baseline to endline was calculated using generalized estimating equations with a link identity, family binomial, and correlation exchangeable. The difference in difference and *p-value* were calculated accounting for the interaction term between time and difficult and challenging status with generalized estimating equations with a link identity, family binomial, and correlation exchangeable.

[a] Utilization is among those with coverage

Supplemental Table 2: Coverage and Utilization by multiple vulnerability statuses

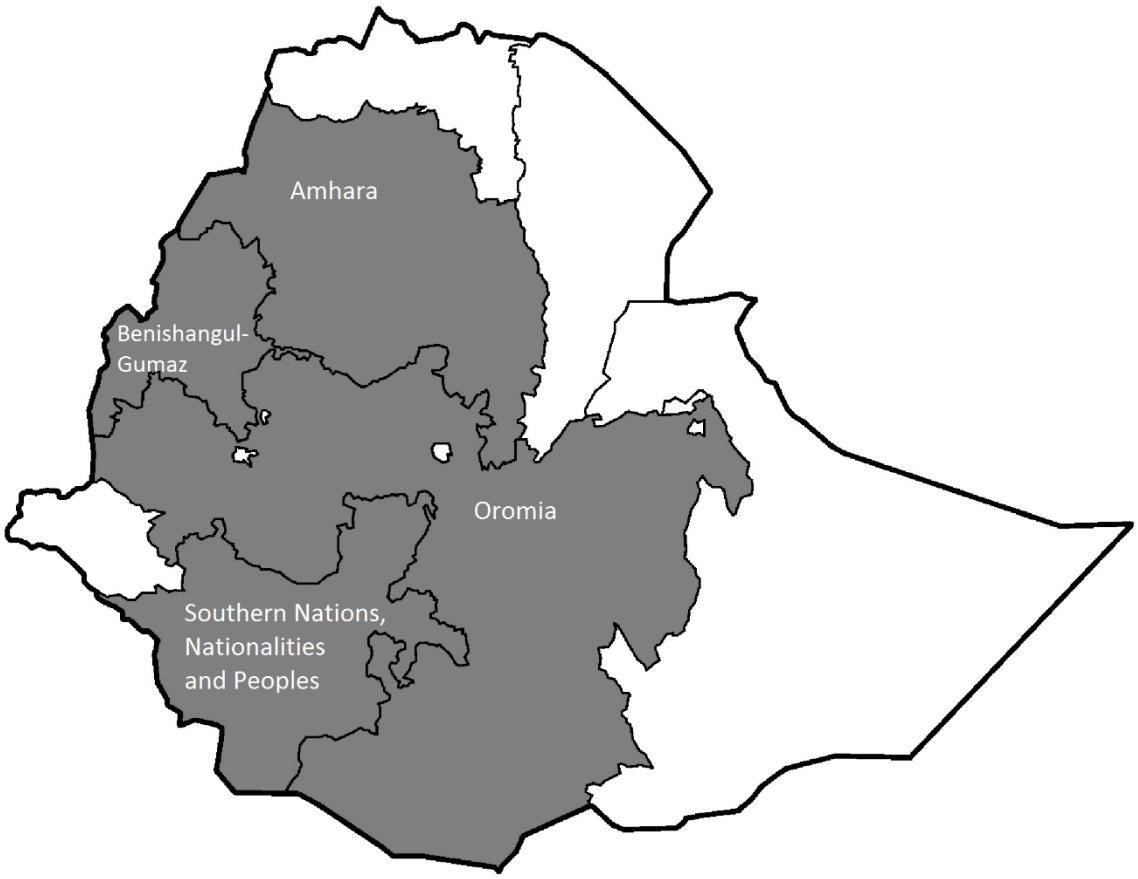
Characteristic	Single Vulnerability HHs			Mult. Vulnerability HHs [b]			Difference between groups	
	Baseline (n=495) n (%)	Endline (n=477) n (%)	Δ in %	Baseline (n=236) n (%)	Endline (n=157) n (%)	Δ in %	Odds Ratio (95% CI)	*p-value*
Coverage of Water	151 (32.3%)	319 (67.3%)	32.5%	72 (31.8%)	109 (69.9%)	35.7%	1.3% (-9.1%, 11.7%)	0.81
Coverage of Latrines	313 (64.1%)	360 (75.5%)	13.5%	139 (60.2%)	113 (72.0%)	12.7%	1.0% (-9.4%, 11.4%)	0.85
Coverage of Hygiene	11 (2.3%)	52 (12.7%)	11.7%	5 (2.2%)	18 (13.1%)	11.1%	-0.3% (-6.6%, 5.9%)	0.92
Utilization of Water [a]	43 (28.5%)	152 (47.8%)	19.0%	27 (38.0%)	68 (62.4%)	24.4%	3.9% (-13.1%, 20.8%)	0.65
Utilization of Latrines [a]	167 (53.9%)	225 (62.7%)	10.6%	85 (61.6%)	80 (70.8%)	9.2%	-2.9% (-16.8%, 10.9%)	0.68
Utilization of Hygiene [a]	10 (90.9%)	49 (94.2%)	2.8%	3 (60.0%)	17 (94.4%)	28.3%	26.4% (-19.6%, 72.4%)	0.26

Note: The change in percent from baseline to endline was calculated using generalized estimating equations with a link identity, family binomial, and correlation exchangeable. The difference in difference was calculated by subtracting the non-vulnerable household change in percent from the vulnerable household change in percent. The odds ratio and *p*-value for the difference between groups were calculated using generalized estimating equations with a link logit, family binomial, and correlation exchangeable, accounting for the interaction between time and vulnerability.

[a] Utilization is among those with coverage

[b] Multiple vulnerability households includes any household meeting at least two of the vulnerability statuses (lowest 20% SES, HH with orphan, HH headed by female, HH with disabled person, HH with chronically ill person

Appendix I: Regions of program implementation



Appendix II: Kebeles sampled at baseline and endline, by partner

CARE		Catholic Relief Services		Living Water International		WaterAid		World Vision	
Woreda	***Kebele***	**Woreda**	***Kebele***	**Woreda**	***Kebele***	**Woreda**	***Kebele***	**Woreda**	***Kebele***
Estie	Angachat	Bora	Berita Sami	Aroresa	*Bubisa	Arbaminch Zuria	*Chano Chalba	Assosa	Abande
	Datgiorgis		Doyo Leman		Elitamo		*Chano Dorga		Abramo
	Desguaagamach		*Ombole		Jengalo Tadota		Dega Chenge		Algela
	*Durgiemashent	Dugda	*Kelo Kabite		Sabo		*Kodo		Amba 11
	*Eletdibana		*Koye Jejeba		*Welemegado		*Wusamo		Amba 8
	Rechaquisquam		*Tepo Cheroke	Doyo Gena	*Begdamo Geteme		*Zeyese Dembele		Ashura
	*Wuchibasenqua	Jelidu	Chilanko		Bekefa		Zeyese Elgo		*Dareselam
Farta	Addeder		*Gindatemem	Gumer	*Abake		Zigiti Perasso		Komoshiga 28
	Askuma		Kolu Gelan		*Arekit Sheleko	Dita	*Andro Giglo		*Tsetse
	*Debelima	Kalu	Ancharo		Injofa		*Goza		Turnet
	*Denquaraenzona		*Bosena	Hadaro Tunto	*1st Tunto		*W/Dayche	Dembia	Atiklt Teleft
	Fartaquisquam		Choressa		2nd Tunto		*Woyza Tuka Gana		Ayimba
	Genamechawocha		*Mekaniti		Ajora	Kamba	*Balta Soke		Chahit
	Kanat	Kelela	Gumero		*Hachacho		*Balta Toylo		Gebeba Chilona Salj
	Mahideremariam		Guyema		Mugunja		*Dombe/Sale		*Gorgora
	Medebgubida		*Martikos	Libon	Adulala Meacha		*G/Hanika		Guramba Bata Chankua
	Sahirna		*Mukech		Adulala Town				Guramba Mikael Jankura
	*Simna		Tirtira		Almecha				Koladiba 1
	*Soras		Tuluya	South Wello	13				*Sankissa
			*Wodegutu		Pasomile Town				Senbet Debir

*=*Kebele* located in a "difficult & challenging" area as of baseline survey