Evaluation of Sustainability and Health Impacts of Community Managed Projects for Sostu Tirba Kebele

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Introduction

Waterborne and water-washed disease place an enormous economic and social burden on rural and poor people. One-third of the world's population is estimated to lack access to basic sanitation and one-sixth to lack access to improved water sources. A larger associated disease burden placed upon low income populations most impacts Sub-Saharan Africa and Southeast Asia (WHO, 2009). Approximately 2 million people will die from preventable, diarrheal illness in 2012 causing four percent of deaths and five percent of health loss due to disability world-wide (WHO and UNICEF, 2000). Quantified in total Disability Adjusted Life Years (DALY), diarrheal disease accounts for up to 6.4% of the total disease burden in Sub-Saharan Africa (Lopez, 2006). In sub-Saharan Africa, many rural areas rely predominantly on subsistence agriculture and already suffer from low rates of investment, low technology, and poor productivity. Thus, one cost-effective and humanitarian strategy to increase productivity is to reduce waterborne disease burden and improve household health outcomes.

Interventions that improve water sources in rural communities aim to reduce waterborne and water-washed morbidity. For women, increased access to an improved water source lessens physically demanding labor associated with water-related household tasks and increases per capita consumption (Cairncross and Feachem, 1993; Demeke, 2009). Another benefit is that women and their families are generally healthier and safer when distance to water is decreased (Wang and Hunter, 2010). Another study in Ghana found that increased access also accrues benefits to women such as increased time savings for other activities which benefit household hygiene and sanitation, and a perception of better family well-being (Arku, 2010).

There is also strong evidence that water quality is a very important factor that can significantly reduce self-reported diarrhea (Kremer and Patterson-Zwane, 2010). However, access to an improved water source does not necessarily imply improved water quality or reduction in waterborne and water-washed disease incidence. While improvement of a water source for rural areas generally constitutes protection of an existing water source or development of a safe source closer to the target community, such interventions do not ensure access to a safe water supply at the household level. A meta-analysis by Wright et al. (2002) for countries in Africa, South Asia, and South America found that contamination increases at the household level is proportionally greater in households for where fecal and total coliform count at the source are low. In addition, Wright et al. (2002) describes that contamination is context specific and varies wildly based upon local practices at the household level. Given this complication, it makes sense that there is controversy in literature regarding whether improvements in the water source necessarily reduces diarrheal disease incidence (Tumwine et al., 2002). Some have advocated that improvement of other sanitation and hygiene practices make a far greater improvement in reduction of morbidity (Esrey et al., 1985; Tidsell, 1993).

Sufficient water quality at the source or even household level does not ensure that a household is spared from other contamination sources that can increase morbidity (Eisenberg et al., 2007). Thus, one important way to increase water safety and decrease incidence of diarrheal is to disinfect the water. There are two strategies that could be applicable in the rural context of sub-Saharan Africa: SODIS (solar disinfection), or dosing with a chemical disinfectant such as chlorine. While there have been many attempts to make POU (point of use treatment), POU can be much more difficult to implement because such activities require behavioral change at the household level in two aspects: (1) better handling and storage techniques for water (Lindskog and Lindskog, 1988; Mintz et al., 1995) and (2) the functionality and behavior use of such POU systems (Elsanousi et al., 2009). An advantage of chlorine dosing at the source is that a correct dose, contact time for disinfection, and a residual can be provided to the households.

Disinfection at the source while an applicable strategy for the vast majority of pathogenic organisms does not completely ensure safety of water source. A ubiquitous parasite that occurs in the environment is *Cryptosporidium* is resistant to chlorine dosing in its cyst form in its lifecycle (USEPA, 2001). *Cryptosporidium* can be transmitted from fecal contamination in both fecal and livestock, thus, the protection of water sources and contamination of household water sources were also measured to confirm the presence or absence of this organism. Contamination of cryptosporidium at a water source may require better protection of the water source in the future, while contamination at the household level, but not at the source may indicate the need to explore control measures at the household level to prevent the contamination of fecal matter in water sources.

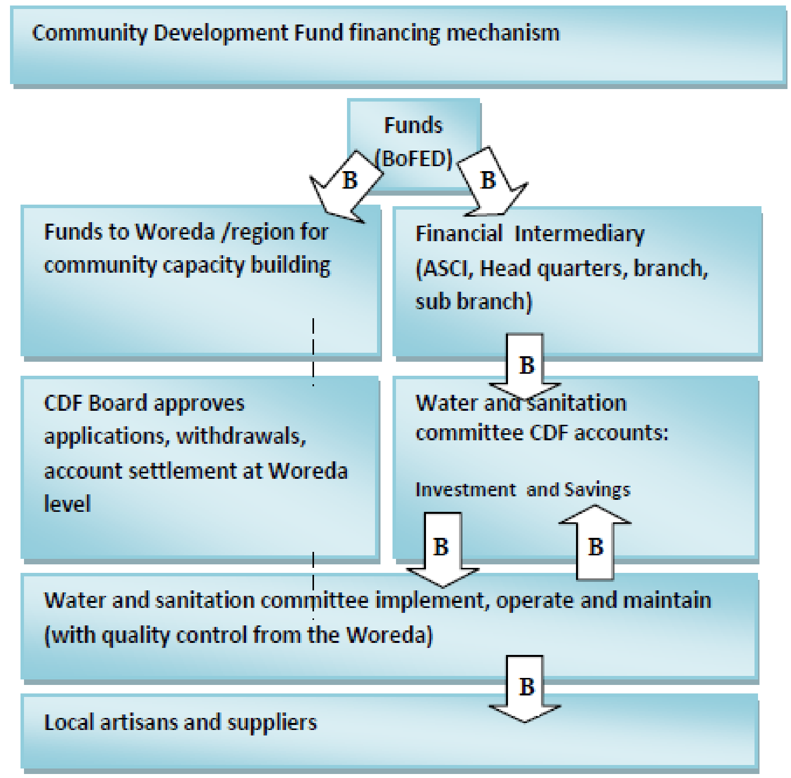

Figure 1. Schematic for funding mechanism and implementation of Community Managed Projects (image taken from WSP, 2010).

Linking Sustainability of Water Scheme to Water Quality

FINNIDA (Finnish International Development Agency), a Finnish NGO, is implementing a CMP (Community Managed Project) approach in the financing, construction, and long term maintenance of improved water points in the Amhara region of Ethiopia. The CMP financial approach is summarized in Figure 1. The sources of funds are from the Finnish government. Funds are transferred to the Amhara National Regional State Bureau of Finance and Economic Development (ANRS,BoFED). The funds are distributed to the *woreda* (administrative district) Office of Finance of Economic Development and. These funds are ultimately utilized by the *woreda* Water Resource Development Office for: (1) capacity building and training exercises, (2) implementation, and (3) running costs (Figure 1) and ACSI (Amhara Credit and Savings Institution) specifically for construction of new water points.

In communities, WATSANCOs (Water and Sanitation Committees) are formed and are responsible for the entire development stage including planning and implementation, and long term operation and maintenance of the water schemes. WATSANCOs apply to the *woreda* Water resource development office for implementation of these low tech schemes that include the construction of a hand dug well (HDW) or protection of a spring water source. The communities are required to finance at least 15% of the implementation costs, and contribute local labor and materials.

The results of using a CMP are reported to increase overall sustainability including feelings of community ownership and long-term operation and maintenance of these schemes. A 2010 study conducted of 70 water schemes in Amhara found that CMP schemes had a higher satisfaction rating in implementation (WSP, 2010). Overall functionality was 94% compared to the Amhara average of 75%, although many CMP schemes were recently implemented within the past 5 years while other schemes have been in service for more than 20 years.

The objectives of this study were threefold: (1) evaluate the impact of CMP versus non-CMP in terms of sustainability of water schemes and health impacts on the community, (2) understand mechanisms of waterborne disease in Tirba to enhance future local interventions, especially for future construction of water points in the area, and (3) recommend future WASH (water, sanitation, and health) interventions that could be effectively coupled with CMP to achieve a greater impact in achieving a positive health outcome.

Materials and Methods

Study Area

The rural *kebele* (administrative zone) of Sostu Tirba located in the center-west portion of the Amhara National Regional State of Ethiopia (22 km^2) encompasses 24 water points and smaller *gotts* (centers of settlement) (Figure 2). This rural kebele was chosen because it was an area where the management of water points could be compared without other confounding factors such as different practices/culture or different construction techniques/design utilized in the implementation of the water point, itself. There were 15 water points that were constructed by the Community Managed Project (CMP) approach and nine water points that were constructed by FINNIDA prior to the CMP approach, but still utilizing the same construction processes and technology. The break-down of CMP compared to non-CMP water schemes is shown in Figure 3. Tirba was also chosen because of the high incidence of diarrheal disease incidence reported by the *woreda* health office. In 2008, Tirba reported 32 AWD (acute watery diarrhea) cases. It is likely that more go unreported given that road access to the nearby town (distance) of Gimjabet is difficult especially in the rainy season, and some *gotts* are located more than 10 km from the nearest hospital.

Mapping was conducted in ArcGIS ArcMap version 9.2. The data input for WASH and related mapping included location of the water source points, water quality data results, and household level information gathered from household interviews.

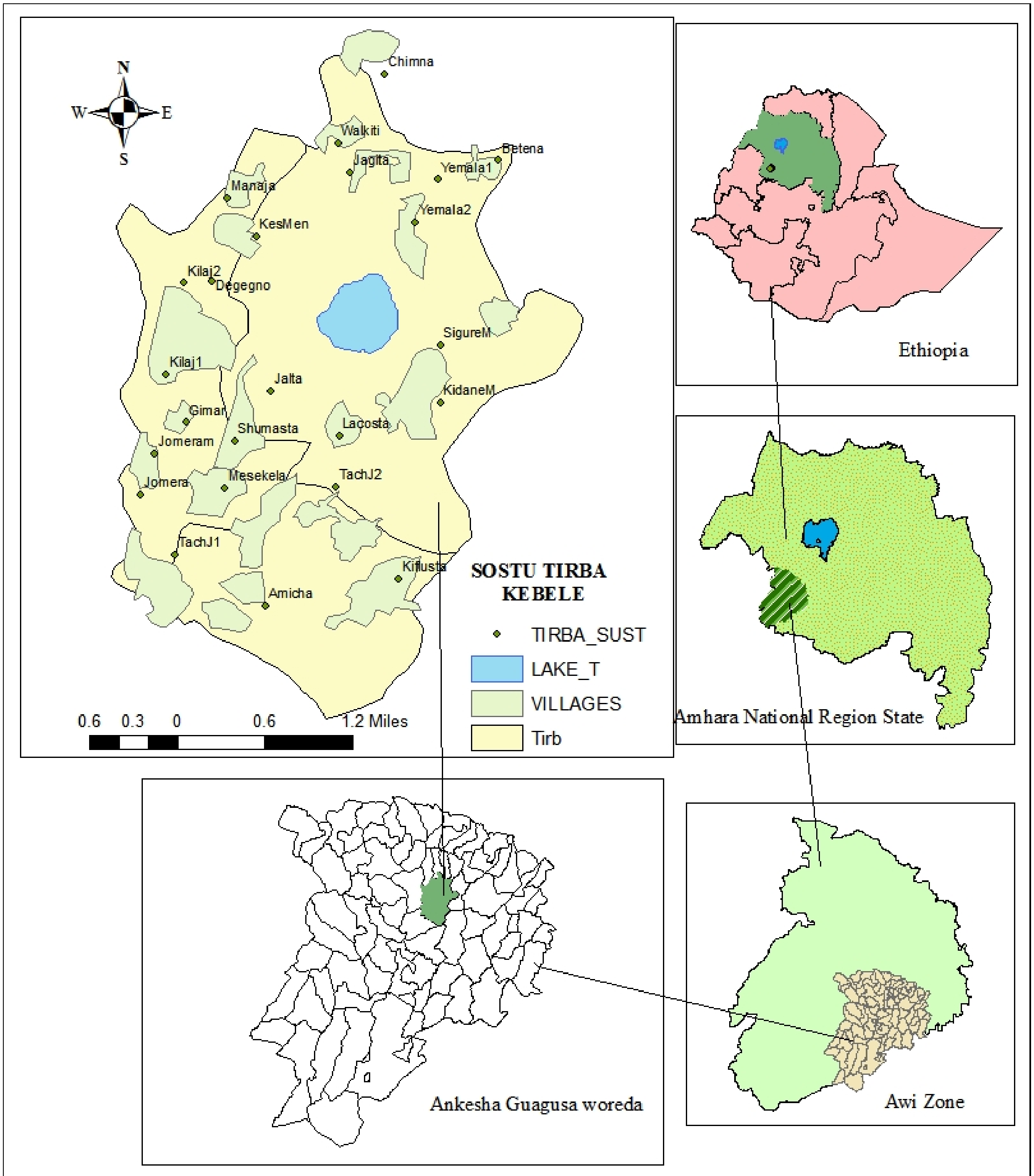

Figure 2. The study area of Tirba *kebele*.

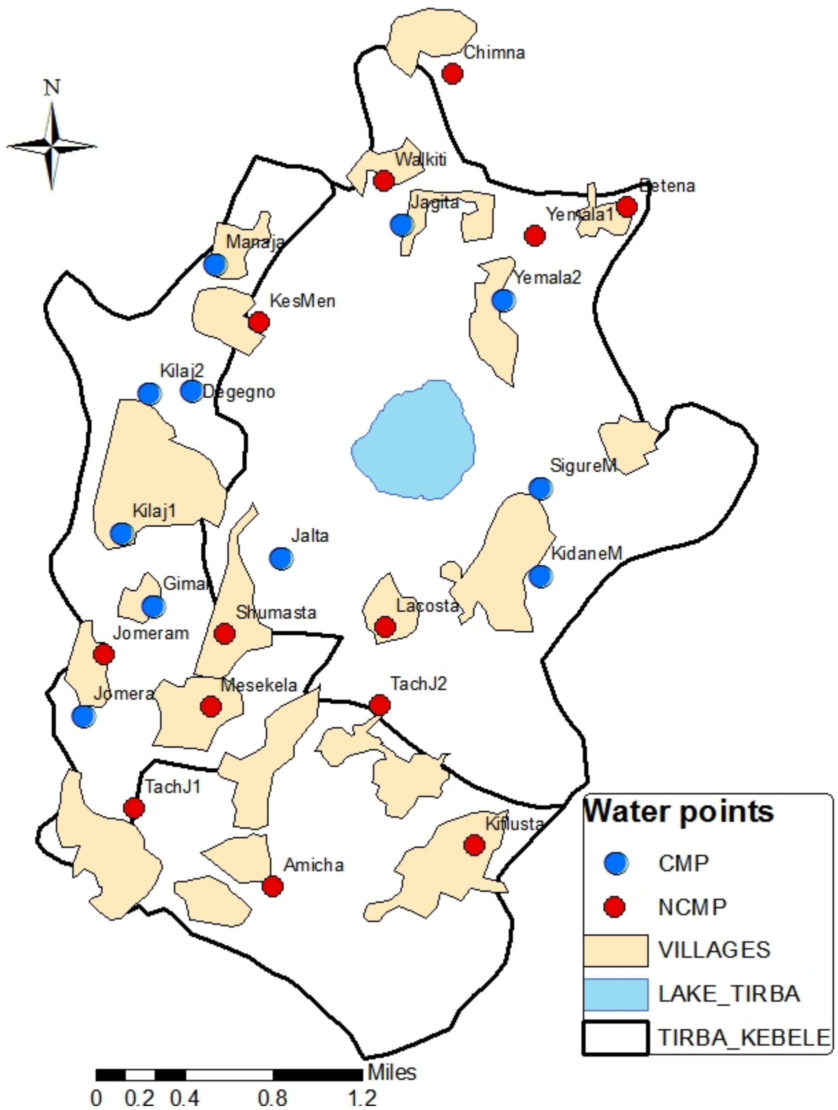

Figure 3. Map of water points studied in Tirba and their scheme designation: non-CMP or CMP.

Interviews with Households, Water Sanitation, and Health Committee, and Pump Attendants

Household interview questions covered seven topics: (1) socio-economic conditions, (2) water supply, (3) transport, handling and storage of water, (4) hand washing behavior, (5) latrine use, (6) other sanitation and hygiene behaviors, and (7) health. Questions for the survey were largely adapted from baseline health and sanitation surveys from (1) Health Environments for Children Survey Instrument (WHO/CEHA, 2008), (2) WHO/UNICEF Joint Monitoring Survey (WHO/UNICEF, 2004), and (3) Demographic and Health Survey (USAID, 2011). Additional questions were added after household observations took place. The interviews occurred in the interviewee's household and took approximately 45 minutes to complete. The households in the survey were chosen by convenience in sampling and household availability. The appropriate sample size (n) of households was found to be 95 based on equation (1) adapted from Alem (2012).

$$n = \frac{z^2 p(1-p)N}{e^2(N-1) + p(1-p)z^2} \quad (1)$$

Where: *N* is the total number of households in Tirba, *p* is the expected proportion of people who are expected to have waterborne disease (since this unknown, a 50% value was chosen as this yields maximum sample size), *e* is the confidence interval (±10%) and *z* is a standard variate from a normal distribution (at the 95% confidence level , z = 1.96).

Interviews were conducted with at least one member from the Water, Sanitation, and Health Committee (WASHCo) and system attendants, where applicable. The interviews for the WASHCo covered four topics with a total of 40 questions: (1) quality and presence of documentation by the WASHCo, (2) financial management by WASHCo including fee collecting structure, (3) management of the system including availability of spare parts and fee structure collection from the community, and (4) water quality and water safety planning procedures and records. Interviews with system attendants covered four topics: (1) training, (2) roles and responsibilities regarding operation and maintenance, (3) functionality of scheme, and (4) areas for improvement. Because the work gauging community and administrator opinion was subjective, opinion variables were assessed on a five point opinion scale (where 5 = strongly agree; excellent, 1 = strongly disagree; poor).

Water Quality Assesment

The two water quality parameters of interest for health outcome included turbidity and fecal coliform count. Turbidity measurements were taken within 24 hours of sample collection in sample vials stored in a cool, dark place. These measurements were taken with a Hach Portable Turbidimeter (2100P) (Hach Company, USA).

Enumeration of presumptive *E. coli* was performed by a membrane filter method using membrane lauryl sulfate broth as described by the British Environmental Agency (BEA, 2009). Samples were filtered and placed in the incubator within 6 hours of sample collection. A 100 mL sample was filtered utilizing a vacuum filter pump on 0.45 µm membrane filter paper. Dilution of the sample by distilled water by a factor of 1:10 and 1:100 was utilized for samples with turbidity above 5 NTU or samples suspected to be highly contaminated with fecal coliforms. The filter paper was placed on an absorbent pad in a petri dish that was saturated with 2 mL of membrane lauryl sulfate broth (producing a red color). The petri dish was labeled and sealed and placed in an incubator set at 44°C (±0.5°C). After 18 hours of incubation, the sample was removed and the colony forming units (CFU) were enumerated using a colony counter. Presumptive E*. coli* CFUs were distinguished under 5-10x magnification unit as those with a yellowish color, indicating presence of anaerobic respiration typical of *E. coli* bacteria.

Detection of Cryptosporidium

The procedure and analysis will be included in updated versions of this report.

Results and Discussion

Sustainability of Water Schemes

Development of Sustainability Indicators

Development of sustainability indicators were formed from interviews with WASHCo committees, discussions with the *woreda* Water Resource and Development Office, the Water, Sanitation, and Health Committee (WASHCo) at the community administrative level, and where applicable, water system attendants. Approximately forty major index variables were categorized which were studied by further survey work at the household level and interviews with WASHCos and system attendants. These index variables were later categorized into three major themes of sustainability: functionality, governance and operation and maintenance, and community opinion.

An emergent focus of sustainability is the ability of schemes to collect fees which are vital for continued system operation and maintenance. The ability to collect fees is largely based upon household willingness to pay: is the scheme providing a service that justifies the cost? The answer to this question is multi-faceted and could be based upon the following topics which are largely based upon attitudes at the household level including: the benefit of the scheme that the household perceives (whether this is a health or labor-saving advantage), the level of functionality of the scheme, and the confidence of the community in the administrators to effectively govern the scheme. These topics can be divided into sub-topics. For example, the level of functionality of the scheme could be considered on the basis of distance from household to the water point which is directly related to labor burden of women. Another is the perception the household has for the quality of water at the scheme which is both related to household health perception and the ability to use this source for different types of water-related consumption including drinking, making local drinks, and sanitation and hygiene.

The ability to collect fees and functionality of the scheme are interrelated and shown in the causal-feedback diagram shown in Figure 4 drawn in Vensim PLE 6.0 software. A central assumption in this diagram is that the level of household satisfaction with their water service will directly impact the ability of the administrators to collect fees and impact the price at which the fee can be charged. The causal-feedback diagram shows several factors that are interrelated to each other by positively self-reinforcing loops and these self-reinforcing feedback loops are summarized in Table 2.

One common link in each feedback loop is the impact of community opinion on functionality of scheme. For example, feedback loop number 3 in Table 2 explores a feedback loop that links community opinion with effective administrative management of the system. An increase or decrease in community opinion would reflect an increase or decrease, respectively, in willingness to pay by community members. Willingness to pay has a positive impact on the fees collected per year and the amount of fees contributed impacts the balance in the bank account. The availability of funds transferred into the bank account opened by the WASHCo has an impact on the ability for the community to purchase spare or replacement parts.

Table 2. Self-Reinforcing feedback loops linked with functionality of the water scheme

Loop	**Description**
Loop 1 (n=3)	The availability of the system operator will be impacted by the community opinion of the scheme. The availability of the system operator will impact functionality (i.e. how many hours the scheme is operated per day) which will impact the community opinion of the scheme.
Functionality of scheme Community opinion *Availability of system operator*	

Loop 2 (n=4) *Functionality of scheme* Community opinion Availability of system operator *Training level of operator*	An operator who is more available will be more likely to undertake training when offered. The training level of the operator will impact how timely infrastructure problems can be resolved. When infrastructure problems are not repaired at the local level, experts have to be called in from the *woreda* level which can take up to one month and significantly reduces system functionality in that time.
Loop 3 (n=6) *Functionality of scheme* Community opinion Willingness to pay Fees collected per year Bank account balance *Availability of spare parts*	The availability of spare and replacement parts will be based upon the funds available to the WASHCo to pay for those spare parts. Fees collected each year will be deposited into the bank account and will determine whether communities can afford spare parts for these systems when needed.
Loop 4 (n=6) *Functionality of scheme* Community opinion Willingness to pay Fees collected per year Bank account balance *Availability of system operator*	The availability of the plant operator could also be incentivized by offering a small salary per month. This salary could be utilized to keep the system open for longer hours or pay for travelling costs associated with trainings made available by the Water Resource Development Office of the *woreda*.
Loop 5 (n=7) *Functionality of scheme* Community opinion Willingness to pay Fees collected per year Bank account balance Availability of system operator *Training level of operator*	The functionality of the scheme will also be based upon the training level of the operator for routine maintenance and to ameliorate more serious problems as they arise. The training level of the operator will be based upon the availability of the plant operator and the frequency and quality of trainings available by the Water Resource Development Office of the *woreda*.

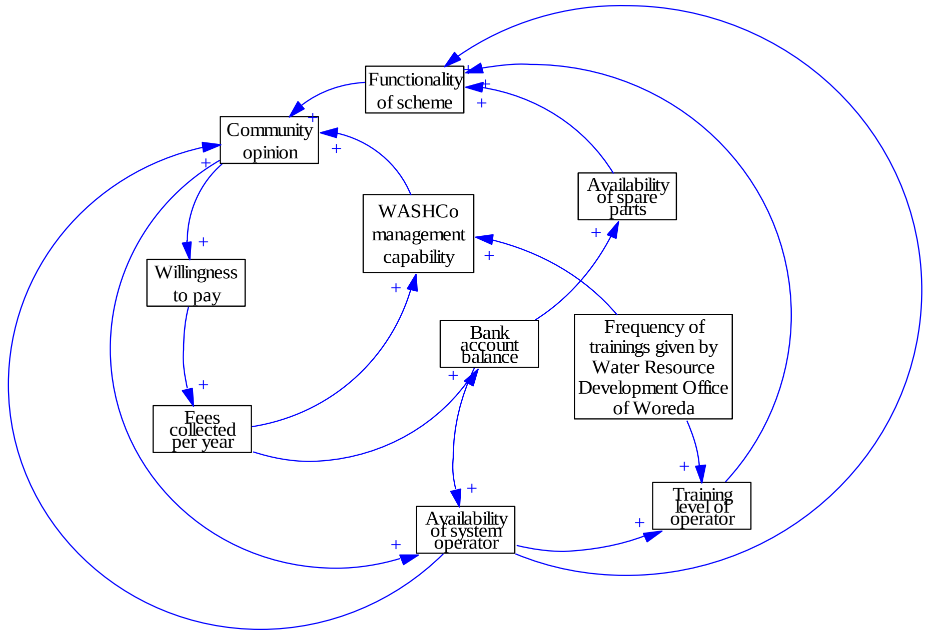

Figure 4. Casual loop diagram linking functionality, community opinion, governance, and operation and maintenance of water schemes studied.

Analysis and Creation of Sustainability Index using Principal Component Analysis

The purpose of utilizing PCA (Principal Component Analysis) was to create a numerical index to rate sustainability based upon the most meaningful parameters in the entirety of the data set with minimum loss of original information (Helena et al., 2000). An index of Water Point Sustainability was developed by a mathematical aggregation of the three components: functionality, governance and operation and maintenance, and community opinion. For these three components, there were 20 indicators represented (Table 4) that had received statistically significant weights when conducting PCA. The water points' sustainability index was a composite ranking of these twenty indicator variables and is shown mapped by community in Figure 4. The sustainability index can be compared with the location of CMP and non-CMP water points (Figure 2). Viewing the data in tabular form (Table 5) indicates that CMP points are associated with significantly higher sustainability index score. The rating scores do not represent the highest sustainability possibility and rather are relative to the performance of the other systems (i.e. 5 = maximum rating, 1 = minimum rating). There were two major reasons that CMP systems received higher sustainability ratings: (1) governance and operation and maintenance and (2) significantly higher community opinion.

One major reason for higher governance and operation and maintenance ratings is reflected in CMP systems having better administration in documenting the collection process for tariffs and in carrying out fee collection. This high governance and operation and maintenance rating is reflected in the requirements of communities that apply for schemes: that they must have a functioning WASHCo that is trained specifically in implementation and daily operating procedures. As part of this requirement, WASHCos must have a constitution and must have a fee collection system in the constitution.

Higher community is the result of the community having greater confidence in the ability of the system attendant to operate and maintain CMP schemes and in the WASHCo to manage the scheme. High community opinion is also related to the community's willingness to pay for the water service and the likelihood that WASHCo will collect future fees. The functionality was also higher and may be in large part due to the higher numbers of system attendants at CMP points compared to non-CMP points. However, more study is required to determine the long-term functionality of CMP managed water points since the CMP water points have only been implemented within the past five years.

Table 4. Component factors and associated scoring factor utilized in the PCA

Component Factors	**Scoring Factor**
Component 1-Governance and Operation and Maintenance	
Public Hearings Held	0.87
Public Audit Held	0.91
Bank Account Present	0.94
Tariff Collection System	0.87
Attendant at Scheme	0.73
Committee	0.86
Implementation Fee Collected	0.71
Spare Parts Available	0.89
Component 2-Community Opinion of Water Scheme and WASHCo	
Household Feels Consulted in the Decision-making Processes	0.84
Household Feels Price is Fair	0.91
Household Feels System is Well-managed Financially	0.87
Household is Confident that System Attendants can Fix Problems as they Arise	0.61
Household is Confident that the Overall Training the WASHCo and System Attendants Received is Adequate	0.59
Household feels that they can Afford all the Water that they want	0.28
Household Members Attended Planning and Public Meetings	0.15
Component 3-Functionality of Scheme	
Average Hours per Day Water is Supplied	0.91
Household Ranking of Water Quality during the Dry Season	0.91
Household Ranking of Water Quality during the Wet Season	0.96
Training for Operation and Maintenance was Available when System was Implemented	0.43
Amount of Birr (re-scaled) Collected Each Year	0.47

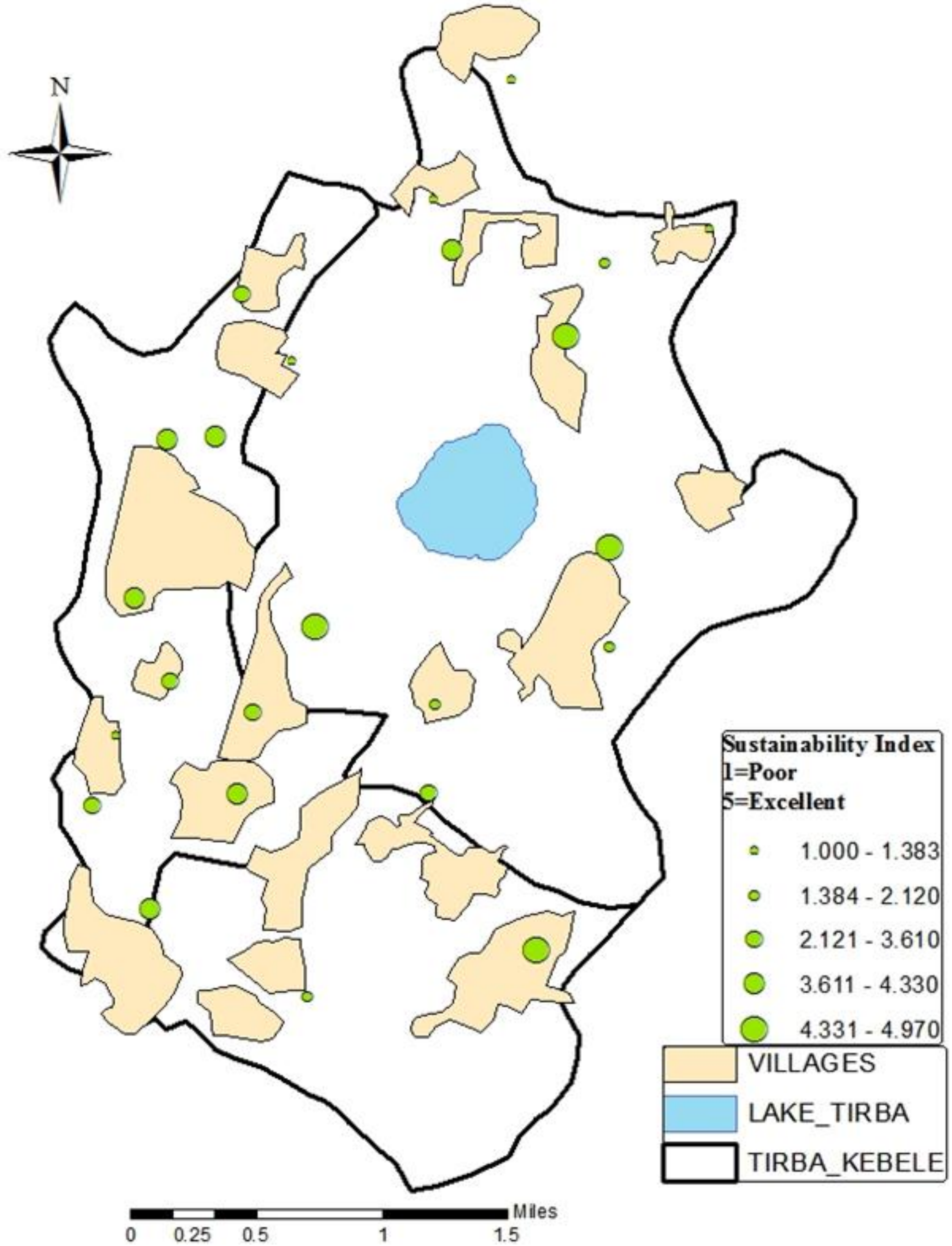

Figure 4. Map of sustainability for each water point in Tirba as measured by the sustainability index developed by PCA.

Table 5. Sustainability rankings for the various water schemes in Tirba

Gott	CMP	Code	Sustainability Index	Governance Index	Public Opinion Index
Yimala – 2	CMP	HDW	4.97	4.99	4.13
Jalta	CMP	Spring	4.49	4.41	4.62
Kiflusta	Non-CMP	HDW	4.47	4.87	4.97
Sigure	CMP	HDW	4.40	4.79	4.54
Jagita	CMP	HDW	4.33	4.82	4.95
Kilaj – 2	CMP	HDW	4.26	5.06	4.75
Meskela	CMP	HDW	4.22	4.82	4.57
Tach Jabela -1	Non-CMP	HDW	4.11	4.82	4.80
Kilaj-1	CMP	HDW	4.00	4.80	4.65
Degegnoch	CMP	HDW	3.97	4.81	4.95
Shumasta	Non-CMP	HDW	3.61	4.41	4.35
Jomera	CMP	HDW	3.61	4.34	4.46
Manja	CMP	HDW	3.54	4.33	4.52
Tach Jabela -2	CMP	HDW	3.53	3.90	4.57
Gimar	CMP	HDW	3.31	4.18	4.33
Yimala – 1	CMP	Spring	2.12	1.00	3.55
Amiche	Non-CMP	HDW	1.94	1.79	4.66
Lakusta	Non-CMP	HDW	1.63	1.49	4.10
Kidammihret	CMP	HDW	1.63	1.53	4.63
Betena	Non-CMP	Spring	1.38	1.00	3.83
Kesmender	Non-CMP	HDW	1.21	1.11	4.48
Chimna	Non-CMP	Spring	1.11	1.16	3.76
Jomera Mikel	Non-CMP	HDW	1.03	1.40	2.82
Walkiti	Non-CMP	Spring	1.00	1.00	1.45

Community Disease Burden and WASH Mapping

A spatial analysis of diarrheal disease incidence revealed that there was little correlation with diarrheal illness and location, although there was a significantly higher incidence of diarrheal illness that was concentrated south of Lake Tirba. When diarrheal illness is overlaid with sustainability (Figure 5), there seems to be very little association between incidence and sustainability or functionality of water source. One important distinction to make between here and other studies (i.e. Wang and Hunter, 2010) that have shown a strong correlation between diarrheal incidence and water point functionality and distance is that in this study, all rural households reported that they traveled 1 km or less to fetch water, thus, by definition of the Ethiopian government all households already have access to improved water sources.

However, there are two concerns with justifying that improved water source necessarily equates with significantly improved health: (1) source water cannot be safe unless well protected and ultimately disinfected by some means, and (2) disease incidence is related to a plethora of other WASH variables such as utilization of a latrine, hand washing, etc.. Utilizing the survey data collected at the household level, a bivariate analysis compared self-reported diarrheal incidence with significant WASH infrastructure and behaviors at the household level. Significant factors (defined as an odds ratio greater than 1.5) are included in Table 6. There were several WASH infrastructure and household behaviors that were not considered significant that have been considered significant in many other studies such as: ‘unsafe’ disposal of children's feces and 'unsafe' method of disposal of wastewater (Tumwine et al., 2002).

Table 6. WASH infrastructure and behavior associated with diarrheal incidence using a Bivariate Analysis

Factor	Odds Ratio	95% Confidence Interval
Open Defecation Currently Practiced	1.94	1.02-3.45
Having Cover Overhead of Latrine	1.78	0.95-3.30
Utilizing Less than 10 L/Person/Capita Water	1.77	1.74-3.56
Animals Have Separate Dwellings from Human Beings	1.53	0.84-2.76

The bivariate analysis was extended to include other variables that were socio-economic as related to diarrheal incidence and these are summarized in Table 7. The strength of several variables were surprising at first glance and these were related to the size and extent of irrigation on a household's plot, owning more than 0.15 ha/capita, and the common and historical practice to this area of open defecation before subsequent intervention that has occurred within the past five years by public health officials.

Table 7. Other factors associated with diarrheal incidence using a Bivariate Analysis

Factor	Odds Ratio	95% Confidence Interval
Irrigation of land	4.16	1.94-12.55
Open defecation before health campaign	4.01	1.88-10.87
Owning more than 0.15 ha/capita	1.81	1.02-3.41

The bivariate relationships that were particular strong were included in a multi-regression analysis. The results confirmed that the following relationships were significant when the multi-regression analysis was run: irrigation, improper living arrangements with animals, and open defecation before health campaign. The results are surprising given that irrigation has the strongest association with diarrheal disease. In the bivariate analysis, there was also a positive association between diarrheal illness and owning land (Table 8).

These results seem to suggest that there is a strong association either between agricultural productivity and/or socio-economic status of the household and diarrheal incidence. One possibility is that farmers who do not irrigate and have low acreage would more likely have low agricultural productivity. It is possible that low agricultural productivity would increase the possibility that these farmers would be food insecure which could have substantial impacts on household nutrition. There is strong evidence in literature that diarrheal incidence is linked with nutritional status of households. When the average number of acres for irrigation (Figure 6) was compared with diarrheal illness, there was indeed a strong association between the two spatially.

Table 8. Results from the Multivariate Regression Model (significant results with a P-value below 0.10 are bolded)

Factor	Coefficient (β)	Standard Error	P-value	Adjusted Odds Ratio
Open Defecation	0.94	1.10	0.39	2.56
Open Defecation Practiced Before Health Campaign	**1.45**	**0.86**	**0.09**	**4.25**
Hand Washing Station Located by Latrine	0.68	0.69	0.33	1.97
‘Proper’ Defecation Practice on Farm	1.05	0.77	0.17	2.85
Animals Have Separate Dwelling from Human Beings	**1.28**	**0.74**	**0.08**	**3.59**
Irrigation Practiced	**-1.30**	**0.54**	**0.02**	**0.27**
Proper Disposal of Solid Waste	-0.31	0.57	0.59	0.74
Constant	-0.77	3.23	1.00	0.46

One likely cause of the difference in reported health is that households with greater productivity on the farm are more likely to be food secure. It is unknown if there is in fact an increase in the amount of food available to these families. Having access to more calories in the diet does not necessarily equate with better dietary diversity or nutrition at the household level. More study is required to understand what impact this could have on nutrition particularly in terms of dietary diversity and its subsequent links with waterborne disease. There is also a seasonal component to food security which is most likely to occur before the harvest in the long dry season when some farmers have no stored food and very little saved money.

Another surprising result of this analysis was the strength in association between diarrheal disease incidence and households that practiced open defecation before a health campaign. The reduction in open defecation is demonstrated in Figure 7A and 7B. Overall, self-reported open defecation was reduced by 90% before and after this intervention. However, the bivariate analysis reveals a much stronger relationship in reduction of diarrheal incidence for those households that did not practice open defecation before the public health campaign.

There is no relationship between household farm size or presence of irrigation and households having constructed latrines before the health campaign. There is also no relationship with other public health relationships or in the quality of the construction of the latrines. One possibility for the correlation is that open defecation is indeed a significant factor for diarrheal disease incidence. Having a latrine is not sufficient to ensure that all household members are utilizing the latrine. Latrine use may require significant training and study of adoption strategies that go far beyond simply constructing latrines. However, more study is required to understand if this explanation a real possibility.

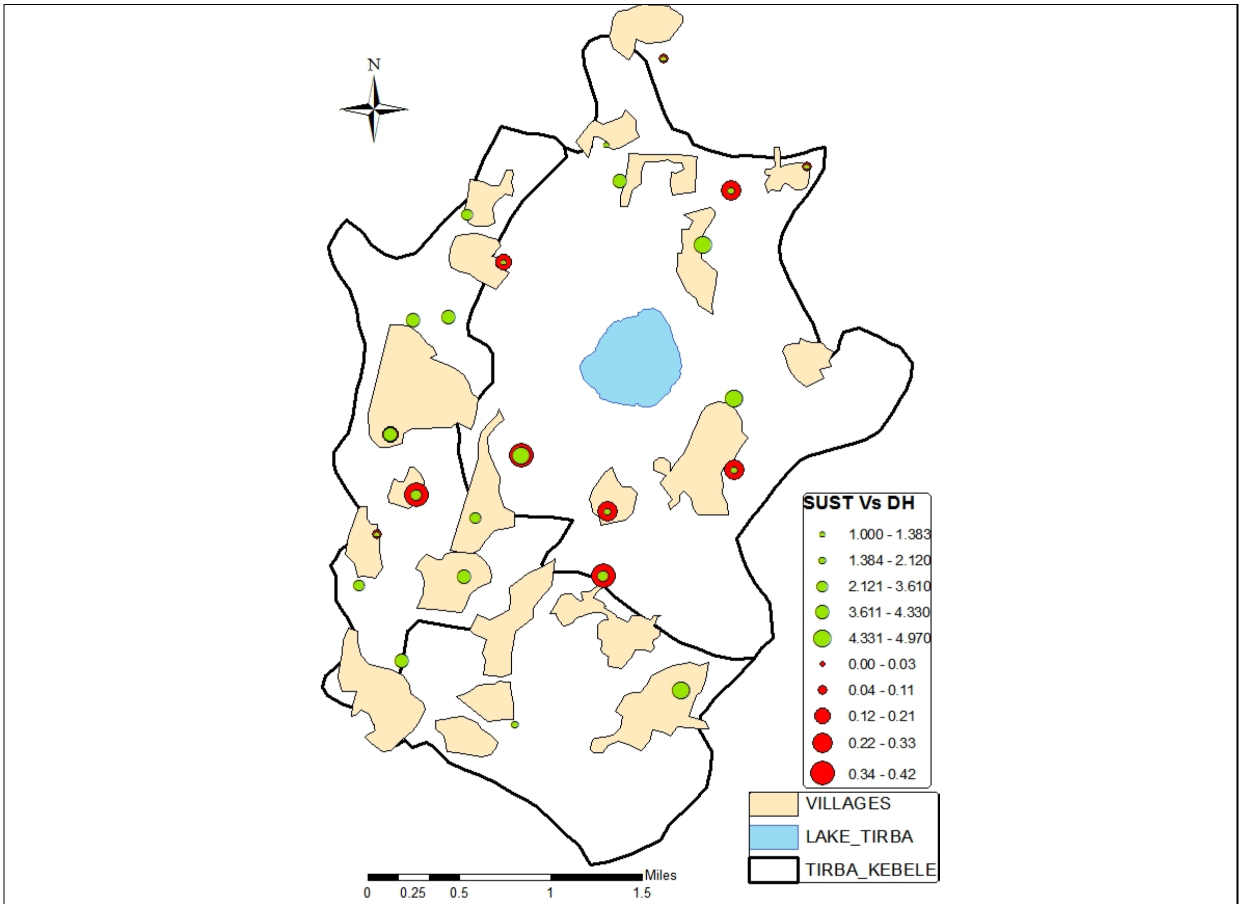

Figure 5. Self-reported diarrheal illness incidence overlaid with sustainability index for each water point in Tirba.

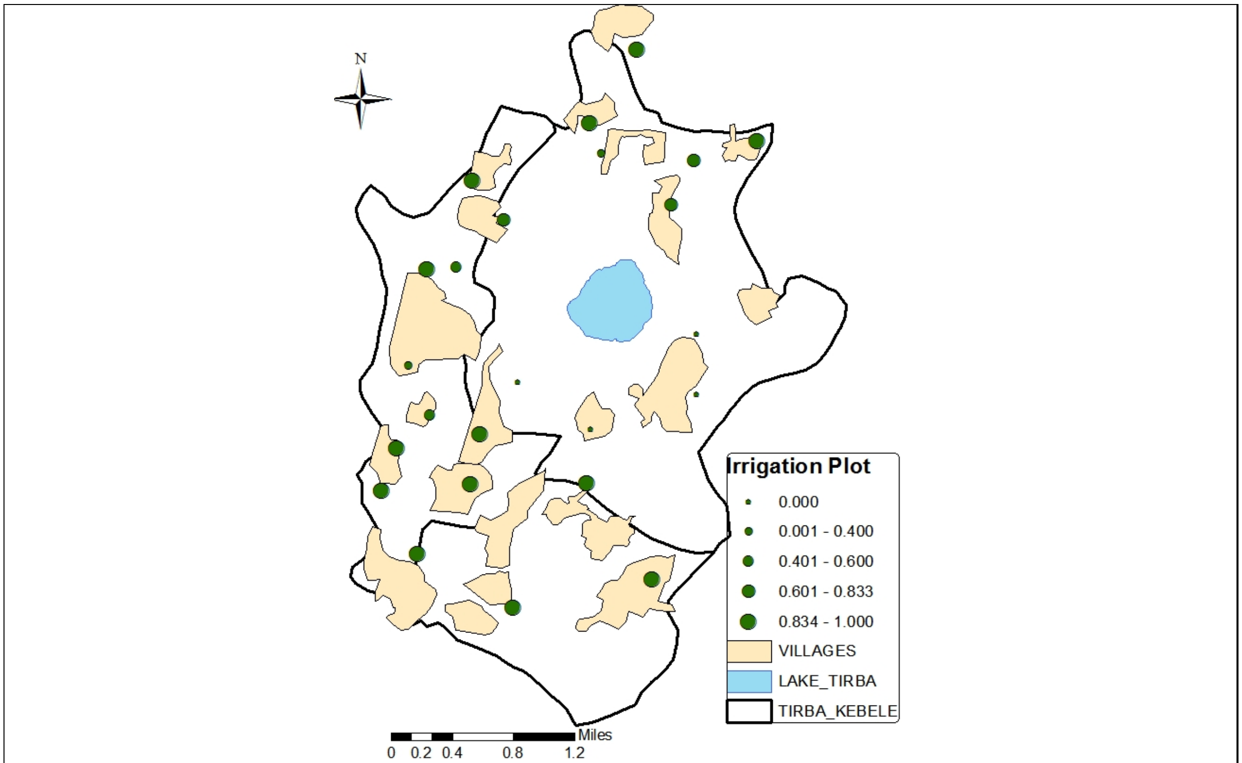

Figure 6. Map of average acres irrigated per household. Higher values of irrigation were presumed to have higher family agricultural productivity.

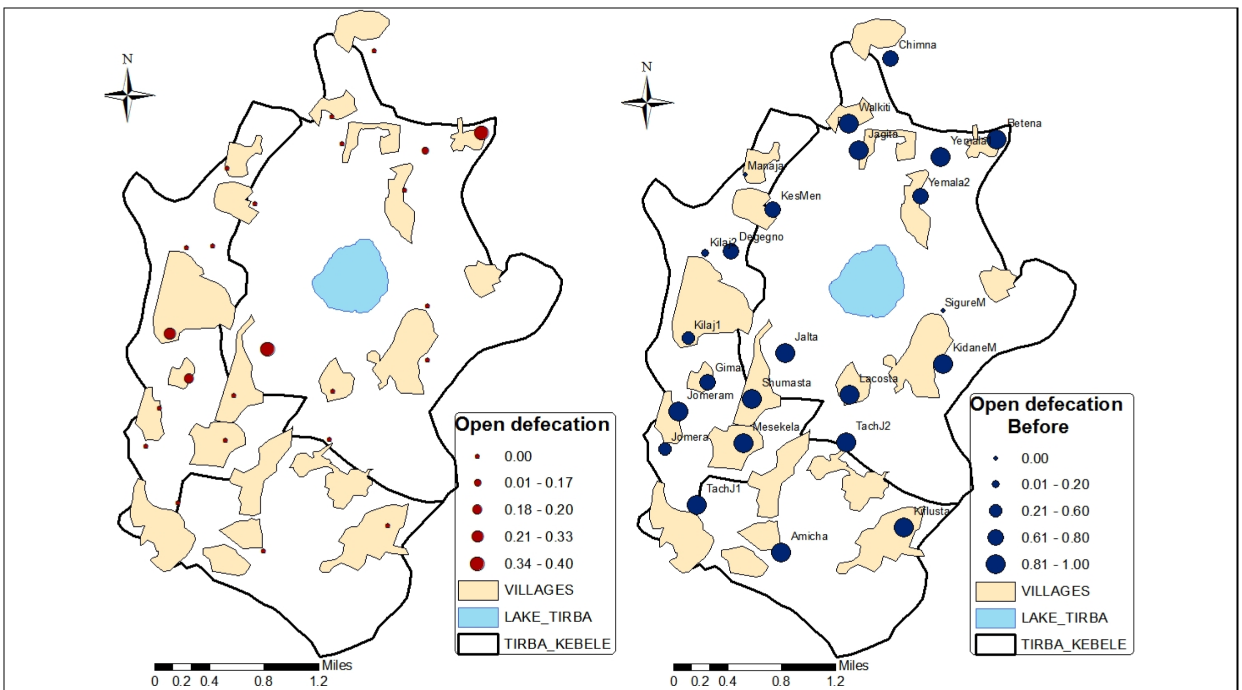

Figure 7 A. Self-reported open defecation after intervention and public health campaign, B. and self-reported open defecation before public health campaign and intervention.

Protection of Water Source

The results obtained from subsequent analysis will be compared to how well water sources were protected and if there were changes in presence/absence of cryptosporidium between house and source. There is evidence that protection of source water does impact the source water quality. It is anticipated that during the long rainy season, the period over which this study was undertaken, that less well protected water sources would have higher turbidity values and higher values of contamination. Higher turbidity values as a result of surface run-off/infiltration into unprotected spring or well sources seems to be a given, however, it is not given that the nature and source of the turbidity is likely to impact the microbial contamination at these sources equivalently. However, the preliminary data obtained does suggest that there was a relationship between turbidity and source water contamination as evidenced by the strong linear relationship between source contamination and turbidity (Figure 8A). There is however no relationship between turbidity and microbial contamination at the household level (Figure 8B).

Sources of Water Contamination at Household Level

Current chlorination dosing is applied with a 20 or 50 gram dose. Such dosing is not effective because there is no contact time built into the system and such a dose is initially too high for water to be usable. After initial dosing and a residence time between hours and days depending on the flow conditions of the system, there will be no chlorine residual left in the system. There had been no chlorine dosing in any of the water sources in two months and therefore, it was very unlikely that there would be any residual chlorine in the water source. Without a residual and without a POU treatment system available it is likely that there will be household water contamination (Jensen et al., 2002). Water contamination at the household level was measured by comparing source contamination to household contamination measured in fecal coliform count. The results shown in Figure 9 suggest that there is no significant difference between source quality and the final contamination at consumption.

The most likely cause of such spikes in contamination resulted in the nature by which transfer and drinking vessels are handled. One likely source of contamination results from hand contact with water during these stages. There were no significant differences in final contamination between clay pot or jerikan transfer vessels, although there is slightly higher contamination found in this study initially for users of clay pot transfer vessels as opposed to jerikan.

Most surprising in Figure 9 is the large increase in contamination between source and first transfer vessel in the household. One possibility for this increase is that users' hands are coming into contact with water in the transfer vessel when they are handling water between the source and transfer vessel. Another study in literature found that the geometric was 177 CFU/100 mL and highly variable for hand rinsing samples (Oswald et al., 2007). The results at the drinking vessel were on the same order of magnitude as the geometric mean in the Oswald et al. (2007) study. Such high CFU concentrations are likely correlated with concentrations in glasses because of the cleaning and handling method of the drinking vessels and steps in between. Figure 8B suggests that there is no correlation between turbidity and contamination in source waters suggesting that contamination by hands or other surfaces causing high fecal contamination may not deposit significant amounts of turbidity and thus, contamination may not be readily observable by household users.

The way transfer vessels are currently handled enable contamination to spread to the transfer vessel. While water transfer vessels are covered with plastic, it is observed that users are regularly washing and touching the plastic covers before placing them in the jerikan or clay pot. In addition, water is filled to the brim in these transfer vessels so that the plastic provides a surface to spread contamination.

There is also an average increase of 35% between transfer vessels and drinking vessel. Such results suggest that the drinking vessel provides a surface for water contamination resulting from poor household handling practices. The most likely practice that causes contamination is that the household often wipes the glass out by hands. Another household practice is leaving standing water in the glass. The quality of water for washing dishes is often recycled and below the quality of the source water, however, there is not a significant amount of water left in the glass to probably significantly increase contamination, so it is unlikely this is a significant way contamination is spread.

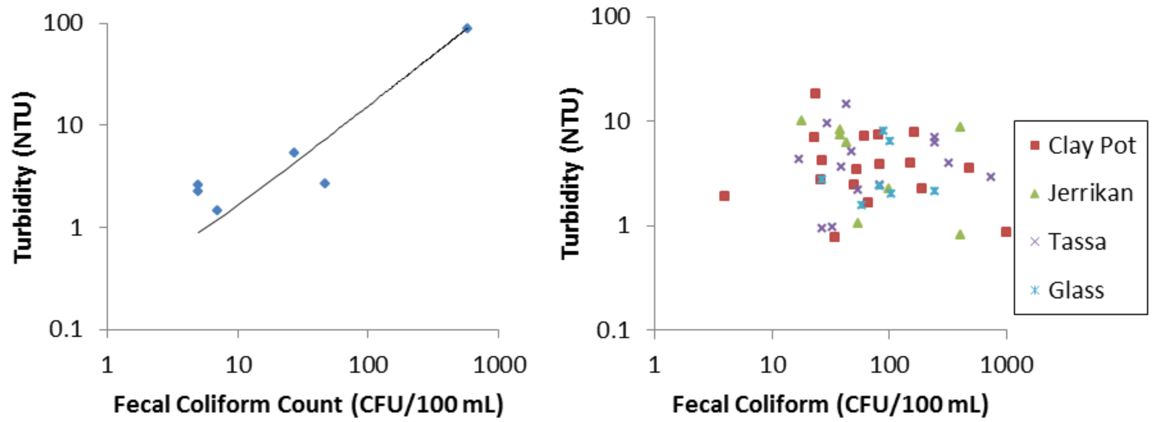

Figure 8. Relationship between source fecal coliform count and turbidity. B. Relationship between fecal coliform count and turbidity in various household transfer, storage, and drinking vessels.

Recommendations by WASHCos and Water System Attendants

There were two important recommendations reported by both the WASHCos and the Water System Attendants. One such recommendation was the need for more trainings to be conducted by the *woreda*. The water system attendants reported that the trainings would enhance their ability to maintain and fix large-scale systematic failures with pumps when spare parts were available. One corollary effect with increased training could be increased community confidence in the ability of system attendants to operate and maintain the water schemes.

Another important recommendation revealed by system attendants was the desire for a more effective chlorination system. Currently, chlorine is dosed in systems once or twice a year either in 20 or 50 gram doses and applied by the Water Resources Development Board of the *woreda*. The problem with such dosing is that the communities will receive a concentration that is far too large in hand dug well systems for a few hours to days and then communities receive no chlorine dosing in the water. A constant dosing system would enable communities to achieve effective residual at all times of year in the water. Chlorine dosing is a strong possibility in these water point systems. The turbidity in most systems was not above 5 NTU during the rainy season. A turbidity of 5 NTU is the maximum turbidity at which chlorine dosing is still reported to be effective by USEPA (2001).

Conclusions

There are three main conclusions to this study: (1) CMP are far more sustainable compared to non-CMP systems, (2) sustainability of water points is not correlated with final source water contamination at the household level, and (3) even protected sources can still have high contamination at the household level resulting from poor hygenic handling and

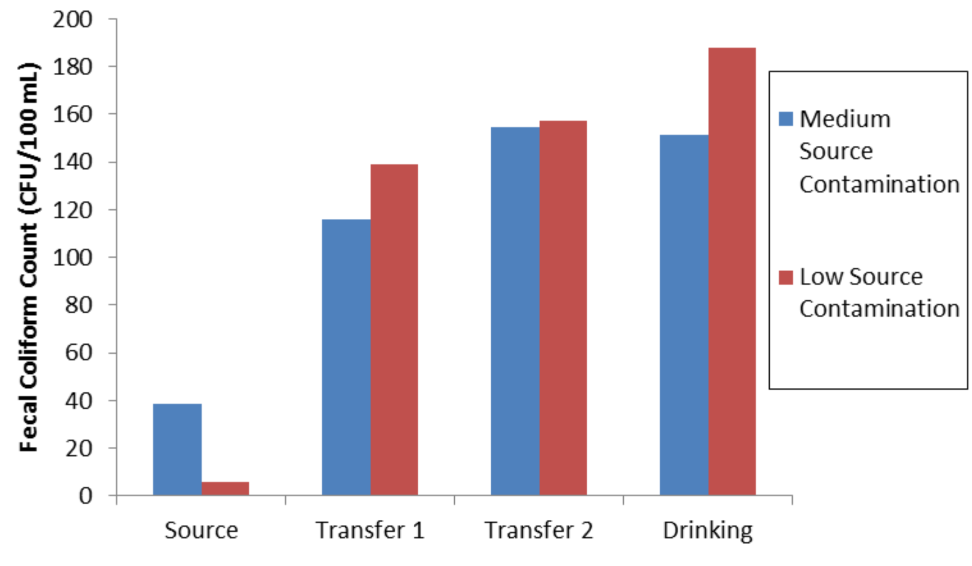

Figure 9. Average fecal contamination measured between source and final consumption at drinking vessel in 18 rural households (n = 61).

storage practices at the household level.

CMP schemes seem to be more sustainable in two important aspects: (1) governance and operation and maintenance and (2) community opinion. CMP schemes are set up utilizing a participatory framework where the community has ownership and therefore investment in the project even in the planning phases. CMP schemes are also better maintained because of the training conducted for both WASHCos and system attendants at the Water Resources Development Board. Community opinion is higher for these schemes because they are better managed and CMP is a transparent and participatory process for members in CMP implemented water points. Functionality was not as strongly associated with CMP, however, there is not a long enough history to compare CMP to non-CMP systems yet to study functionality.

Sustainability of water points is not correlated with final source water contamination at the household. Although it is indisputable that these schemes give much greater and higher quality of water access to women, there is no evidence that the final contamination in the household is affected by initial source water quality (at least for low and medium contamination source waters). In addition to this finding, even protected sources have high contamination at the household level. These two findings together suggest that leaving a residual of chlorine in source water would provide a protective barrier to some of the poor hygienic storage and handling practices of water in the households.

There is a real possibility in the future to test the sustainability of chlorine dosing schemes that could be added on to existing CMP implemented water points here. Future study would also be important in: (1) establishing at what concentration chlorine residual would be effective at the household level given the current handling and storage practices and (2) whether households would be likely to use the water and pay fees associated with chlorine dosing in these systems.

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