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Benefit-Cost Analysis

Economic Costs and Benefits of Three Water and Sanitation Interventions in Rural Haiti

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Haïti Priorise
Un plan de développement alternatif

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Canada

Academic Abstract

This paper has been prepared for the Copenhagen Consensus Haiti Priorise Project. It provides estimates of the economic costs and benefits of three different interventions in the Haitian rural water and sanitation sector: 1) installation of a borehole with a handpump with community management, 2) installation of a borehole with handpump with community management plus a point-of-use water filter (specifically a household-level biosand filter), and 3) a Community-Led Total Sanitation (CLTS) campaign targeting open-defecation. These three interventions were selected based on previous work that documents their relatively low cost, their favorable economic returns, and their applicability in many low-income rural areas in the Global South (Whittington et al. 2009).

We adapted a model that had previously been applied for water and sanitation interventions in other settings, incorporating a different health valuation measure, as well as new data. Specifically, this analysis of three water and sanitation interventions in rural Haiti values health benefits using the concept of the value of an averted Disability Adjusted Life Year (DALY) for both mortality and morbidity. Our previous model of the costs and benefits of water and sanitation interventions used the value of a statistical life (VSL) to estimate the economic value of mortality risk reductions and the cost-of-illness method to measure the economic value of morbidity risk reductions. In conducting the analysis for Haiti, we also updated the model with available data on water and sanitation conditions, baseline diarrheal incidence, and case mortality rates in rural Haiti, as well as other data from recently published research.

We performed a sensitivity analysis on the cost-benefit results by adjusting the discount rate and the assumed economic value of an averted DALY. Our results show that there is a strong economic case for investing in water and sanitation interventions in rural Haiti. We also performed a one-way sensitivity analysis to identify those parameters with the largest impact on the three interventions. The net benefits of the three interventions are sensitive to different parameters. The borehole and handpump with community management intervention is most sensitive to the post-intervention time required to collect 20 liters of water, while the borehole and handpump

with community management plus the biosand filter intervention and the CLTS intervention are most sensitive to the assumed economic value of an averted DALY.

We also conducted Monte Carlo simulations allowing all the model parameters to vary over uniform distributions between assumed low and high values. The results of these simulations show that the CLTS intervention has the tightest distribution of net benefits. Under particular local conditions, any of the three interventions may not deliver positive net benefits, and local decision makers should consider the appropriateness of each intervention carefully, given local realities.

Our results suggest that there is a strong economic case for moving forward aggressively with investments in the water and sanitation sector, even ignoring the moral dimension of the cholera problem. It is nice to know that such actions in the water and sanitation sector would pass a benefit-cost test, but we believe that the citizens of Haiti are morally entitled to remedial actions by the United Nations even if the benefit-cost estimates showed that the interventions were not as attractive economically as, in fact, they are. The Government of Haiti and donors can thus focus on the practical issues of implementing water and sanitation interventions such as those described in this paper, and the challenges of scaling up such efforts. Of course, one would expect to find considerable heterogeneity in local conditions in rural areas of Haiti, and local preferences for sector investment priorities should be considered in investment planning. It will not be the case that increased water and sanitation investments should take priority everywhere in rural Haiti.

Policy Abstract

Overview

Haiti has the lowest coverage rates for improved water and sanitation in the Latin America and Caribbean (LAC) region, on par with some of the lowest coverage countries in the world.[1] Not only does Haiti have the lowest improved water coverage rates in the region, but the rates in each of Haiti's Departments are among the lowest for all administrative units in the region.

Improved water and sanitation coverage in rural Haiti is lower than the coverage in Haiti's urban areas (JMP 2015; EMMUS-V[2] 2012). According to the WHO / UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP), in 2015, only 48% of rural household in Haiti had access to improved water sources, and only 19% had access to improved sanitation facilities.[3]

These low coverage rates translate into significant health burdens. The Global Burden of Disease (GBD) 2015[4] estimates that between 2,000 and 4,500 people in Haiti die from diarrheal disease per year, which is an estimated 2.4% to 4.4% of the GBD estimated annual deaths. Diarrheal disease accounts for a loss of between 160,000 and 370,000 DALYs per year, which is an estimated 4% to 7% of the GDB estimated annual DALYs lost.

In order to address the low coverage rates for improved water and sanitation facilities and heavy burden of disease for people in rural Haiti, this analysis reviews three potential interventions. The interventions are: 1) installation of a borehole with a handpump with community management, 2) installation of a borehole with handpump with community management plus a point-of-use water filter (specifically a household-level biosand filter), and 3) a Community-Led Total Sanitation (CLTS) campaign targeting open-defecation. These interventions are analyzed at the household level and results are provided for household-level impacts.

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[1] JMP (2016).

[2] The EMMUS V is the French acronym for the 2012 DHS survey.

[3] An additional 13% of the rural population uses shared facilities, which the Joint Monitoring Program (JMP) of WHO/UNICEF does not recognize as an improved facility.

[4] IHME 2015

Implementation Considerations

The interventions entail different types of costs. The borehole and handpump with community management intervention includes the capital costs of a borehole (including sinking the borehole) and the ongoing management and maintenance of the system. The borehole and handpump with community management plus the biosand filter intervention includes the above costs with additional capital costs of the biosand filter, cost of time for a community management program to educate households and ensure that they continue to use the filter, and the cost of time for households to be trained on how to use and to clean and maintain the filter. Finally, the costs of the CLTS intervention consist of upfront costs for the construction of a latrine, program costs for running the CLTS intervention, operation and maintenance costs for the latrine, and the time costs for attending trainings and other ongoing CLTS-related activities.

While the two water interventions examined here could potentially include user fees for accessing the borehole and handpump system, this analysis did not include the collection of such user fees. Revenues from user fees are a transfer payment from the water system beneficiaries to the financers of the infrastructure. In addition to this transfer payment, user fees would result in efficiency losses due to reduced household water use.

The Direction Nationale de l'Eau Potable et de l'Assainissement (DINEPA, i.e., the National Directorate for Water Supply and Sanitation), as well as a number of international and local organizations have been working in the water and sanitation sector in Haiti for a long time. Since the 1940s, Haiti has worked with international partners such as the United Nations, the Inter-American Development Bank, the Pan American Health Organization (PAHO), and UNICEF to improve water and sanitation conditions in the country (Gelting et al. 2013). Additionally, an analysis of the water and sanitation sector in Haiti in 2011 found more than 100 NGOs, such as CARE and Plan, are working in the sector. Haiti's *National Plan for the Elimination of Cholera in Haiti, 2013–2022* includes provisions for supporting additional projects to improve water and sanitation services in rural areas. However, these initiatives need additional funding in order to proceed.

There are some risks to the water and sanitation interventions studied here. Despite the recent activity to improve the coordination and institutional structure of the rural water and sanitation sector, data suggest that in rural Haiti there was a slight *decrease* in the access to improved water sources between 1990 and 2015 and a slight increase in access to improved sanitation facilities during the same period. The coverage data do not include information regarding the quality of current water and sanitation services.

Poor sustainability of water and sanitation facilities is another risk. Widmer et al. (2014) found that in two regions in Haiti only 25% of the wells and water points had functioning management strategies. Experience with biosand filters in Haiti has been positive. In one survey of 107 households in the Artibonite Valley more than 90% of households had well-maintained filters between 1 and 5 years after installation (Duke 2006). Experience with CLTS in Haiti has been mixed. An early CLTS intervention by Plan International had only limited success at ending open defecation (Venkataramanan 2015). However, more recently DINEPA has worked with UNICEF and other partner organizations to improve CLTS implementation in Haiti. In late 2016, UNICEF announced encouraging results in a CLTS intervention with a number of communities being declared open-defecation free (Institute of Development Studies 2016).

Rationale for Intervention

All three interventions deliver health benefits by reducing diarrhea morbidity and mortality as well as time savings benefits, either from reducing the time required to collect water or the time required looking for a place to defecate. The borehole and handpump with community management intervention, as well as the borehole and handpump with community management plus the biosand filter intervention, also provide beneficiaries with aesthetic (quality-of-life) benefits associated with increased water use.

The intended beneficiaries of these projects are rural households in Haiti. The *National Plan for the Elimination of Cholera in Haiti, 2013–2022* specifically calls for interventions to improve water and sanitation conditions across the country and especially in remote rural areas with limited access to healthcare facilities. Many international organizations and NGOs have responded by investing in this sector. However, many rural Haitians continue to live without access to these basic services.

This analysis does not include a number of benefits from the proposed water and sanitation interventions studied here. These include improvements in personal safety from ending open defecation (especially for women); and additional health benefits from reducing other non-diarrheal illnesses associated with poor access to water and sanitation services. These benefits are not included because insufficient evidence exists to quantify these benefits and due to time and resource constraints.

Cost Benefit Table

Summary Table

Interventions	Benefit	Cost	BCR	Quality of Evidence
Borehole and Handpump Only	US$4.79	US$2.17	2.2	Strong
Biosand Filter with Borehole and Handpump	US$6.65	US$3.21	2.07	Strong
Community-Led Total Sanitation	US$1.21	US$1.10	1.1	Strong

Notes: All figures assume Mean DALY value of 3 x GDP per Capita and a 5% discount rate.

Benefit and cost values are roundest to the nearest cent.

Contents

Introduction

This paper has been prepared for the Copenhagen Consensus Haiti Priorise Project. It provides estimates of the economic costs and benefits of three different interventions in the Haitian rural water and sanitation sector: 1) installation of a borehole and handpump with community management, 2) installation of a borehole and handpump with community management plus a point-of-use water filter (specifically a household-level biosand filter), and 3) a Community-Led Total Sanitation (CLTS) campaign targeting open-defecation. These three interventions were selected based on previous work that documents their relatively low cost, their favorable economic returns, and their applicability in many low-income rural areas in the Global South (Whittington et al. 2009).

Our approach is to estimate the economic costs and benefits of these interventions for a typical household using global estimates from evaluations of the effectiveness of these particular interventions, as well as publicly-available data on household water and sanitation and health conditions in rural Haiti. The results of our benefit-cost calculations should be viewed as indicative of plausible economic outcomes, not as precise point estimates. In rural Haiti, as elsewhere, there is great heterogeneity in baseline water and sanitation infrastructure, health, and socioeconomic conditions, and in the likely effectiveness of different policy interventions. In some communities and for some households, our estimates of costs and benefits will be too low, in others they will be too high. Moreover, our analysis does not tackle the question of financial feasibility and who should pay for the interventions, which is important given that some households in Haiti are likely unable to afford the costs of these interventions. In this regard, policy makers should consider carefully both upfront investment costs, the costs of sustaining the interventions, and the behavior change required to ensure they will be used. Our benefit-cost analysis includes these various types of costs but does not take a position on who should pay for them.

We largely limit our estimates of the benefits of the interventions to health benefits and time savings. The exception is that we attempt to approximate the aesthetic (quality-of-life) benefits associated with increased water use. There are other important outcomes of water and sanitation interventions that we have not attempted to quantify, such as the improvements in personal safety, especially for women, of ending open defecation. In addition, we restrict the health benefits of the interventions to the reductions they cause in overall diarrhea incidence. This will capture some but probably not all of the health benefits associated with cholera reduction from improved water and sanitation services. It is also important to emphasize that our analysis follows the protocol required by the Copenhagen Consensus Project to quantify the health benefits in monetizing estimates of avoided Disability Adjusted Life Years (DALYs) by multiplying these by different multiples of GDP per capita. This protocol makes an assumption about households' preferences for mortality and morbidity risk reductions that is not based on empirical evidence.

In the next, second section of the paper, we describe baseline water and sanitation coverage in rural Haiti, as well as current health conditions. In the third section, we briefly describe the three interventions. In the fourth section, we present a theoretical framework that motivates our thinking about the economic interpretation of preventive environmental health interventions. In the fifth section, we present the equations we use to calculate the costs and benefits of each of the three interventions. We also present the data and assumed parameters we use in these equations. The fifth section presents the results of the calculations. In the sixth section, we offer our interpretation of the results of these analyses.

Background

Haiti has the lowest coverage rates for improved water and sanitation in the Latin America and Caribbean (LAC) region, on par with some of the lowest coverage countries in the world.[5] Rural coverage is lower than in urban areas (JMP 2015; EMMUS-V[6] 2012). The most comprehensive global statistics are tracked by the WHO / UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP). According to the JMP, in 2015, only 48% of rural Haitian household had access to improved water sources, and only 19% had access to improved sanitation facilities.[7] The

[5] JMP (2016).

[6] The EMMUS V is the French acronym for the 2012 DHS survey.

[7] An additional 13% of the rural population uses shared facilities, which the Joint Monitoring Program (JMP) of WHO/UNICEF does not recognize as an improved facility.

JMP data (Figure 1) illustrate that for rural areas in Haiti there has been a slight *decrease* in the access to improved water sources over the 1990 to 2015 period, as population growth and the destruction of existing infrastructure have combined to outpace expansions in coverage. Unsurprisingly, these low coverage rates also coincide with the highest burden of diarrheal disease in the LAC region (IHME 2015).

These trends in Haiti stand in stark contrast to the improvements witnessed in neighboring Dominican Republic, and in Cuba. In both countries access to improved water sources in rural areas has increased since 1990 (Tables 1 and 2).[8] Cuba and the Dominican Republic are notably richer than Haiti, but the decline in improved water coverage in Haiti also contrasts with several countries that have similar levels of GDP per capita. According to the World Bank, Haiti's GDP per capita in 2015 was US$818, which is most similar to that of four countries in Sub-Saharan Africa: Benin (US$762), Chad (US$776), Tanzania (US$879), and Senegal (US$900). In all four of these countries, access to improved water sources has increased over the past 25 years (Table 3).[9]

In the LAC region, the JMP also provides data that are further disaggregated by administrative regions within countries. Not only does Haiti have the lowest improved water coverage rates in the region, but the rates in each of Haiti's Departments are among the lowest for all administrative units in the region (Figure 2). In addition, the gap in rural coverage between the wealthiest and poorest quintiles is larger in Haiti than in any other country in the region (Figure 3).

The JMP sanitation data show that coverage with improved sanitation in rural Haiti has increased slowly over the past 25 years. Additionally, the percentage of people practicing open defecation has dropped by almost half since 1990. Much of the substitution away from open defecation seems to be towards low-quality unimproved latrines. The percentage of people using such facilities increased by 15 percentage points over the period. Again, these coverage rates and improvements are well below those in the Dominican Republic and Cuba. Both of these countries

[8]In the Dominican Republic access to improved water sources increased by 8 percentage points and in Cuba the increase from 1995, the earliest date with available data, was 14 percentage points.
[9]The lowest increase was in Tanzania, where access to improved water sources from 1990 to 2015 increased by 1%; in Chad the increase was 8%, in Benin 23%, and in Senegal 26%.

started in 1990 with much higher improved sanitation coverage and both have increased coverage faster than Haiti has (Tables 4 and 5).

With regard to rural sanitation coverage, Haiti is similar to or ahead of most of the previously listed African countries as shown in Table 6. Haiti started in 1990 with higher coverage rates than Benin, Chad, and Tanzania, and access in Haiti increased faster than in those three countries. Senegal is the one exception; improved sanitation coverage started ten percentage points higher there in 1990 and also increased faster over this period.

The JMP data show that open defecation rates were higher in rural Haiti than in rural areas in any other country in the LAC region, except Bolivia (Figure 4). The JMP also show that coverage rates with improved sanitation were lower than 40% in every Department in Haiti (Figure 5).

The results of the EMMUS-V survey suggest that the JMP data may be overly optimistic. In terms of access to water, slightly more than half of households in rural areas primarily rely on water from unprotected sources, and that only about 39% use piped water, protected sources, or public taps and standpipes (improved sources) as their main source (Figure 6).[10]

In 2009, in an effort to address this persistent gap in service provision, the Haitian Parliament approved new legislation entitled, "The Framework Law Covering the Organization of the Water Supply and Sanitation Sector," which established the Direction Nationale de l'Eau Potable et de l'Assainissement (DINEPA, i.e., the National Directorate for Water Supply and Sanitation), in the Ministry of Public Works, Transport, and Communications. DINEPA is responsible for implementing Haiti's national water and sanitation policies, improving sector performance, and providing oversight for the sector (Gelting 2013). Among other reforms, the law called for formalizing the

[10] Other authors have discussed the limitations of the JMP data, which conflate access and use, and do not account for water quality and household water storage and handling practices (Shaheed et al. 2014). Household in Haiti do appear to know that poor drinking water quality is a problem, however. A majority of rural households reports treating their water before consumption (EMMUS-V 2012), mostly using chemical disinfection methods. A study evaluating fecal contamination of water sources in Haiti found that "sixteen percent of water points were non-functional at any given time; 37% [overall] had evidence of fecal contamination, and 25% [of] improved water sources had fecal coliforms versus 81% in unimproved sources" (Widmer et al. 2014, p. 790).

local water committees operating public water systems in rural communities with fewer than 10,000 people. Meanwhile, the government was tasked with direct management of systems serving more than 10,000 people (Figaro 2011).

Following a massive earthquake in January 2010 that killed more than 200,000 people, the national government (including this new directorate) was quickly forced to shift its focus to emergency relief and away from investing in long term infrastructure improvements in water, sanitation, and health. DINEPA specifically worked with both international and local partners to provide emergency water and sanitation services to the more than one million internally-displaced persons living in camps near the capital city of Port au Prince. In the initial stages of the emergency response, the United States Centers of Disease Control (CDC) reported that water and sanitation infrastructure in Haiti was inadequate and "would certainly facilitate transmission of cholera (and many other illnesses) …" (CDC 2010).

After the 2010 earthquake, a number of multilateral, bilateral, and non-governmental organizations accelerated investments in water, sanitation, and hygiene-related projects throughout the country. These efforts unfortunately proved insufficient to prevent the outbreak of cholera. By May 2016, nearly 800,000 people were believed to have been infected by the disease, which had also caused an estimated 9,145 deaths (U.N. General Assembly 2016).

DINEPA released a national plan for eliminating cholera from Haiti by 2022 that called for dramatically "accelerating current investments for the construction of water and sanitation infrastructure" (Ministry of Public Health and Population 2013, p. 39). The targets of this plan were to increase access to potable water and sanitation to 85 and 80 percent, respectively. While water supply and sanitation interventions thus appear to be a clear priority for the Haitian government, achieving these targets will require sustained political commitment, significant new expenditures on infrastructure, and improvements in institutions.

Descriptions of the Interventions

Borehole and Handpump with Community Management

In Haiti, as part of the cholera response that tried to move people away from more-easily contaminated open wells and surface water resources, DINEPA and other organizations installed many boreholes with handpumps to provide citizens with access to safer water. International and non-governmental organizations often choose to provide boreholes and handpumps because "large numbers of wells can be dug quickly and cheaply, providing an immediate positive outcome," and because pumps offer "a substantial improvement in terms of [protection from] fecal contamination" (Widmer et al. 2014, p. 794).

The installation process for a borehole with a handpump typically requires that a drilling rig sink a well that reaches the groundwater aquifer. Contractors may need to transport their equipment to remote locations with poor or no access to roads. Sometimes more than one well must be sunk to reach groundwater. Dry holes occur when the well is too shallow or dug in the wrong location. The cost of the well increases with the depth required to reach the groundwater. In Haiti, local well contractors typically suggest sinking wells to a depth of 50–150 feet, depending on the location (Widmer et al. 2014, p. 794). Shallower wells than this are not advised, as these may be prone to contamination from surface sewage outlets or contaminated shallow aquifers (Widmer et al. 2014, p. 794). In the final step, a handpump must be installed that can be used to lift water from the groundwater level to the surface. The system and its components are illustrated in Figure 7.

While the borehole and handpump system is easy to operate, previous work has documented that achieving sustained maintenance can be a challenge. In an inventory of water points in the region of Haiti around Leogane and Gressier, researchers found that "16% of wells/water points were non-functional" and "only 25% had evidence of a management strategy" (Widmer et al. 2014, p. 792). Studies in other countries have documented even higher rates of dysfunction of existing wells (Miguel and Gugerty 2005), and emphasize the need for community ownership, the collection of user fees, supply chain management, and maintenance programs (e.g. Aliprantis 2016).

The upfront financial cost of a borehole and handpump is estimated to be US$6,500 for the component parts and installation; this accounts for the risk that some drilling attempts will be unsuccessful. An associated capacity building program including behavior change education and the establishment of a community management structure – critical for ensuring repairs and community-level management of the infrastructure – costs an additional estimated additional US$3,500. Therefore, the total upfront cost per borehole and handpump is estimated to be US$10,000. Each system is assumed to serve 60 households, and the per household upfront cost is thus estimated to be US$167. Additionally, there is an expected annual cost of US$100 per borehole and handpump for routine maintenance and repairs. The costs of ongoing community management to monitor the functionality and safeguard the infrastructure is estimated to be US$500/system per year. The total costs over the lifetime of the project (estimated at 15 years) on a per month per household basis is thus about US$2.20 (assuming a discount rate of r = 5%). This cost includes a per month cost of almost US$0.90 for the individual components of the borehole and the drilling of the well, US$0.50 for the capacity building program and regular management of the system, and US$0.80 for regular maintenance on the borehole and handpump and replacement parts. These costs are significant for some poor households in rural Haiti. One of the major challenges associated with this intervention therefore relates to financing both installation and sustainability, and to obtaining community buy-in in effectively managing the asset.

Borehole and Handpump with Community Management, plus Household Biosand Filter

Our second intervention is to provide households with access to a borehole and handpump system as well a household point-of-use (POU) technology (specifically a household-level biosand filter). We will provide estimates for the benefits and costs of the complete system (all three: borehole, handpump, and biosand filter). While many different POU technologies exist, we selected the biosand filter because it has been shown to be cost-beneficial in other settings (Whittington et al. 2012), and has also been tested and shown to be effective and accepted by rural households in Haiti (CDC 2012, Duke et al. 2006, Sisson et al. 2013, Thomson et al. 2015, and Lantagne and Clasen 2013). Duke et al. 2006 conducted a convenience (non-random) survey of 107 households in the Artibonite Valley of Haiti and found that more than 90% of households had well-maintained filters between 1 and 5 years after installation. The researchers also found that the biosand filters had a bacterial removal efficiency of 99%. Sisson et al. (2013) found in their study that household filters could continue to function even 12 years after installation.

Biosand filters can be constructed from locally available materials and are relatively easy to install. To construct a biosand filter, one needs a plastic or cement container, which is then filled with layers of sand and gravel (Figure 8). The outlet pipe is adjusted to ensure that the container will maintain water slightly above the sand layer. A "biologically active slime layer (*Schmutzdecke*)" grows on top of the sand and gravel layers and helps remove pathogens from the water (Whittington et al. 2009, p. 561). The sand and gravel layers of the filter decrease turbidity and water contamination via physical filtration.

In order to use the technology, an individual simply pours water into the top of the filter and then collects clean, purified water from the storage container placed at the outlet of the filter. This action is in itself not time consuming, but beneficiaries must often wait for the water to make its way through the filter, especially when the filter is not used regularly. A typical household biosand filter system is able to purify around 30-60 liters per hour (Whittington et al. 2009). A biosand filter not only improves the visual appearance of water by removing suspended solids, but also removes many bacteria, viruses, and parasites.

While household biosand filters provide high-quality drinking water, they have some drawbacks. In order to maintain a sufficient flow, the filters require periodic (semi-annual) cleaning that includes stirring and removal of the top layer of sand. Just after cleaning, the household should not use the filter until the biofilm layer re-establishes itself, which takes a few days. The filter is also large and heavy, making it difficult to move and inconvenient or impossible for households living in tight quarters.

The upfront financial cost of the program to purchase and distribute a biosand filter (this includes behavior change promotion) is estimated to be US$75 per filter with an additional expected cost of US$25 for transporting the filter. This is in addition to the costs of the borehole and handpump intervention and results in a per household upfront financial cost of US$267. The ongoing financial costs arise from the routine maintenance and repairs and community management for the borehole and handpump. Therefore, the total costs over the lifetime of the project (estimated at 8 years for the biosand filter) on a per month per household basis is US$3.20 (assuming a discount rate of r = 5%). This cost includes the per monthly cost resulting from the borehole and handpump intervention and an additional US$0.90 of costs that are specific to the biosand filter. These combined costs are again likely to be significant for some poor rural households in Haiti.

Community-Led Total Sanitation (CLTS)

CLTS is a behavior change strategy for ending open defecation. The approach attempts to raise awareness among community members of the risks associated with open defecation. The aim is to increase villagers' perceived need to end open defecation and to ensure that every household and individual uses a latrine, thereby achieving "total sanitation." Dr. Kamal Kar developed CLTS in Bangladesh in 2000, and it has subsequently been used in more than 60 countries.

The community-level intervention starts with a "triggering" event, during which the community gathers together and participates in a set of activities that attempt to create a desire for change in sanitation practices, i.e., to achieve an end to open defecation. The CLTS facilitator asks community members to create a map of their village, detailing where people live and where they engage in open defecation. Then the group may take a transect walk through the community to identify the location of human feces. The facilitator leads a discussion on the fecal-oral transmission routes and explains that even if people cannot see disease-causing organisms, their water or food supply may still be contaminated. The community then discusses the costs to the household of its members getting sick with diarrhea, the requirements and costs of building safe sanitation facilities, and the importance of ensuring universal use of such facilities.

Once a community is successfully triggered, it develops a strategy for ensuring that every household may gain access to improved sanitation. A community is sometimes offered guidance on alternative infrastructure solutions. Some donors and governments may offer financial incentives to construct latrines (Gertler et al. 2015 and Kolsky et al. 2010). Communities are encouraged to innovate and use local materials to ensure that an acceptable technology is available to all households, and that solutions should be "odor- and insect-free, and [that] feces must not be visible" (Whittington et al. 2009, p. 549).

Although CLTS is now used in many countries, there is mixed evidence on its effectiveness at reducing open defecation (Gertler et al. 2015, Pickering et al. 2015, Pattanayak et al. 2009, Guiteras et al. 2015, and Hammer and Spears 2016). While a few studies have found that CLTS interventions "appear to have resulted in 100% open-defecation-free villages," in most cases the uptake of latrines has been much lower (Whittington et al. 2009, p. 550). While some interventions adhere to the pure version of CLTS as envisioned by its founder Kamal Kar, others have experimented with including subsidies to incentivize latrine coverage. In Mali, Pickering et al. 2015, did not provide subsidies, but included follow-up visits every 2-4 weeks for triggered communities, and found that access to private latrines almost doubled in the treated villages. Hammer and Spears (2016) found that a sanitation strategy which paired subsidies with a CLTS-like behavioral change intervention increased latrine coverage from 15% in control villages to 23% in treatment villages, an eight percentage points increase. This effect was statistically significant.

In Haiti, a variety of international organizations are supporting CLTS programs, including Plan International, UNICEF, Oxfam, the French Red Cross, Goal, CARE, World Vision, Catholic Relief Services and Partners in Health (Venkataramanan 2015). The upfront financial cost per household for constructing a pit latrine in Haiti is estimated to be US$20.[11] This upfront capital cost is accompanied by a monthly US$0.30 program cost per household to cover the expenses of delivering the behavioral intervention as well as any additional follow-up designed to induce sustained use of latrines. The last component of the total financial costs of the latrine is the operation and maintenance costs, which is estimated to be US$0.42 per household per month. This O&M cost includes purchasing items such as soap, a pail, or other necessary items to clean or repair a latrine. With total monthly costs of $1.10 per household per month, this basic sanitation intervention is considerably cheaper than the water supply interventions described above.

[11] The average cost of rural latrine options in Haiti (Hutton and Varughese 2016).

Theoretical Framework

We present a simple model of household decision making regarding health prevention adapted to the special case of environmental health and water and sanitation behavior to provide insight into the various components of the economic costs and benefits of the three WASH interventions (Pattanayak and Pfaff 2009; Whittington and Pattanayak 2015). This model helps to organize thinking about how households value investments and behavioral changes in water and sanitation, and also provides the rationale for government interventions to spur private uptake of preventive technologies and behaviors.

In this conceptual model, the demand for improved water and sanitation is one of many potential utility-improving investments that a household can make. We follow Whittington and Pattanayak (2015), and focus on a general category of water and sanitation investments.[12] A household produces health and other outcomes that affect well-being by combining scarce inputs of labor, money, capital, and other factor inputs. Specifically, a household must make tradeoffs between consumption (Z), leisure (T_1), and production of health (S). These tradeoffs are conditioned on a household's preferences (θ), which represents a household's individual expression of risk aversion, discount rates, or altruism, etc.

A household maximizes utility subject to a health production function constraint and a household budget constraint. The health production function depends on environmental quality (Q),[13] which is a function of public policies (G) and other households' averting behaviors (A), and the extent of a household's own averting or coping activities a, which require investment of time, money, or knowledge. For example, if poor sanitation is widespread in a community, environmental quality may become degraded, and the health effects of this can be offset in part by a household engaging in household point-of-use water treatment or private latrine construction, which are a form of a.

[12] In other words, we do not consider household choices between different types of water and sanitation interventions.
[13] In our case, the environmental quality of interest is the quality of local water and sanitation conditions.

Such averting behavior requires household allocation of time (T_2) and material inputs (M) at a per unit cost (p), and may also require knowledge (K) with a search cost per unit (r).[14]

Households also face budget and time constraints. Expenditures on consumption and health production inputs cannot exceed total household income (E), which is in turn affected by the allocation of time to income generation (w). Time devoted to income generation (w), leisure time (T_1), time spent sick (S), and time spent coping with poor environmental quality (T_2) cannot exceed the total time available (T). We assume that these two constraints are binding, and that a household chooses the bundle of health, leisure and consumption (and corresponding averting behavior a) that maximizes well-being or utility. At this optimal point, the marginal opportunity costs of time and money are just equal to the marginal utility generated by these efforts, or marginal benefit of averting behavior a.

This framework allows us to consider the valuation of the costs and benefits of the three interventions analyzed here. The optimization is represented in the Lagrangian (L) in equation 1 below, where μ and λ are the Lagrange multipliers, representing the shadow prices for increased income and averting behavior respectively.

$$L_{T1,T2,Z,M,\lambda,\mu} = Max\ U[T_1, Z, S(a, Q\{G,A\}, a|\theta] - \lambda[f(a, T_2, M, K)] + \mu[E+w(T-S-T_1-T_2) - pM - rK - Z] \quad (1)$$

To understand the allocation of time and resources the first-order conditions of the utility maximization problem are presented below.

$$\begin{bmatrix} L_{T1} \\ L_Z \\ L_a \\ L_M \\ L_{T2} \\ L_K \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} U_{T1} - \mu \cdot w \\ U_Z - \mu \\ U_a + U_S.S_a - \lambda \cdot f_a - \mu.w.S_a \\ -\lambda f_M - \mu \cdot p \\ -\lambda f_{T2} - \mu \cdot w \\ -\lambda f_K - \mu \cdot r \end{bmatrix} \cdots \begin{pmatrix} 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{pmatrix}$$

Source: Whittington and Pattanayak 2015

[14] Additional details and discussion of these ideas and extensions appear in Pattanayak & Pfaff (2009).

This system of equations allows us to calculate the optimal allocations of leisure time, consumption, and health production as a function of averting behavior. Households are assumed to spend their time and money in such a way that the marginal opportunity costs equal the marginal utility gains from household decisions. These equations can then illustrate the optimal allocation of leisure time (T_1), time spent preventing illness (T_2), income spent on consumption (Z), income spent on acquiring inputs (M) or knowledge (K) to help prevent negative health outcomes as functions of the exogenously determined variables, which are wages (w), price of inputs for avoiding negative health outcomes (p), households' preferences (θ), total income (E), public policies (G) and the overall community's aggregate behavior (A) that influence environmental quality.

This utility-maximization framework provides a way to consistently estimate the net private value of health improvements that arise from specific avoidance behaviors (such as consuming water from an improved water source, or using point-of-use water treatment technology). This is because households will weigh the various private costs and benefits that result from such behaviors when choosing the optimal level of (or demand for) risk reductions. However, actual averting expenses will tend to underestimate potential benefits if and when technological limitations exist. That is, if individual decisions are constrained below optimal avoidance by lack of access to better technology, demand may exceed the level implied by actual avoidance. In addition, if avoidance produces positive spillovers on others, these spillovers will not be adequately considered in private decisions.

Expenses on treatment of illness will also underestimate the demand for improved health because they do not include non-pecuniary benefits such as mortality risk reductions and avoided pain and suffering (Cropper et al. 2004). In the absence of estimates of the complete set of demand relationships embedded in equations 2-7, for specific interventions, health and environmental economists typically use the value of a statistical life (VSL) to monetize mortality risk reductions. They may use either stated preference methods or revealed preference methods to measure VSLs, which could include the economic value of avoided pain and suffering. When using estimates of costs of illness and VSL to value mortality and morbidity risk reductions, it may be necessary to adjust for other non-health benefits and/or costs. For example, if a particular water supply intervention also delivers savings in terms of reduced water collection time, this benefit should also be included.

The Copenhagen Consensus Haiti Prioritise Project has instructed the authors of all of the sector papers to use an alternative approach to quantify the economic value of the health benefits that result from interventions considered in its priority setting exercise. This alternative approach estimates the economic value of the health benefits as the product of the DALYs (Disability Adjusted Life Years) avoided and a multiple of GDP per capita. The Copenhagen Consensus Project requires analysts to value a DALY at three different multiples of GDP per capita (1 time, 3 times, and 8 times).

When considering the use of this alternative, atheoretical measure of health benefits, it is important to recognize that if the true economic value of a DALY avoided is in fact approximated by the per capita GDP in a country, this measure would include the entire stream of benefits associated with improved health because both avoided mortality and morbidity outcomes are included in the calculation of avoided DALYs. In other words, this estimate already includes avoided cost-of-illness expenses and all of the benefits that stem from reduced illness (including increased education or productivity). Also, the product of DALYs avoided and the GDP per capita multiplier would not include non-health benefits that result from increased water consumption, time savings, or improved aesthetics unrelated to health. In fact, back-of-the-envelope calculations using the 1x and 3x multiples of GDP per capita for Haiti suggest that the implied VSL for an average statistical life (in terms of life years remaining) would be within the same order of magnitude as the values obtained from research studies aimed at quantifying the value of a statistical life as a function of income (Hammitt & Robinson 2011).[15]

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[15] Note that a 3% (real) discount rate converts 55 undiscounted years to 27 years. A 5% discount rate results in 19 years. The formula for these calculations is:
$1 – (\exp(-\delta LE)/ \delta$, where: δ = the discount rate; and LE = life expectancy.
This formula is obtained by taking a limit over t years of the standard exponential discounting function $\Sigma_I \, I / (1+\delta)^t$.
If we assume a 54 year average life expectancy, which is the average number of years of life saved due to avoided diarrheal disease deaths (which themselves fall disproportionately on young children), then the implied VSL without discounting life expectancy would be 3*$720/person-yr*54yrs = $116,640/avoided death. Discounting future life expectancy at 3% (the typical WHO approach) would yield 3*$720/person-yr*27yrs = $58,320. Using per capita GDP

Calculation of Costs and Benefits of the Three Interventions[16]

Each of the three interventions requires different inputs, which entail different costs and results in different outcomes with associated economic benefits. In this section of the paper, we present the equations used to calculate the costs and benefits of each intervention. We also present the data and assumptions used in the calculations.

Borehole and Handpump with Community Management

Benefits

The benefits from the borehole and handpump with community management intervention are the times savings from collecting water, the aesthetic (quality of life) benefits from additional water use, and the health benefits from consuming higher quantities of water from an improved source. The total benefits from the borehole and handpump intervention are calculated on a monthly per household basis as presented below:

$$B^{BH} = B^{TS\text{-}BH} + B^{A\text{-}BH} + B^{H\text{-}BH} \qquad (1)$$

Where:

B^{BH} = total monthly per household benefits from the borehole and handpump;
$B^{TS\text{-}BH}$ = total monthly per household benefits from time savings;
$B^{A\text{-}BH}$ = total monthly per household aesthetic benefits; and
$B^{H\text{-}BH}$ = total monthly per household health benefits.

The total monthly per household benefits from time savings are the product of (1) value of time saved not collecting water, which is estimated to be 50% of the unskilled hourly wage rate, 2)

would yield values 3 times smaller, while using a multiple of 8 would multiply them by 8/3. The latter would appear to be well above the typical VSL values that are used for low-income countries such as Haiti.

[16] This assessment will utilize the basic approach that was described in Whittington et al. 2009, and extended in subsequent work (Whittington et al. 2012). In these papers, the authors discussed and analyzed the major costs and benefits of conventional piped water and sewer solutions, and compared them with those of the decentralized water and sanitation interventions that are considered here. While many populations around the globe would prefer piped water and sewer services, this option is often unaffordable in the short and medium term, especially in rural areas. Even without considering ongoing maintenance requirements, the capital requirements for network services would be unavailable for covering all rural Haitians. Therefore, the interventions analyzed under this paper are typical approaches used for providing "intermediate levels of water and sanitation services (such as public taps and communal sanitation facilities)" (Whittington et al. 2009, p. 25).

difference in time spent collecting water after the intervention in hours for a trip to collect 20L of water, and time spent before the intervention in hours for a trip to collect 20L of water, (3) baseline quantity of water consumption divided into 20 liter units, and (4) number of people per household:

$$B^{TS\text{-}BH} = \left(\frac{W_u}{2*8}\right)*(T_C^1 - T_C^0)*(Q_0/20)*H \qquad (2)$$

Where:

W_u = unskilled daily wage;
8 = number of working hours in a day;
$\frac{1}{2}$ = ratio of the value of the time saved not collecting water to the unskilled wage rate;
T_C^1 = hours spent per trip collecting 20L of water after the intervention;
T_C^0 = hours spent per trip collecting 20L of water at baseline;
Q_0 = per person quantity of water consumed at baseline; and
H = number of people per household.

The consumer surplus associated with the increased water consumed due to the fall in collection time consists of two components: aesthetic and health-related benefits. We thus estimate the total monthly household aesthetic benefits as a portion of the consumer surplus. Specifically, we calculate the aesthetic benefits as the product of (1) value of time saved not collecting water, which is estimated to be 50% of the unskilled hourly wage rate, (2) a parameter for the proportion of aesthetic benefits that are non-health related and calculated as one minus the proportion of aesthetic benefits that are health-related, (3) the quantity of additional water consumed after the intervention divided into 20 liter units, and (4) the ratio of aesthetic benefits to time savings (which essentially scales the amount additional consumer surplus associated with the higher consumption amount):

$$B^{A\text{-}BH} = \left(\frac{W_u}{2*8}\right)*(1-B_h)*(Q_T/20)*R_{AT} \qquad (3)$$

Where:

W_u = unskilled daily wage;
8 = number of working hours in a day;
$\frac{1}{2}$ = ratio of the value of the time saved not collecting water to the unskilled wage rate;
B_h = proportion of aesthetic benefits that are health related;
Q_T = quantity of additional water consumed by the household after the intervention; and
R_{AT} = ratio of aesthetic benefits to time savings benefits.

The total monthly per household health benefits are calculated by the product of (1) the Copenhagen Consensus supplied estimate for the value of a DALY as a multiple of GDP per capita, (2) the estimated reduction in diarrhea from the borehole and handpump intervention, (3) the number of people per household, (4) the baseline diarrhea incidence in cases per person per year divided by 12 to convert it into a monthly rate, and (5) the DALYs avoided. The DALYs avoided is calculated as the sum of the product of 1) the case fatality rate of diarrhea, and 2) the weighted present value of life expectancy in years lost due to diarrhea-related deaths, and the product of 3) the survival rate of diarrhea, 4) the average diarrhea case duration in days divided by 365 to obtain an annual amount of days spent sick, and 5) the DALY weight for diarrhea. The calculation is presented below:

$$B^{H\text{-}BH} = V^{DALY} * R_{BH} * H * (D_I/12) * (CFR_D * PV(LE) + (1-CFR_D) * (D_D/365) * DALY_D) \quad (4)$$

Where:

V^{DALY} = Copenhagen Consensus estimate value for a DALY;
R_{BH} = estimated reduction in diarrhea from the borehole and handpump;
H = number of people per household;
D_I = diarrhea incidence in cases per person per year;
CFR_D = case fatality rate from diarrhea cases;
$PV(LE)$ = present value of years of lives lost from diarrhea related deaths;
D_D = duration of average diarrhea case in days;
$DALY_D$ = DALY weight for diarrhea.

The weighted present value of life expectancy in years lost due to diarrhea-related deaths is the weighted sum of a function of mortality rates, discount rate, and life expectancy, for the sixteen 5-year age groups from 0-79, and an additional group containing all Haitians 80 years old and above:

$$PV(LE) = \frac{1}{M}\sum_{i=1}^{17} M_i * \left(1 - e^{(-r*LE_i)}\right)/r \quad (5)$$

Where:

$PV(LE)$ = present value of years of lives lost from diarrhea related deaths;
M = total number of annual deaths from diarrhea;
i = 17 5-year aggregated age groups;
M_i = total number of annual deaths in age group i;
LE_i = expected additional life years of age group i; and
r = discount rate.

Costs

The costs for the borehole and handpump intervention include the upfront capital investment required to install the borehole and handpump, the upfront costs to explain and deliver the behavior change and management program to the community, plus the annual management costs, and the ongoing operation and maintenance (O&M) costs of the project. The total upfront capital costs are the sum of (1) borehole and handpump parts and installation, and (2) costs of program delivery and initial capacity building.

The total monthly household cost is the sum of the monthly capital and O&M costs[17]:

$$C^{BH} = C^{C\text{-}BH} + C^{O\&M} \qquad (6)$$

Where:

C^{BH} = total household monthly cost;
$C^{C\text{-}BH}$ = monthly household capital cost; and
$C^{O\&M}$ = monthly household O&M cost, which covers repairs and management costs.

The monthly household capital costs of the borehole and handpump intervention equal the product of 1) the initial capital costs and 2) the annual capital recovery factor, divided by 3) the number of households served by a borehole, and divided by 4) 12 months per year to convert the annual capital costs to monthly capital costs:

$$C^{C\text{-}BH} = ((C^{P} + C^{CAP}) * CRF_{BH}) / (12 * N_{BH}) \qquad (7)$$

Where:

$C^{C\text{-}BH}$ = monthly household capital cost;
C^{P} = up-front cost of borehole and handpump parts and installation;
C^{CAP} = up-front costs of program delivery and initial capacity building for behavior change promotion and management training;
CRF_{BH} = annual capital recovery factor; and
N_{BH} = number of households served by a borehole.

[17] We do not include user fees in this equation because we do not specify who should pay for this intervention. User fees would in fact represent a transfer from users to those who finance the infrastructure.

The annual capital recovery factor is a function of the discount rate and the expected lifetime of the borehole and handpump system:

$$CRF_{BH} = (r*(1+r)^{P\text{-}BH})/((1+r)^{P\text{-}BH}-1) \quad (8)$$

Where:

CRF_{BH} = capital recovery factor;
r = discount rate; and
$P\text{-}BH$ = expected lifetime of the borehole and handpump system.

The ongoing monthly operation and maintenance costs per household is the sum of (1) annual operation and maintenance costs, and (2) annual community management costs (including personnel to secure and monitor use of the infrastructure), divided by (3) number of households served by a borehole and divided by 12 months per year to convert the annual capital costs to monthly capital costs:

$$C^{O\&M}=(O_{BH}+M_{BH})/(12*N_{BH}) \quad (9)$$

Where:

$C^{O\&M}$ = monthly operation and maintenance costs per household;
O_{BH} = annual operation and maintenance costs;
M_{BH} = annual management costs; and
N_{BH} = number of households served by a borehole.

Borehole and Handpump with Community Management plus Household Biosand Filter

Benefits

The benefits of the borehole and handpump with community management plus biosand filter intervention are greater than the benefits offered by the borehole and handpump with community management intervention because the biosand filter improves drinking water quality and increases the health benefits to the household. The benefits of the borehole and handpump with community management plus biosand filter intervention are the sum of 1) total monthly per household incremental health benefits from using the water collected from the borehole and handpump,[18] 2) total monthly per household benefits from time savings from the borehole and handpump with community management intervention, 3) total monthly aesthetic benefits of the borehole and handpump with community management intervention, and 4) monthly health benefits from filtering the water with a biosand filter:

$$B^{BH+SF} = B^{BH}(1-R_F) + B^{TS\text{-}BH} + B^{A\text{-}BH} + B^{SF} \quad (10)$$

Where:

B^{BH+SF} = total monthly per household benefits from the biosand filter and borehole and handpump with community management intervention;
B^{BH} = total monthly per household health benefits from using the water collected from the borehole and handpump;
R_F = estimated reduction in diarrhea from the biosand filter;
$B^{TS\text{-}BH}$ = total monthly per household benefits from time savings from the borehole and handpump with community management;
$B^{A\text{-}BH}$ = total monthly per household aesthetic benefits the borehole and handpump with community management; and
B^{SF} = additional health benefits from filtering the water collected from the borehole and handpump with a biosand filter.

The health benefits from using the biosand filter to treat drinking water are the product of 1) Copenhagen Consensus-supplied estimate of the economic value of a DALY as a multiple of GDP per capita, 2) weighted filter use over the lifetime of the filter, (3) estimated reduction in diarrhea from using the water collected from the borehole and handpump and filtering it with the biosand filter, (4) number of people per household, (5) annual baseline diarrhea incidence rate divided by 12 months per year to convert the annual rate to a monthly rate, multiplied by the DALYs avoided from the intervention:

[18] In this calculation, the monthly health benefits per household from using the water collected from the borehole and handpump with community management is treated as an incremental health benefit. This is done because the health benefits from treating water with the biosand filter and the benefits from the borehole and handpump system are not additive. In this calculation, we first estimate the health benefits from using the biosand filter alone. We then adjust the total health benefits by the remaining risk of diarrhea after accounting for the reduction from treating drinking water with the biosand filter to calculate the incremental health benefits from borehole and handpump with community management intervention.

$$B^{SF} = V^{DALY} * W_{USE-F} * R_F * H * (D_I/12) * (CFR_D * PV(LE) + (1-CFR_D) * (D_D/365) * DALY_D) \quad (11)$$

Where:

V^{DALY} = Copenhagen Consensus estimate of the economic value of a DALY;
W_{USE-F} = annual weighted filter use over the lifetime of the project;
R_F = estimated reduction in diarrhea from the biosand filter;
H = number of people per household;
D_I = baseline diarrhea incidence in cases per person per year;
CFR_D = case fatality rate from diarrhea cases;
$PV(LE)$ = present value of years of lives lost from diarrhea-related deaths;
D_D = duration of average diarrhea case in days; and
$DALY_D$ = DALY weight for diarrhea.

The weighted filter use is a function of (1) daily usage rate of a filter, (2) declining use of the filter over its lifetime, (3) lifetime of the filter, and (4) the percent of the year the biosand filter cannot be used based on the number of times a year the filter needs to be washed and days required for the biofilm to regrow:

$$W_{USE-F} = D_{USE}((1+RFD^{-1})-(RFD*(1+RFD)^{(P-F)-1})^{-1})*((365-WASH*T_{GROWTH})/365)/P\text{-}F \quad (12)$$

Where:

W_{USE-F} = annual weighted filter use over its lifetime;
D_{USE} = daily usage rate of a filter;
RFD = annual rate of which households stop using the filter;
$WASH$ = number of times a year the filter needs to be washed;
T_{GROWTH} = number of days required for the biofilm to regrow; and
$P\text{-}F$ = expected lifetime of the biosand filter.

Costs

The total costs for the borehole and handpump with community management plus biosand filter intervention are the previously calculated costs of the borehole and handpump with community management intervention, plus the capital costs of the biosand filter, the software costs of delivery (including behavior change promotion and education on how to use the filter), ongoing programming and capacity building, and the time and maintenance costs incurred by the households.

The total monthly household cost of the borehole and handpump with community management plus biosand filter intervention is the sum of 1) total monthly household costs from the borehole and handpump with community management intervention, as calculated in equation 6, 2) monthly household capital costs of the biosand filter, 3) monthly program costs for the biosand filter distribution per household, and 4) monthly costs of time spent by the household maintaining the filter:

$$C^{BH+SF} = C^{BH} + C^{C-F} + C^{PR} + C^{TC-F} \quad (13)$$

Where:

C^{BH+SF} = total monthly household cost of the borehole and handpump with community intervention plus the biosand filter;
C^{BH} = total monthly household costs from the borehole and handpump intervention;
C^{C-F} = total monthly household capital costs of the biosand filter;
C^{PR} = total monthly program costs for the biosand filter distribution per household; and
C^{TC-F} = total monthly cost of time spent by the household maintaining the filter.

The household monthly capital cost of the biosand filter is the product of 1) total capital costs of the biosand filter (including the distribution program and costs of transportation for the filter), 2) annual capital recovery factor, defined in equation 8 but calculated with parameters for the biosand filter, divided by 12 months per year to convert annual capital costs into monthly costs:

$$C^{C-F} = (D^C + T^C) * CRF_F / 12 \quad (14)$$

Where:

D^C = one-time cost of the filter and the distribution program;
T^C = one-time cost of transportation for the filter; and
CRF_F = annual capital recovery factor for the biosand filter;

The total monthly per household program costs for the biosand filter distribution is the product of (1) the hours required of a community manager per household per year, (2) the hourly wage rate for the community manager, estimated as twice the unskilled wage hourly wage, and divided by (3) 12 months per year to convert annual costs into monthly costs:

$$C^{PR} = (T_{CM} * 2 * (W_u/8))/12 \quad (15)$$

Where:

C^{PR} = monthly household program costs for the biosand filter distribution;
T_{CM} = hours required of a community manager per household per year; and
W_u = unskilled wage rate.

The total monthly cost per household of maintenance for the biosand filter is the sum of (1) the product of training time per household on how to use the filter, the value of time being trained to use the filter, and the capital recovery factor, and (2) the product of the monthly time spent washing the filter in minutes divided by 60 to convert the time spent washing the filter into hours, the number of times a filter needs to be washed in a year divided by 12 months per year to convert this into a monthly number of washes, and the value of time spent washing the filter:

$$C^{TC\text{-}F} = (T_{T\text{-}F} * (\frac{W_u}{2*8}) * CRF_F)/12 + (T_M * WASH * \frac{W_u}{2})/(60*12) \qquad (16)$$

Where:

$T_{T\text{-}F}$ = time spent per household learning to use the filter in hours;
W_u = unskilled daily wage;
8 = number of working hours in a day;
$\frac{1}{2}$ = ratio of the value of time spent learning to use the filter to the unskilled wage rate;
$\frac{1}{2}$ = ratio of the value of time spent cleaning and maintaining the filter to the unskilled wage rate;
CRF_F = annual capital recovery factor;
T_M = number of minutes spent washing the filter per wash; and
$WASH$ = annual number of times a filter needs to be washed.

Community-Led Total Sanitation (CLTS)[19]

Benefits

The benefits from CLTS intervention are the sum of the time savings resulting from defecating at home rather than spending time walking to a place to defecate in the open, and the health benefits from using an improved sanitation facility:

[19] Note that a CLTS intervention could be combined with either of the first two interventions, i.e., CLTS is not mutually exclusive of 1) borehole and handpump with community management; or 2) borehole and handpump with community management plus household biosand filter.

$$B^{CLTS}=B^{TS\text{-}CLTS}+B^{H\text{-}CLTS} \quad (17)$$

Where:

B^{CLTS} = monthly per household benefits of the CLTS intervention;
$B^{TS\text{-}CLTS}$ = monthly per household benefits from time savings due to CLTS; and
$B^{H\text{-}CLTS}$ = monthly per household health benefits from CLTS.

The monthly per household benefit from time savings due to CLTS is the product of (1) time spent by adults in the household per month looking for a place to open defecate, (2) value of time saved not walking or searching for open defecation sites (estimated as half the unskilled wage rate), and (3) weighted latrine use over the lifetime of the latrine:

$$B^{TS\text{-}CLTS}= T_{H\text{-}OD} * \frac{W_u}{2*8} * W_{USE\text{-}CLTS} \quad (18)$$

Where:

$T_{H\text{-}OD}$ = hours per month spent by adults per household walking to and looking for a place to open defecate;
W_u = unskilled daily wage;
8 = number of working hours in a day;
$\frac{1}{2}$ = ratio of the value of time saved not walking to the open defecation site to the unskilled wage rate
$W_{USE\text{-}CLTS}$ = annual weighted latrine use over the lifetime of the latrine.

The time spent per household looking for a place to open defecate is a product of (1) number of times adults in a household open defecate per month, and (2) minutes spent per trip looking for a place to open defecate divided by 60 minutes to convert this into an hourly rate:

$$T_{H\text{-}OD}=N_{H\text{-}OD}*T_{OD}/60 \quad (19)$$

Where:

$N_{H\text{-}OD}$ = number of times adults in a household open defecate per month; and
T_{OD} = minutes spent per trip walking and looking for a place to open defecate.

The number of times adults in a household defecate in the open per month is the product of (1) number of adults per household, (2) number of roundtrips to defecation sites per adult per day, and (3) an estimate of 30 days per month:

$$N_{H\text{-}OD}= H_{ADULTS}*OD*30 \quad (20)$$

Where:

$N_{H\text{-}OD}$ = number of times adults in a household defecate in the open per month;
H_{ADULTS} = number of adults per household; and
OD = number of roundtrips per adult to defecation sites per day.

The weighted use of a latrine over its lifetime is a function of (1) uptake of latrines from the CLTS intervention, (2) latrine usage rate, (3) the declining use of the latrine over its lifetime, and (4) lifetime of the latrine:

$$W_{USE\text{-}CLTS} = UP_{CLTS} * LU * ((1+RLD^{-1}) - (RLD * (1+RLD)^{(P\text{-}CLTS)-1})^{-1} / P\text{-}CLTS \qquad (21)$$

Where:

$W_{USE\text{-}CLTS}$ = annual weighted use of the latrine over its lifetime,
UP_{CLTS} = percent uptake of latrines from the CLTS intervention;
LU = latrine usage rate;
RLD = annual rate of households stopping to use the latrine per year; and
$P\text{-}CLTS$ = expected duration of the effects of the CLTS program.

The monthly per household health benefits from the CLTS intervention are calculated by the product of (1) Copenhagen Consensus-supplied estimate of the economic value of a DALY as a multiple of GDP per capita, (2) weighted use of the latrine over its lifetime, (3) estimated reduction in diarrhea from the CLTS program,[20] (4) the number of people per household, (5) the annual baseline diarrhea incidence rate divided by 12 months per year to covert the rate into a monthly rate, and (6) the DALYs avoided from the intervention:

$$B^{H\text{-}CLTS} = V^{DALY} * W_{USE\text{-}CLTS} * R_{CLTS} * H * (D_I/12) * (CFR_D * PV(LE) + (1-CFR_D) * (D_D/365) * DALY_D) \qquad (22)$$

Where:

V^{DALY} = Copenhagen Consensus estimate for the economic value of a DALY;
$W_{USE\text{-}CLTS}$ = annual weighted use of the latrine over its lifetime;
R_{CLTS} = estimated reduction in diarrhea from CLTS;
H = number of people per household;
D_I = baseline diarrhea incidence in cases per person per year;

[20] We do not include indirect benefits to other community members that arise from latrine use, and thus may underestimate the health benefits of CLTS. Though improved sanitation is widely believed to deliver such benefits, we do not believe that the relationship between CLTS campaign effects and these external benefits has been sufficiently well established to include them, particularly when CLTS interventions lead to only modest reductions in open defecation.

CFR_D = case fatality rate from diarrhea cases;
$PV(LE)$ = present value of years of lives lost from diarrhea related deaths;
D_D = average duration of diarrhea case in days; and
$DALY_D$ = DALY weight for diarrhea.

Costs

The costs of the CLTS intervention are composed of the capital costs for latrine construction, the program costs of implementing a CLTS campaign, which includes significant behavior change promotion, the operation and maintenance costs the latrine, and the household time spent in training and in other activities related to the CLTS campaign.

The total monthly per household cost of the CLTS intervention is the sum of (1) monthly capital costs of CLTS per household, (2) the annual financial operation and maintenance costs per household divided by 12 to convert into a monthly cost, (3) monthly costs of ongoing CLTS activities for CLTS per household, and (4) the monthly cost of time spent by households on the CLTS program and maintaining latrines per household:

$$C^{CLTS}=C^{C\text{-}CLTS}+(C^{O\&M\text{-}CLTS}/12)+C^{P\text{-}CLTS}+C^{TC\text{-}CLTS} \quad (23)$$

Where:

C^{CLTS} = total monthly household cost of the CLTS intervention;
$C^{C\text{-}CLTS}$ = monthly household capital costs of CLTS;
$C^{O\&M\text{-}CLTS}$ = annual household financial cost of operation and maintenance for CLTS;
$C^{P\text{-}CLTS}$ = monthly household behavior change program cost of CLTS; and
$C^{TC\text{-}CLTS}$ = monthly household cost of time spent by households on the CLTS program and maintaining latrines

The monthly capital costs per household of the CLTS intervention is the product of (1) capital cost of a latrine, (2) latrine uptake rate, and (3) annual capital recovery factor for a latrine divided by 12 months per year to convert the factor into a monthly capital recovery factor:

$$C^{C\text{-}CLTS}=(C_L*UP_{CLTS}*CRF_{CLTS})/12 \quad (24)$$

Where:

C_L = up-front capital cost of a latrine;
UP_{CLTS} = percent uptake of latrines from the CLTS intervention; and
CRF_{CLTS} = annual capital recovery factor for the CLTS intervention.

The monthly per household cost of time is the sum of three products representing different time costs for the CLTS intervention. The first component is the ongoing participatory and maintenance times required for CLTS, which is the product of (1) time requirements per household for participating, (2) cost of time for continuing to participate in the CLTS program follow-up activities, and (3) uptake rate of latrine from the CLTS intervention. The second component is the time spent in training for CLTS households that take up the latrine, which is the product of (1) uptake rate of latrine from the CLTS intervention, (2) initial training time for CLTS for participating households, (3) cost of initial training time for CLTS participating households, and (4) annual capital recovery factor of CLTS. The third component is the time spent by households that choose not to build a latrine after participating in the initial CLTS intervention, which is the product of (1) the percent of people that do not build a latrine, (2) the time spent in initial training by households that do not choose to build a latrine, (3) cost of time spent in CLTS training for non-participating households, (4) annual capital recovery factor of CLTS, and divided by (5) the 12 months per year to convert the annual cost into a monthly cost of CLTS per household:

$$C^{TC\text{-}CLTS}=(T_{CLTS}*\frac{W_u}{2*8}*UP_{CLTS}+UP_{CLTS}*T_{T\text{-}CLTS}*\frac{W_u}{2*8}*CRF_{CLTS}+(1-UP_{CLTS})*T_{T\text{-}NON\text{-}CLTS}*\frac{W_u}{2*8}*CRF_{CLTS})/12 \quad (26)$$

Where:

T_{CLTS} = annual time requirements per household for participating;
UP_{CLTS} = percent uptake of latrines from the CLTS intervention;
$T_{T\text{-}CLTS}$ = initial training time for CLTS for participating households;
$T_{T\text{-}NON\text{-}CLTS}$ = time spent in initial training by households that do not choose to build a latrine;
CRF_{CLTS} = annual capital recovery factor for the CLTS intervention;
W_u = unskilled daily wage;
8 = number of working hours in a day; and
$\frac{1}{2}$ = ratio the value of time spent in training for both participating and non-participating households to the unskilled wage rate
$\frac{1}{2}$ = ratio the value of time spent on ongoing CLTS activities to the unskilled wage rate

Parameter Values and Sources

Table 7 presents the data and parameters values used in the equations above for the calculation of the benefits and costs of each of the three interventions. To the extent possible, we have adjusted the parameter estimates and assumptions to ensure that the benefit and cost calculations presented in this paper are in real (i.e. net of inflation) 2014 US dollars. For example, the Copenhagen Consensus Project's GDP per capita estimates for Haiti which we use in the economic valuation of DALYs are in 2014 dollars. We will continue to refine these calculations to ensure that all estimates are expressed in 2014 US dollars to the extent possible.

Results

Borehole and Handpump with Community Management

Benefits, Costs, and Benefit-Cost Ratio

The results of the benefit-cost calculations for the borehole and handpump with community management intervention are presented in Table 8, assuming a discount rate of 3% and a DALY value of 3 times GDP per capita. The total benefits per household per month are estimated to be US$5.20. A majority (67%) of the total monthly household benefits from the borehole and handpump intervention is from the time savings due to shorter trips to collect water (US$3.51 per household per month). A household is estimated to gain US$1.50 per month in health benefits and US$0.19 per month in aesthetic benefits.

The total monthly cost of this intervention is US$2.0. The largest component is the up-front capital cost (38% of the total). The management costs – which comprise the time and/or salaries of community members managing the infrastructure – constitute 35% of the total monthly costs per household. The costs for capacity building, training and program implementation constitute 20% of the total. The smallest component of the total cost is the ongoing operation and maintenance costs, which is for infrastructure upkeep and repairs (7%).

Table 9 presents the results of a sensitivity analysis that shows how changes in the discount rate and value of a DALY affect the estimates of costs and benefits. The monthly household benefits range from US$3.89 to US$7.70 across the nine cases (Table 9). The costs are unaffected by the assumed DALY value, and in the nine cases presented in Table 9 range from US$2.00 to US$2.87 per household per month depending on the assumed discount rate.

The total net benefits range from US$1.01 to US$5.71 per household per month for the nine cases shown in Table 9. The net benefits assuming a DALY value of 3 times GDP per capita and a discount rate of 3% are US$3.20. The benefit-cost ratio ranges from 1.35 to 3.86 for the nine cases and is 2.6 assuming a DALY value of 3 times GDP per capita and a discount rate of 3%.

Additional Sensitivity Analysis

One-way sensitivity analyses show that the net benefits of this water supply intervention are most sensitive to the factors that influence the benefits of time savings (Figure 9a). These include the baseline and post-intervention water collection times, and the factors that influence the value of time – namely the market wage and the adjustment that accounts for the difference between the value of time spent collecting water and this wage rate. Another important parameter that influences the results is the number of households served by the borehole because this influences the cost per household. Two parameters related to the total health benefits – the value of each averted DALY and the % reduction in diarrhea from this intervention – are somewhat less important, as is the discount rate.

Borehole and Handpump with Community Management plus Biosand Filter

Benefits, Costs, and Benefit-Cost Ratio

The results of the benefit-cost calculations for the borehole and handpump with community management plus biosand filter intervention are presented in Table 10, assuming a discount rate of 3% and a DALY value of 3 times GDP per capita. The total monthly household benefits from the borehole and handpump with community management plus biosand filter intervention are estimated to be US$7.72. A majority of the benefits are from the monthly household health benefits (US$4.02). A household gains an estimated US$3.70 per month in time savings benefits and aesthetic benefits from the borehole and handpump with community management intervention.

The total monthly per household cost of this intervention is US$2.96. Two thirds of the costs are from the borehole and handpump with community management intervention (67%). The next largest component is from the up-front capital costs of producing, planning, and transporting the biosand filters to the household (30%). The community manager's time and the time required for maintenance represent only a small percent of the total monthly costs (3%).

Table 11 presents the results of a sensitivity analysis that shows how changes in the discount rate and value of a DALY affect the estimates of costs and benefits. The monthly household benefits range from US$4.21 to US$14.56 across the nine cases (Table 11). The costs are unaffected by the assumed DALY value, and in the nine cases presented in Table 11 range from US$2.96 to US$4.20 per household per month depending on the assumed discount rate.

The total net benefits range from US$0.01 to US$11.61 per household per month for the nine cases shown in Table 11. The net benefits assuming a DALY value of 3 times GDP per capita and a discount rate of 3% are US$4.76. The benefit-cost ratio ranges from 1.00 to 4.92 for the nine cases and is 2.6 assuming a DALY value of 3 times GDP per capita and a discount rate of 3% (the benefit-cost ratio in this case is the same as the benefit-cost ratio in the estimated base case of the borehole and handpump with community management intervention).

Additional Sensitivity Analysis

One-way sensitivity analyses show that many of the same factors influencing the borehole and handpump with community management intervention are also important in affecting the net benefits of this combined water supply and treatment intervention (Figure 9b). However, the ranking of these factors varies somewhat. In particular, the value of each averted DALY becomes much more significant because the combined intervention delivers much larger health benefits than the simple water supply improvement. The discount rate increases in significance, now following only the time parameters in terms of importance in shifting net benefits. The number of households served by the borehole in turn decreases somewhat in the ranking.

Community-Led Total Sanitation (CLTS)

Benefits, Costs, and Benefit-Cost Ratio

The results of the benefit-cost calculations for the CLTS intervention are presented in Table 12, assuming a discount rate of 3% and a DALY value of 3 times GDP per capita. The total health benefits per household per month in this base case are US$1.49 per month. Two thirds (US$1.00) of the total benefits per household per month are health benefits. The times savings benefits are one third of the total benefits, $0.49 per household per month.

The total monthly cost per household is estimated to be US$1.09. The operation and maintenance cost is $0.42 per household per month, which is 38% of the total monthly cost per household. The capital costs, program costs, and time costs contribute 22%, 27%, and 12% of the total monthly household cost, respectively.

Table 13 presents the results of a sensitivity analysis that shows how changes in the discount rate and value of a DALY affect the estimates of costs and benefits. The monthly household benefits range from US$0.62 to US$3.14 across the nine cases (Table 13). The costs per household per month of the CLTS intervention range from $1.09 to $1.15, and are unaffected by the assumed DALY value. Changes to the discount rate have a smaller effect on the range of monthly household costs than on the range of benefits.

The net benefits assuming a DALY value of 3 times GDP per capita and a discount rate of 3% are US$0.40/hh-month. The total net benefits range from -US$0.53 to US$2.06 per household per month for the nine cases (Table 13). The benefit-cost ratio is 1.37 assuming a DALY value of 3 times GDP per capita and a discount rate of 3%. The benefit-cost ratio ranges from 0.54 to 2.90 for the nine cases and per household per month for the nine cases (Table 13).

Additional Sensitivity Analysis

As with the combined water supply and treatment intervention described previously, the value of each averted DALY is the most significant parameter in affecting the net benefits of the CLTS intervention (Figure 9c). Several adoption parameters – related to the success of uptake and use are also very important for this intervention, emphasizing the importance of behavior change in determining outcomes. Other important parameters include the discount rate, the reduction in diarrhea due to the intervention, the operation and maintenance costs of the latrine, the market wage (which influences the value of time savings from this intervention), and the case fatality rate due to diarrhea.

Multi-Parameter Sensitivity Analyses

We also conducted multi-parameter Monte Carlo simulations, allowing the model parameters to vary over uniform distributions between their assumed low and high values (Figure 10). There are several findings of interest. First, the distribution of net benefit outcomes for the CLTS intervention is much tighter than for the water improvement interventions. This makes sense because the water supply interventions are larger and costlier. This contributes to a longer tail on the negative side of both the distributions of the water supply interventions, and also leads to greater variation in total benefits because the time savings can be large in locations with poor access to water, and where the opportunity cost of time is very high.

Second, the cumulative distribution of net benefits for the combined water supply and biosand filter treatment intervention is mostly shifted to the right of the borehole and handpump with community management intervention. This is because the addition of the biosand filter only provides health benefits, while the borehole and handpump with community management delivers mostly time savings. Third, the proportion of simulations with negative net benefits is highest with the CLTS intervention, suggesting that this intervention is less likely to consistently deliver net benefits. Nonetheless, all three interventions will fail to deliver positive net benefits in some situations. Hence decision makers should consider the appropriateness of each intervention carefully, given local realities.

Conclusion

In this final section, we discuss how we believe the Eminent Panel should interpret the results of our benefit-cost calculations of the three water and sanitation interventions presented in this paper. The results for the most plausible case (3% discount rate and economic value of a DALY = 3 times GDP per capita) and all of the sensitivity analyses for 1) the borehole and handpump with community management; and 2) the borehole and handpump with community management plus household biosand filter, show that the benefits are consistently greater than the costs. We consider benefit-cost ratios on the order of two to be quite plausible in typical conditions in rural Haiti, even though important benefits have not been included in our estimates.

Similarly, the CLTS intervention has positive net benefits in most plausible cases. We suggest that a benefit-cost ratio of 1.4 seems quite reasonable for the CLTS intervention. This estimate does not account for potential positive spillovers to other households. Moreover, there are important, unquantified benefits to women and girls that result from the CLTS intervention. Specifically, open defection forces women and girls to walk away from their homes on a daily basis to unprotected, secluded locations where their personal safety may be at risk. While there is evidence of an association between open defecation rates and violence against women, the current studies are unable to adequately quantify this relationship (Jadhav et al. 2016, Winter and Barchi 2016, and House and Cavill 2015).[21]

We emphasize that the protocol required by the Copenhagen Consensus Haiti Priorise Project for estimating the economic benefits of health improvements does not take account of households' preferences for avoiding cholera infection. All three interventions examined in this paper should reduce the risk of cholera infection. However, we have not included additional health benefits associated with reducing cholera because this would risk double counting. Estimates of incidence and case fatality rates for overall diarrhea for Haiti should already include cholera because the global burden of disease data do not distinguish between non-cholera and cholera-specific cases of diarrhea. Also, the estimates of the overall effectiveness of the three interventions come from systematic literature reviews for reductions in overall diarrhea, which include cholera. We do not believe that there is sufficient evidence from the literature to distinguish the effectiveness of these interventions at reducing cholera-specific diarrhea and non-cholera diarrhea. Of course, the Haitian people may value the mortality and morbidity risks of cholera differently from the risks of other types of diarrhea. However, it is not possible to capture these different perceptions for mortality and morbidity risk reductions for different diseases using the Copenhagen Consensus protocol for measuring health benefits based on an assumed economic value of a DALY.

The cholera epidemic in Haiti introduces a new dimension to the likely benefits of water and sanitation investments. The risks households face from cholera infection, and the economic consequences of the behaviors that they may pursue to avoid cholera, have not been adequately

[21] See Annex for additional discussion.

quantified in our benefit-cost calculations due to limited time and resources. Moreover, the benefit-cost calculations do not incorporate the moral dimension that arises from the fact that the cholera epidemic was caused by the (unintentional) actions of the United Nations peacekeeping force. We believe that the United Nations should accept its responsibility for their actions, and do everything reasonably possible to reduce the threat of cholera infection to the citizens of Haiti.

Our results suggest that there is a strong economic case for moving forward aggressively with investments in the water and sanitation sector, even ignoring the moral dimension of the cholera problem. Such actions in the water and sanitation sector would pass a benefit-cost test, but the citizens of Haiti are morally entitled to remedial actions by the United Nations even if the benefit-cost estimates showed that the interventions were not as attractive economically as, in fact, they are. The Government of Haiti and donors can thus focus on the practical issues of implementing water and sanitation interventions such as those described in this paper, and the challenges of scaling up such efforts.

Of course, one would expect to find considerable heterogeneity in local conditions in rural areas of Haiti, and local preferences for sector investment priorities should be considered in investment planning and budget allocation decisions. It will not be the case that increased water and sanitation investments should take priority everywhere. Given the DALY valuation protocol and the assumptions about the value of time saved collecting water used in this analysis, it is important to acknowledge that these benefit-cost calculations reveal little about how households themselves perceive the economic benefits from these three interventions. In other words, even though the benefits are estimated to be significantly more than the costs, households may not perceive that water and sanitation interventions are this attractive, and they may be unwilling or unable to pay for the interventions. Even if water and sanitation infrastructure is delivered, behavior change and community acceptance or effective collective management of the interventions may not occur. Thus, project implementation in the rural water and sanitation sector may be more challenging than these calculations might seem to suggest.

Interventions	Discount	Benefit	Cost	BCR	Quality of Evidence
Borehole and Handpump with Community Management	3%	US$5.20	US$2.00	2.6	Strong
	5%	US$4.79	US$2.17	2.2	
	12%	US$4.27	US$2.87	1.5	
Borehole and Handpump with Community Management Plus Biosand Filter	3%	US$7.72	US$2.96	2.6	Strong
	5%	US$6.65	US$3.21	2.1	
	12%	US$5.32	US$4.20	1.3	
CLTS Intervention	3%	US$1.49	US$1.09	1.4	Strong
	5%	US$1.21	US$1.10	1.1	
	12%	US$0.87	US$1.15	0.8	

Notes: Mean DALY value of 3 x GDP per Capita. Benefit and cost values are rounded to the nearest cent.

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Annex

Data

Data on baseline water and sanitation conditions and diarrheal disease in rural Haiti are limited. Before the 2010 earthquake and subsequent cholera outbreak, Cravioto et al. (2011, p.13) said that "there did not appear to be any national or regional systematic reporting system for diarrheal disease in Haiti." Furthermore, Haiti-specific data on baseline health level, status quo behavior, and costs of interventions are scarce. Whenever possible, we used data from standardized data collection approaches such as the DHS surveys (EMMUS-V 2012), the JMP (2015), the Global Burden of Disease (2015), and peer-reviewed studies.[22] Our data assumptions are summarized in Table 7. We discuss some of the key assumptions behind our model parameterization for each successive intervention below, where they deviate from the prior global analysis discussed in Whittington et al. (2009).

For the borehole and handpump intervention, the baseline collection time data was derived from self-reported time to water source as reported in the EMMUS-V survey. Low and high estimates were obtained based on the minimum and maximum average responses from all rural households living within an administrative department. Our base case is the average over all the departments. The percent reduction in diarrhea due to water project intervention is derived from a systematic review of the literature on diarrhea reduction from water interventions (Prüss-Ustün et al. 2014), which updates the estimates from previous meta-analyses.

[22] The EMMUS-V, conducted from Jan-Jun 2012, was a nationally-representative household level survey focused on health in Haiti. The survey includes data from 13,181 households around the country, of whom 7,987 live in rural areas. The household survey data provide information on water sources, water treatment practices, and time to water source. In addition, mothers with children under the age of 5 answered questions on their children's incidence of diarrhea in the past two weeks and whether blood was present in child's stool. This information allows us to better understand the distribution of diarrhea rates across rural areas in various Departments in Haiti. The GBD is a collaborative that estimates health losses from different factors (IHME 2015). The analysis used to measure the impact of inadequate water and sanitation focuses on diarrheal diseases (Wolf et al. 2014, Prüss-Ustün et al. 2014).

For the biosand filter, the parameter for the reduction of diarrhea due to the intervention is adjusted based on the updated findings from Prüss-Ustün et al. 2014. Similarly, the reduction in CLTS is revised based on more recent findings in Pickering et al. (2015).

Our benefit estimates include only a limited set of positive health outcomes from water and sanitation interventions. According to the *Burden of Disease from Inadequate Water, Sanitation and Hygiene in Low- and Middle-Income Settings: A Retrospective Analysis of Data from 145 Countries* report, there is reason to expect that inadequate water and sanitation conditions are related to a number of other diseases and health risks. Nonetheless, our analysis focuses on diarrheal diseases due to the limited evidence on the effectiveness of the various interventions at reducing these other diseases and negative health consequences. Therefore, our findings are likely to understate the health benefits.

In addition, a number of additional non-health benefits are omitted due to a lack of strong causal evidence. For example, latrine access may reduce "the vulnerability of rural women and girls … as one of the major benefits of CLTS, together with gains in privacy, convenience, self-respect…Toilets close by their dwellings can significantly reduce the daily risks and anxieties experienced by women and girls" (House and Cavill 2015, p. 2). While two studies (Winter et al. 2016 and Jadhav et al. 2016) find an association between access to sanitation facilities and lower prevalence of gender-based violence, no research has established a causal link between these two variables. Similarly, UNICEF lists a number of other gender-related benefits from improved water and sanitation interventions, including lower rates of tardiness or drop out from schools among girls. While time savings are included in the analysis, it is possible that women disproportionately benefit from these time savings, given that they are a) primarily responsible for collecting water, and b) likely to miss school due to lack of access to proper sanitation during menstruation. As with gender-based violence, we are unaware of any studies that provide quantitative and causal estimates of these linkages.

Tables and figures

Table 1: Dominican Republic Rural Water Coverage

RURAL WATER					
Estimated coverage 2015 update					
Year	Total improved	Piped onto premises	Other improved	Other unimproved	Surface water
1990	76%	45%	31%	13%	11%
1995	77%	48%	29%	13%	10%
2000	78%	51%	27%	13%	9%
2005	79%	53%	26%	14%	7%
2010	81%	56%	25%	13%	6%
2015	82%	58%	24%	14%	4%

Source: JMP WHO/UNICEF 2015

Table 2: Cuba Rural Water Coverage

RURAL WATER					
Estimated coverage 2015 update					
Year	Total improved	Piped onto premises	Other improved	Other unimproved	Surface water
1990					
1995	76%	43%	33%	22%	2%
2000	77%	45%	32%	21%	2%
2005	81%	50%	31%	17%	2%
2010	86%	56%	30%	12%	2%
2015	90%	59%	31%	7%	3%

Source: JMP WHO/UNICEF 2015

Table 3: Comparative Rural Water Coverage

RURAL WATER				
Estimated coverage 2015 update				
Year	Benin Total improved	Chad Total improved	Tanzania Total improved	Senegal Total improved
1990	49%	37%	45%	41%
1995	54%	39%	45%	46%
2000	59%	41%	45%	52%
2005	63%	42%	45%	57%
2010	68%	44%	45%	62%
2015	72%	45%	46%	67%

Source: JMP WHO/UNICEF 2015

Table 4: Dominican Republic Rural Sanitation Data

RURAL SANITATION				
Estimated coverage 2015 update				
Year	Improved	Shared	Other unimproved	Open defecation
1990	62%	11%	8%	19%
1995	64%	12%	7%	17%
2000	67%	12%	7%	14%
2005	70%	13%	6%	11%
2010	73%	14%	4%	9%
2015	76%	14%	4%	6%

Source: JMP WHO/UNICEF 2015

Table 5: Cuba Rural Sanitation Data

RURAL SANITATION				
Estimated coverage 2015 update				
Year	Improved	Shared	Other unimproved	Open defecation
1990	68%	5%	22%	5%
1995	73%	5%	17%	5%
2000	77%	6%	12%	5%
2005	82%	6%	8%	4%
2010	86%	6%	6%	2%
2015	89%	7%	2%	2%

Source: JMP WHO/UNICEF 2015

Table 6: Parameter Values and Sources

Symbol	Parameter	Low	Mean	High	Notes
Common Parameters Across Interventions					
H	Household size	4.2	4.7	5.2	Haiti DHS 2012 data on rural household size across Departments
W_u	Market wage for unskilled labor ($/day)	0.50	1.25	2.00	Jeuland and Whittington (2009)
$\frac{W_u}{2}$	Value of time / market wage for unskilled labor	0.50	0.50	0.50	Given assumption as 50% of group average earnings under analysis
D_I	Diarrhea incidence (cases/pc-yr)	0.9	1.0	1.1	Total cases obtained from Global Burden of Disease, and weighted by the size of the rural population taken from the World Bank Data Bank and the percent or self-reported under 5 diarrhea rates as recorded in the DHS 2012 Women's Questionnaire.

$DALY_D$	Diarrhea DALY weight	0.09	0.11	0.14	A weighted value of severity is calculated by the responses on self-reported blood in child under 5's stool in the DHS 2012 Women's Survey in rural areas within Departments and the weighted DALY value based diarrhea severity rates from the WHO
D_D	Diarrhea case duration (days)	3.40	4.80	5.10	Lamberti LM, Fischer Walker CL, Black RE (2012)
CFR_D	Diarrhea case fatality rate (%)	0.03%	0.05%	0.06%	Global Burden of Disease 2015
LE	Current life expectancy	42.7	55.1	59.1	The Haiti DHS 2012 data was used to calculate a sex ratio across the rural Departments for average life expectancy, and min and max is taken from two other countries in the World Bank Low Income Country classification and using the percentage decrease in life expectancy as assumed in Haiti (Sierra Leone and Nepal).
V_{DALY}	Value of averted DALY ($)	820.00	2460.00	6560.00	Given weights and given GDP
r	Real, net of inflation, discount rate (%)	0.03	0.05	0.12	Given assumption
Borehole and Handpump with Community Management Parameters					
N_{BH}	# Households served by borehole	30	60	90	Whittington et al. 2009
Q_0	Baseline per capita consumption (daily)	23	19.5	13.6	Function of collection time from Whittington et al. 2009. If collection time is more than 1.5 hours per 20 liters, baseline consumption is assumed to be 5 liters per day, otherwise F= (30 – (50/3)*Collection Time
Q_T	Consumption after intervention (L/day)	28.4	25	21.6	Calculated as function of distance to water source
T_C^0	Status quo collection time (hrs/20L) - traditional source	0.42	0.63	0.98	Haiti DHS 2012
T_C^1	Collection time (hrs/20L) - improved source	0.10	0.30	0.50	Whittington et al. 2009
B_h	Percentage of aesthetic benefits that are actually health-related	0	25	50	Whittington et al. 2009
R_{AT}	Ratio of aesthetic & lifestyle benefits to time savings benefits	0.00	0.25	0.50	Whittington et al. 2009
R_{BH}	% Reduction of diarrhea due to borehole and handpump	0.00	0.11	0.22	Wolf et al. 2014
$P\text{-}BH$	Life of project (yrs)	10.00	15.00	20.00	Jeuland and Whittington 2009
M_{BH}	Management costs, annual, mostly non-pecuniary - village ($)	200.00	500.00	800.00	Jeuland and Whittington 2009
O_{BH}	O&M expenditures, repairs, annual ($)	50.00	100.00	150.00	Jeuland and Whittington 2009
CRF_{BH}	Capital recovery factor	0.08	0.10	0.15	$=(r*(1+r)^{P-BH})/((1+r)^{P-BH}-1$
C^P	Capital cost of borehole + handpump ($)	5000.00	6500.00	8000.00	Jeuland and Whittington 2009

C^{CAP}	Program costs - capacity building and management ($)	2000.00	3500.00	5000.00	Jeuland and Whittington 2009
Borehole and Handpump with Community Management plus Biosand Filter Parameters					
RFD	Rate of disuse (% of filters per year)	0.01	0.03	0.05	Jeuland and Whittington 2009
T^{C}	Transportation cost ($)	15.00	25.00	35.00	Jeuland and Whittington 2009
T_{M}	Maintenance time (minutes/wash)	10.00	15.00	20.00	Jeuland and Whittington 2009
WASH	Number of washes per year	2.00	6.00	10.00	Jeuland and Whittington 2009
T_{GROWTH}	Days before biofilm regrowth	3.00	5.00	7.00	Jeuland and Whittington 2009
R_{F}	Reduction of diarrhea from use of filter (%)	0.08	0.34	0.53	Wolf et al. 2014
P-F	Life of filter (yr)	6.00	8.00	10.00	Jeuland and Whittington 2009
T_{CM}	Community manager time (hr/hh-yr)	1.00	2.00	3.00	Whittington et al. 2009
D^{C}	Cost of biosand filter + program ($)	60.00	75.00	90.00	Jeuland and Whittington 2009
D_{USE}	Daily usage rate (%)	0.60	0.80	1.00	Jeuland and Whittington 2009
T_{T-F}	Training time (hrs/hh)	4.00	8.00	12.00	Whittington et al. 2009
CRF_{F}	CRF	0.14	0.15	0.20	$=(r*(1+r)^{P-F})/((1+r)^{P-F}-1$
***CLTS* Parameters**					
N_{H-OD}	Number of adults per household	2.2	2.9	3.2	Haiti DHS 2012 Rural data by Department
T_{OD}	Time to site of open defecation - status quo (min/trip)	10.00	15.00	20.00	Whittington et al. 2009
OD	Round trips to defecation site per day	0.75	1.00	1.25	Whittington et al. 2009
UP_{CLTS}	Uptake of latrines (%)	0.20	0.40	0.60	Whittington et al. 2009
LU	Usage of latrines (%)	0.50	0.75	0.90	Whittington et al. 2009
R_{CLTS}	% Reduction of diarrhea due to CLTS intervention	0.10	0.25	0.40	Mean of Wolf et al. 2014 and Whittington et al. 2009
P-CLTS	Life of project (yrs)	2.00	3.00	4.00	Whittington et al. 2009
RLD	Rate of disuse of latrines (%/yr)	0%	3%	6%	Whittington et al. 2009
$T_{T-NON-CLTS}$	Time in initial training (days/non-participating hh)	2.00	3.00	4.00	Whittington et al. 2009
T_{T-CLTS}	Time in initial training (days/participating hh)	5.00	10.00	15.00	Whittington et al. 2009
T_{CLTS}	Ongoing time expenses per year (hrs/participating hh-yr)	5.00	10.00	15.00	Whittington et al. 2009
C_{L}	Capital cost of one latrine ($)	10.00	20.00	30.00	Hutton and Varughese 2016
$C^{O\&M-CLTS}$	O&M cost: soap, water, pail, etc. (US$/yr)	2.00	5.00	8.00	Whittington et al. 2009
C^{P-CLTS}	Program costs - upfront and ongoing ($/hh per month)	0.20	0.30	0.40	Whittington et al. 2009
CRF_{CLTS}	CRF	0.35	0.37	0.42	$=(r*(1+r)^{P-F})/((1+r)^{P-F}-1$

Table 7: Borehole and Handpump with Community Management Sensitivity Analysis

	DALY Value (1x GDP/Capita)			DALY Value (3x GDP/Capita)			DALY Value (8x GDP/Capita)		
	Discount Rate (3%)	Discount Rate (5%)	Discount Rate (12%)	Discount Rate (3%)	Discount Rate (5%)	Discount Rate (12%)	Discount Rate (3%)	Discount Rate (5%)	Discount Rate (12%)
Total Benefits	$4.20	$4.06	$3.89	$5.20	$4.79	$4.27	$7.70	$6.61	$5.22
Total Costs	$2.00	$2.17	$2.87	$2.00	$2.17	$2.87	$2.00	$2.17	$2.87
Net Benefits	$2.20	$1.89	$1.01	$3.20	$2.62	$1.39	$5.71	$4.43	$2.34
B-C Ratio	2.10	1.87	1.35	2.60	2.20	1.49	3.86	3.04	1.82

Source: Authors' Calculations

Table 8: Household Results for Borehole and Handpump with Community Management plus Biosand Filter (with 3% Discount Rate, Value of DALY 3 x GDP per Capita)

	Household			
	No Intervention	Borehole and Handpump with Community Management plus the Biosand Filter	Change	% of Total
Benefits (US$/HH per month)				
Times savings ($)	$0	$3.51	+$3.51	46%
Time to collect water (hrs/20 liters)	.6	.3	+.3	
Time to collect baseline water consumption (hrs/month)	81	40	+40	
Baseline Consumption (liters)	2720	-	-	
Aesthetic benefits ($)	-	$0.19	+$0.19	2%
Water Consumption (liters)	2720	3490	+770	
Health Benefits ($)	-	$4.02	+$4.02	52%
DALY lost to Diarrhea (DALY)	$4*10^{-3}$	$2.7*10^{-3}$	$1.3*10^{-3}$	
Total Benefits	-	$7.72	+$7.72	
Costs (US$/HH per month)				
Capital Costs ($)	-	$0.89	-$0.89	30%
Community maintenance program ($)	-	$0.05	-$0.05	2%
Household time and maintenance time ($)	-	$0.02	-$0.02	1%
Costs from Borehole and Handpump ($)	-	$2.00	-$2.00	67%
Total Costs	-	$2.96	$2.96	
Net Benefits	-	$4.76	$4.76	
B-C Ratio	-	2.61	2.61	

Source: Authors' Calculations

Table 9: Borehole and Handpump with Community Management plus Biosand Filter Sensitivity Analysis

	DALY Value (1x GDP/Capita)			DALY Value (3x GDP/Capita)			DALY Value (8x GDP/Capita)		
	Discount Rate (3%)	Discount Rate (5%)	Discount Rate (12%)	Discount Rate (3%)	Discount Rate (5%)	Discount Rate (12%)	Discount Rate (3%)	Discount Rate (5%)	Discount Rate (12%)
Total Benefits	$5.05	$4.68	$4.21	$7.72	$6.65	$5.32	$14.56	$11.58	$7.82
Total Costs	$2.96	$3.21	$4.20	$2.96	$3.21	$4.20	$2.96	$3.21	$4.20
Net Benefits	$2.10	$1.47	$0.01	$4.76	$3.45	$1.12	$11.60	$8.37	$3.62
B-C Ratio	1.71	1.46	1.00	2.61	2.07	1.27	4.92	3.61	1.86

Source: Authors' Calculations

Table 10: Household Results CLTS (3% Discount Rate, Value of DALY 3 x GDP per Capita)

	Household			
	Baseline	Borehole and Handpump Only	Change	% of Total
Benefits (US$/HH per month)				
Times savings ($)	$0	$0.49	+$0.49	33%
Time to open defecation site (hrs/month)	21.6	6.3	+15.3	
Health Benefits ($)	-	$1.00	$1.00	67%
DALY lost to Diarrhea (DALY)	$4*10^{-3}$	$3.7*10^{-3}$	$3*10^{-4}$	
Total Benefits	-	$1.49	+$1.49	
Costs (US$/HH per month)				
Capital Costs ($)	-	$0.24	-$0.24	22%
Program Costs ($)	-	$0.30	-$0.30	27%
Operation and Maintenance Costs ($)	-	$0.42	-$0.42	38%
Time Costs ($)	-	$0.13	-$0.13	12%
Total Costs	-	$1.09	$1.09	
Net Benefits	-	$0.40	$0.40	
B-C Ratio	-	1.37	1.37	

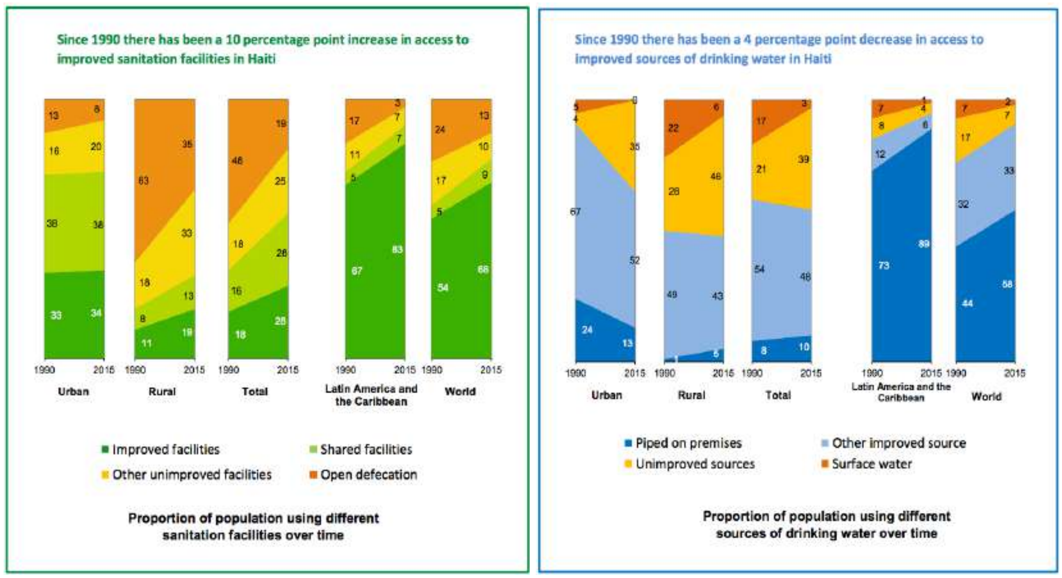
Source: Authors' Calculations

Table 11: CLTS Sensitivity Analysis

	DALY Value (1x GDP/Capita)			DALY Value (3x GDP/Capita)			DALY Value (8x GDP/Capita)		
	Discount Rate (3%)	Discount Rate (5%)	Discount Rate (12%)	Discount Rate (3%)	Discount Rate (5%)	Discount Rate (12%)	Discount Rate (3%)	Discount Rate (5%)	Discount Rate (12%)
Total Benefits	$0.82	$0.73	$0.62	$1.49	$1.21	$0.87	$3.14	$2.42	$1.50
Total Costs	$1.09	$1.10	$1.15	$1.09	$1.10	$1.15	$1.09	$1.10	$1.15
Net Benefits	-$0.26	-$0.37	-$0.53	$0.40	$0.12	-$0.28	$2.06	$1.32	$0.35
Benefit-Cost Ratio	0.76	0.67	0.54	1.37	1.11	0.76	2.90	2.20	1.31

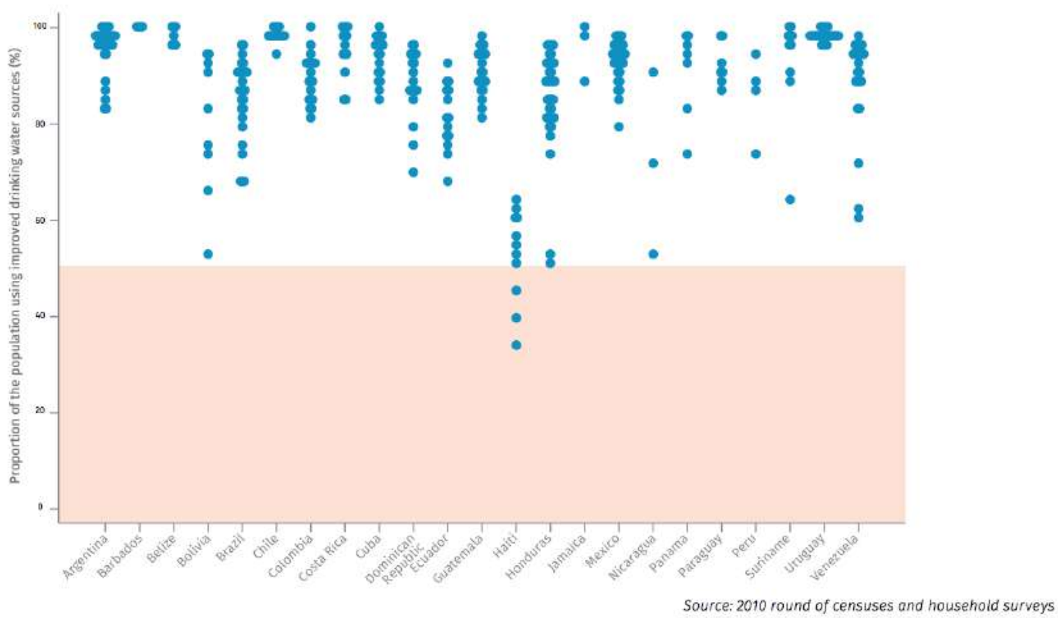
Source: Authors' Calculations

Figure 1: JMP Sanitation and Water Coverage Rates in Haiti 2012



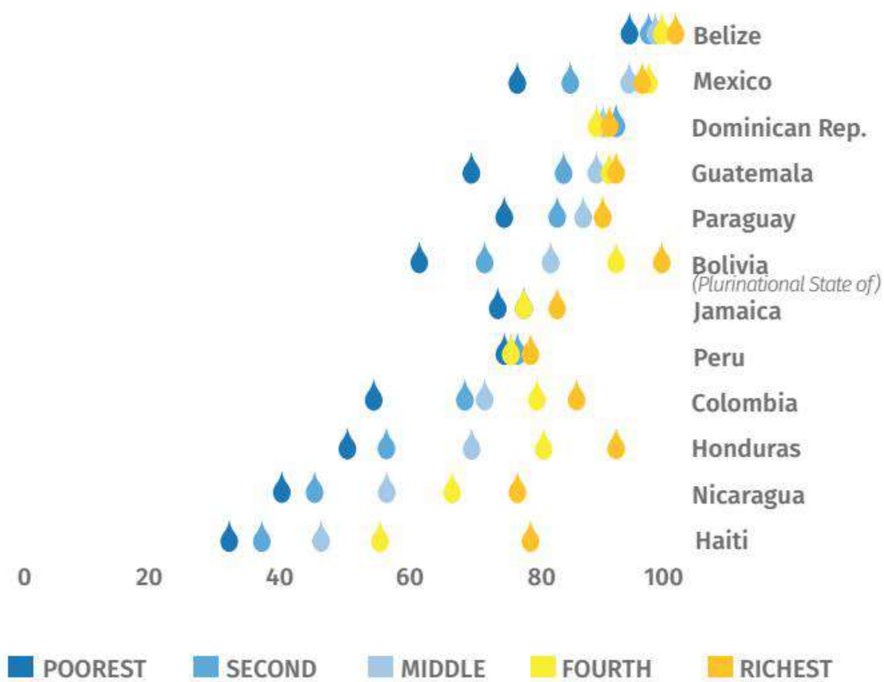
Source: JMP WHO/UNICEF 2015

Figure 2: Coverage with Improved Water Sources by Administrative Region in Latin America and the Caribbean



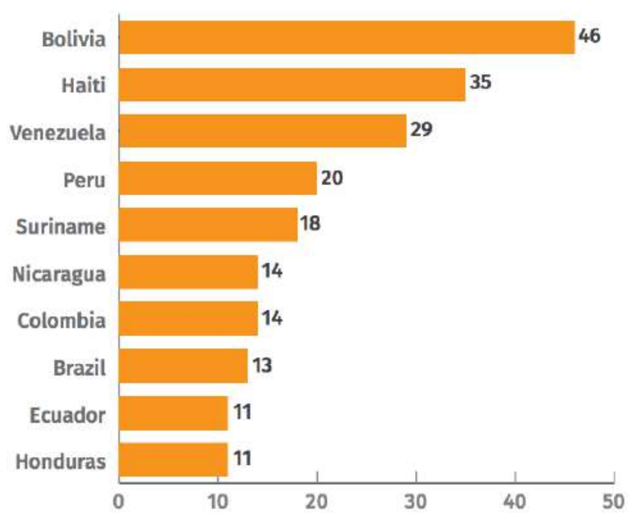
Source: JMP WHO/UNICEF 2016

Figure 3: Use of improved drinking water by rural wealth quintile (%)



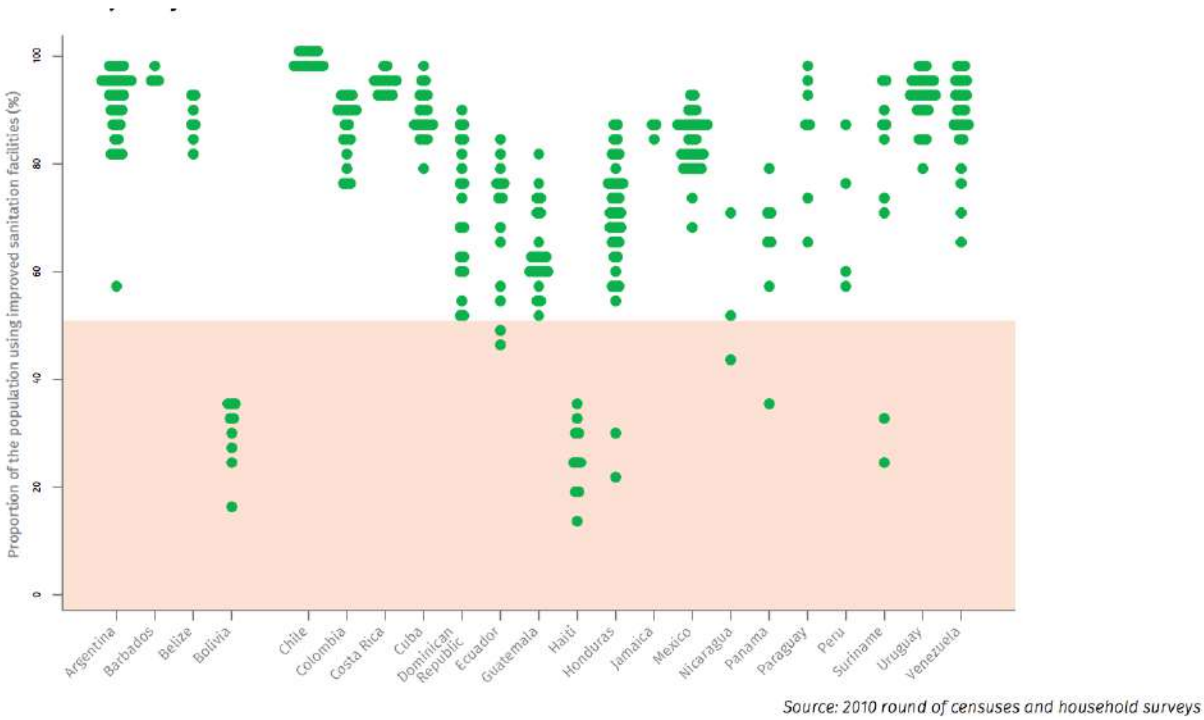
Source: JMP WHO/UNICEF 2016

Figure 4: Percent of Rural Population Practicing Open Defecation



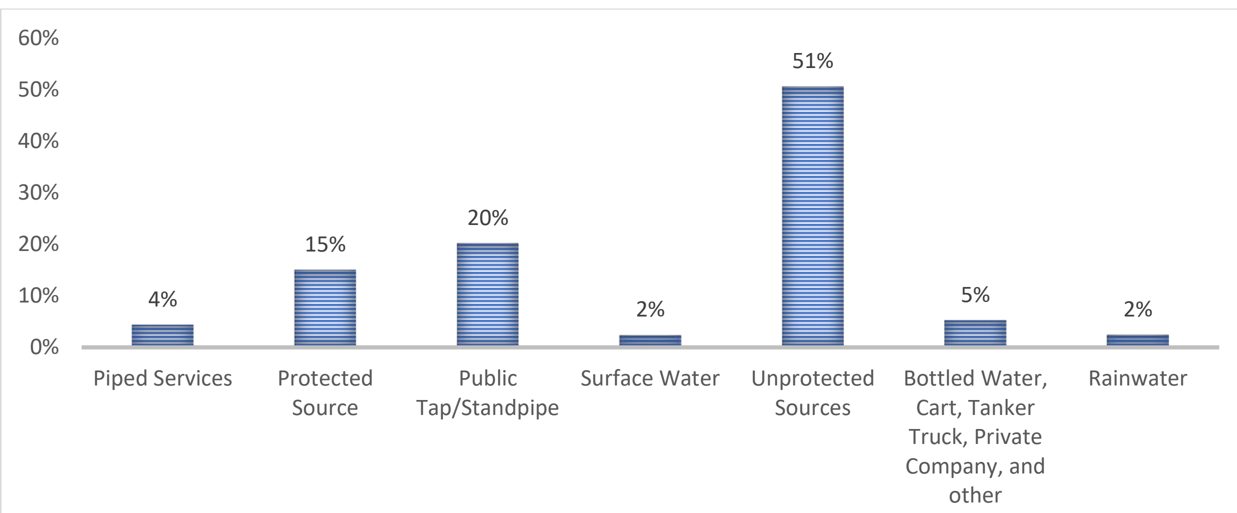
Source: JMP WHO/UNICEF 2016

Figure 5: Coverage with Improved Sanitation Facilities by Administrative Region in Latin America and the Caribbean



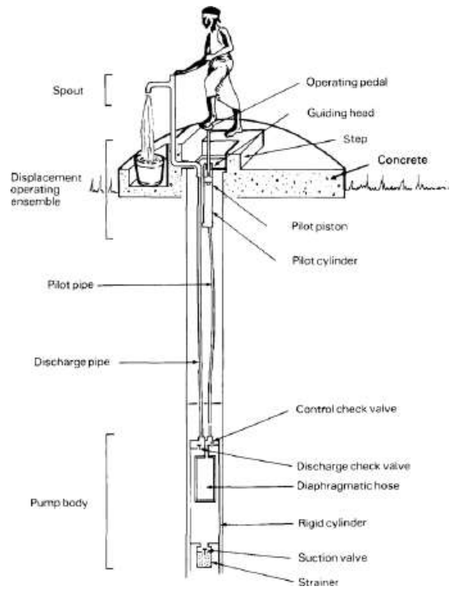
Source: JMP WHO/UNICEF 2016

Figure 6: Rural Households Primary Water Source



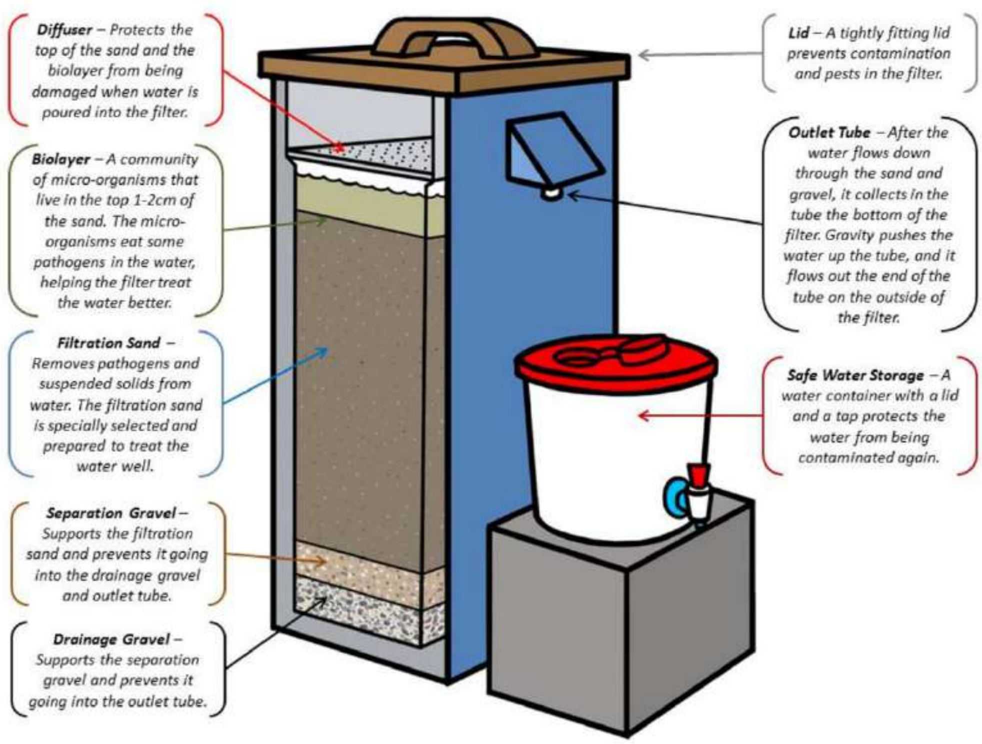
Source: EMMUS V 2012

Figure 7: Components of Borehole and Handpump



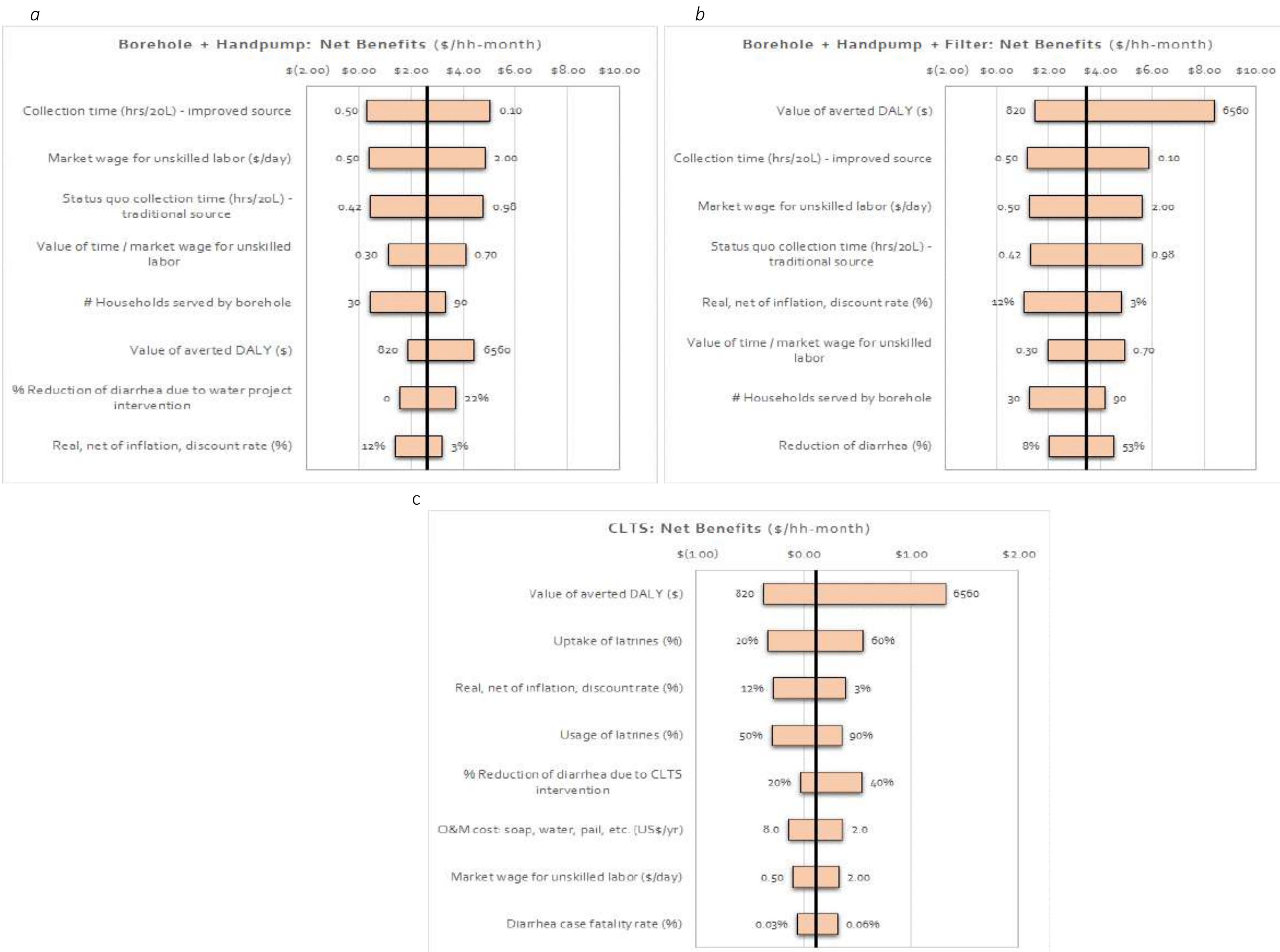
Source: UN Food and Agriculture Organization

Figure 8: How a Biosand Filter Works



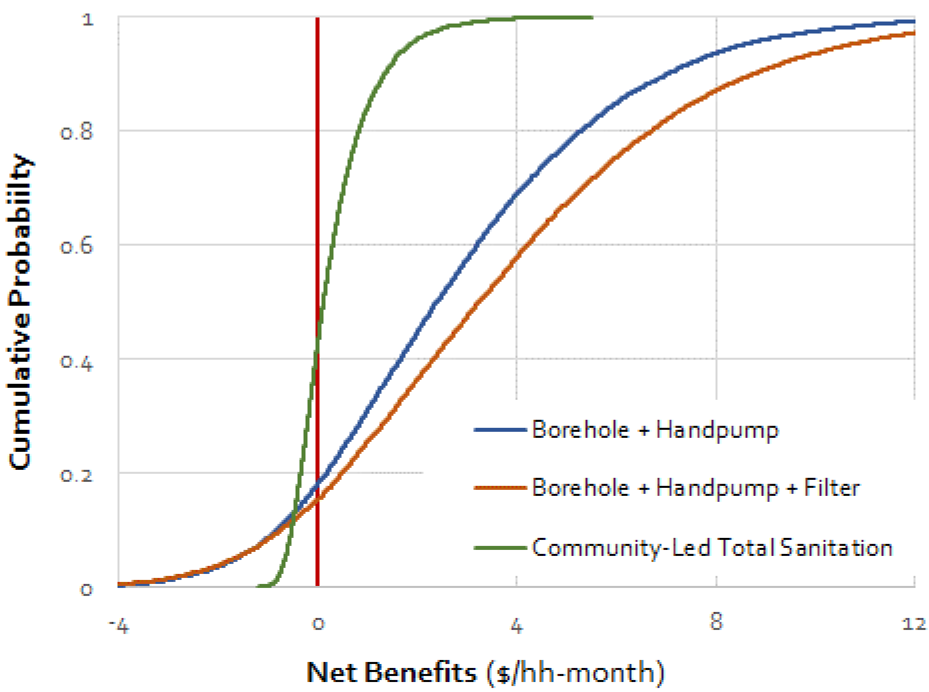
Source: CAWST.org

Figure 9a-c: One-way sensitivity analysis for the WASH intervention options



Source: Authors' calculations

Figure 10: Multiple parameter Monte Carlo analysis for the WASH intervention options



Source: Authors' calculations

Particularities of Rural Areas in Haiti: Strategies for Implementation of Interventions

Haiti Priorise

Alain Perodin
Advisory Board Member

Contents

Introduction

This article aims to highlight the prevailing situation in rural communities in Haiti, including the opportunities and especially the difficulties faced by the inhabitants of these communities, both at the economic and at the socio-cultural level. These meager opportunities and the significant constraints affecting the various Haitian rural communities, which have many similarities, are very important factors to be taken into account for:

1. Determining key priorities and feasible interventions to achieve sustainable results

2. Understanding the delay in the progress of these communities, despite the many and varied interventions of local and external cooperative efforts

3. Better addressing the possible responses to foreigners or even the sectoral character and mentality

4. Possibly providing a framework for the implementation of interventions at the community level

In this article, we will summarize, on the one hand, the current situation in Haiti to better understand the macro context. On the other hand, with the meager data available on rural communities (generally neglected), we will present their common characteristics and, finally, attempt to propose strategies for realizing priority actions, these strategies being usable in different fields of intervention. In other words, we are going to propose some methods drawn from experience with the Haitian rural mentality to facilitate the implementation of interventions.

The points related in this text will mainly come from a review of available local data, but also from field experience across multiple rural communities in the country.

The aim of this article is to give a truly local perspective to the implementation of planned rural interventions in Haiti (the considerations to be taken into account, seen from a local perspective and habituated to the various varied characteristics of the terrain).

Context

Haiti occupies the western third of the island of Hispaniola, situated between the Atlantic Ocean and the Caribbean Sea. It is a tropical country, mostly mountainous. Haiti is the second most populous country in the Caribbean, just behind Cuba[1] with about 52% of the population living in urban areas.https://fr.wikipedia.org/wiki/D%C3%A9mographie_d%27Ha%C3%AFti - cite_note-3

Vulnerability to natural disasters is a very serious disadvantage. Two-fifths of Haitians remain vulnerable to frequent natural disasters, exacerbated by widespread deforestation across the country[2]. The main natural disasters are frequent hurricanes (with a hurricane season extending

[1] (Haiti, 2017)
[2] Idem

from May to November), which always have a significant negative impact on rural communities, and earthquakes. The most recent is that of October 2016, which caused enormous material damage and a significant blow to the national economy.

Haiti suffers from extreme poverty, with considerable consequences. More than 6 out of 11 million Haitians (59%) live below the poverty line of 2.42 dollars per day, and more than 2.5 million (24%) live below the extreme poverty line of 1.23 dollars per day. The level of indebtedness of households living below the poverty line reaches 80% in Port-au-Prince and 94% in rural areas affected by the January 2010 earthquake. In Haiti in 2011, 13% more of very poor households were indebted than before the earthquake of January 12, 2010[3].

The depreciation of the national currency, the gourd, only worsens households' economic situation, with a current rate of 69 HTG for 1 USD. Haiti also remains one of the most unequal countries on the planet, with a Gini index of 0.61 in 2012[4].

Access to basic services is very limited in Haiti, particularly in rural areas. The populations of remote rural areas do not have access to essential services such as water and sanitation, health services, education and so on, which causes the priorities of these communities to be many and varied.

At the national level, 40% of the population has no access to safe drinking water, 80% has no access to sanitary facilities and 40% lacks access to health services. Other problems include hygiene and food insecurity, with more than 20% of children under 5 years of age suffering from chronic malnutrition and 65% suffering from anemia.

From an educational point of view, about 55% of men and 51% of women are literate, with a high concentration in urban areas. Public and free education accommodate only 20% of the school population, which makes Haiti the Caribbean country with the highest rate of illiteracy[5].

[3] (HL/Haitilibre)
[4] (Haiti Presentation, 2017)
[5] (Systeme educatif d'Haiti, 2016)

Rural Communities in Haiti: Characteristics

Approximately 5 million Haitians live in rural areas. Rural communities in Haiti have the following characteristics in general [6]:

- Difficult geographic access
- Very low average socio-economic level
- Very limited access to basic social services
- Culturally different and very changeable, according to the various localities, even neighboring localities
- Low average educational level
- Increased vulnerability to natural disasters
- Irregular income based mainly on agriculture and livestock, while it should be noted that arable land is very limited because of the deforestation that remains a source of income
- Lack of access to credit
- Chronic indebtedness of the population
- Perception of disease highly influenced by culture
- Sectoral character[7]

In other words, to summarize, Haitian rural communities generally live in restriction/poverty and sometimes even extreme restriction/poverty with notable consequences, such as:

- Interruption of children's education or simply lack of schooling for children
- Destruction of trees/deforestation for the manufacture of charcoal

[6] The rural environment in Haiti varies from one community to another, but in general the characteristics cited are common to them, however they may be present at different levels.
[7] This sectorisation is both geographical and cultural. This means that neighboring rural localities may not share the same problems and may have distinctly different perceptions of solutions to common problems.

- Increased vulnerability
- Rural exodus/growth of shanty towns in urban areas
- Short-term loans
- Decreased access to basic services
- Creation of a vicious circle of poverty

Rural communities face multiple problems related to the various characteristics mentioned above, and these problems are faced at different levels depending on the communities studied. However, the characteristics specified are common to these communities. This means that some interventions, such as WASH, may not represent urgent priorities for certain localities, hence the common failures recorded in some experiments described in the report (maintenance of wells). The low level of education also represents a significant obstacle to the implementation and sustainability of interventions.

Again, inflation associated with the continued depreciation of the gourd weakens the purchasing power of the country's households and reduces access by the population to basic social services and, by extension, will reduce the commitment and the decision to invest in certain types of interventions. The lack of visible and concrete impact of a WASH intervention can cause a lack of engagement of by population.

This being said, another point to consider is the Haitian mentality or that of the most disadvantaged. The interventions with concrete results are generally prioritized and better received by the beneficiaries, especially the interventions concerning the visible problems cited that they have faced for too long. For example, for a rural community whose income is based on agriculture (as in most rural communities), the distribution of fertilizers will have far more impact on the population than WASH interventions. Hence, by extension, weak engagement of the beneficiary community will result in this type of project.

The Issue of WASH in Haiti

National coverage in Haiti for drinking water is 64% with a rate of 77% in urban areas and only 48% in rural areas [8]. About 3 million Haitians draw drinking water from rivers and unprotected sources, thus the water is of questionable quality, contributing to the prevalence of diarrhea in children.

The rate of access to basic sanitation is 26%. At the national level, 23% of the population practice open defecation, 41% of the population in rural areas[9]. These rates are the basis for possible transmission of fecal-oral diseases, increased vulnerability of populations, and possibly impoverishment linked to disease burden.

With such stable rates of access to water and sanitation in recent years, it is pertinent to wonder about the importance that rural populations attach to these WASH problems, especially in comparison to the many other problems they face.

Recommendations

Preconditions must be put in place to ensure successful WASH interventions in rural Haiti. Below are the principal recommendations, which are needed in order to increase efficiency and reduce the risk of failure. The practical recommendations below concern parallel and indirect actions that can increase the effectiveness of interventions.

Psycho-Socio-Economic Study of Each Targeted Community

A successful intervention in a rural community is not necessarily adaptable to all rural communities, hence the emphasis on the specific characteristics of each environment. The results are not adaptable for various reasons, such as:

- Different economic level (especially) related to the decision to invest in this cost
- Another more urgent problem (nutrition, visible health problems, etc.)

[8] (Haiti Eau et assainissement les defis)
[9] Idem

- Perception of the WASH problem and impact on the population
- Visible impact of the problem of water and sanitation in the community
- Perception of the external actors imposing a project in their environment
- Educational level

In this sense, it is essential to study local tendencies by means of surveys or focus groups in order to better identify the support for the most urgent and relevant problems, taking into account local characteristics. The issue of access to water and sanitation for rural communities is important, but may not be a vital area of intervention, given the many difficulties encountered. They may also be relevant to some communities and not to others, who are not aware of or do not have any knowledge of the domain, resulting in low engagement, a source of intervention failure.

It is necessary then to establish a list of priorities to be filled and, of course, to address them according to the importance accorded by the population. Hence the setting of prerequisites for other problems to resolve.

Engagement of the Beneficiary Population

Frequent meetings with beneficiary populations or representatives/leaders are needed for a full discussion of the problem under study. It is imperative to gather grievances and explore their views on the problem of access to water and sanitation. They are the real elements in contact with the problem and their solutions can sometimes be, on the one hand, more relevant and, on the other, contrary to those proposed by the interventions.

It is not uncommon for WASH interventions to have already been implemented in their community and, in this case, it is imperative to discuss with them the likely causes of failures. Moreover, the proposed interventions (remotely in this case) may not reflect or solve the problem they are facing. It is therefore indispensable to gather their proposed solutions to problems and to see how these align with the proposed interventions.

Decisions made at a distance from the reality (different for each community), in offices without any prior study of the real needs and the engagement of the beneficiaries, are doomed to failure. It should be noted that many times a problem may seem in need of urgent solution by the intellectual community (for example, sanitation in this case) and not be a concern for the beneficiary community (see literature review), hence the lack of commitment and engagement.

These meetings will align the proposed interventions with the needs and solutions of the communities. The ultimate effect will be the effective ownership of the intervention by the beneficiaries and the assurance of the sustainability of the intervention and of permanent commitment.

Multi-sectoral Approach

It is essential to involve all sectors of local life in the decision-making process (CASEC, religious, etc.) with a view to addressing the various problems, in particular the problem of water and sanitation, in an inter-sectoral and integral way.

Education

After ensuring that the water and sanitation problem is a priority issue for beneficiaries, emphasis should be placed on educating the population and community leaders:

1. For community leaders (with responsibility)
2. The population in general

The educational aspect is a pillar to ensuring a successful intervention. On the one hand, there is the education of community leaders so that, after taking ownership of the idea, they serve as mediators for the community. It should be noted that in "closed" rural communities, these leaders play a truly authoritarian role and can involve the community in the implementation of projects and ensure respect for the principles and conditions governing the use of interventions. Leaders are very influential and can mobilize their peers for the successful implementation of interventions once accepted. However, it is necessary to avoid creating a perverse effect by giving too much responsibility to a leader, who is a risk for appropriating the well, for example, which could be the basis for conflicts. Alternatively, give responsibility to four or five leaders.

Before, during and after the implementation of the intervention, permanent education of the beneficiaries is necessary (through churches, for example) to raise awareness about the benefits associated with the intervention. In general, behavior change takes time, but this is an investment in long-term awareness that is necessary for genuine sustainability.

Conclusion

The domain of water and sanitation is a relevant area to take into account when intervening in rural areas in Haiti. However, it is certainly not the only, and sometimes not the highest, priority. Hence the importance that must be placed on the peculiarities unique to each community.

The various recommendations proposed in this article are intended to better focus WASH interventions and, above all, to reduce the probable risks of failure. In summary, the main points to retain are:

- Attention to the various peculiarities of rural communities
- Study of the perception of the problem among beneficiaries
- Active engagement of the population in the search for solutions
- Continuing education on the benefits of interventions
- The inter-sectoral approach to the problem and the search for solutions
- Above all, the determination of the position of the intervention in relation to the priorities of the communities

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Haiti faces some of the most acute social and economic development challenges in the world. Despite an influx of aid in the aftermath of the 2010 earthquake, growth and progress continue to be minimal, at best. With so many actors and the wide breadth of challenges from food security and clean water access to health, education, environmental degradation, and infrastructure, what should the top priorities be for policy makers, international donors, NGOs and businesses? With limited resources and time, it is crucial that focus is informed by what will do the most good for each gourde spent. The Haïti Priorise project will work with stakeholders across the country to find, analyze, rank and disseminate the best solutions for the country. We engage Haitans from all parts of society, through readers of newspapers, along with NGOs, decision makers, sector experts and businesses to propose the best solutions. We have commissioned some of the best economists from Haiti and the world to calculate the social, environmental and economic costs and benefits of these proposals. This research will help set priorities for the country through a nationwide conversation about what the smart - and not-so-smart - solutions are for Haiti's future.

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