PHOTO CREDIT: JESSICA TRIBBE

COMMUNITY-LED TOTAL SANITATION PERFORMANCE ENVELOPE STUDY

FINAL REPORT

FEBRUARY 2022

This document was produced for review by the United States Agency for International Development. It was prepared by Tetra Tech.

Prepared for the United States Agency for International Development by the Water, Sanitation, and Hygiene Partnerships and Learning for Sustainability (WASHPaLS) project under Task Order Number AID-OAA-TO-16-00016 of the Water and Development Indefinite Delivery Indefinite Quantity Contract (WADI), contract number AID-OAA-I-14-00068.

Tetra Tech Contacts:

Morris Israel, Project Director
morris.israel@washpals.org

Jeff Albert, Deputy Project Director
jeff.albert@washpals.org

Lucia Henry, Project Manager
lucia.henry@tetratech.com

Tetra Tech
1320 N. Courthouse Road, Suite 600, Arlington VA 22201
Tel: 703-387-2100 Fax: 703-414-5593
www.tetratech.com/intdev

COMMUNITY-LED TOTAL SANITATION PERFORMANCE ENVELOPE STUDY

FINAL REPORT

FEBRUARY 2022

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

CART	Classification and Regression Tree
CLTS	Community-Led Total Sanitation
CI	Confidence Interval
CRSHIP	Cambodia Rural Sanitation and Hygiene Improvement Programme
FGD	Focus Group Discussion
fsQCA	fuzzy-set Qualitative Comparative Analysis
GC	Global Communities
GPS	Global Positioning System
IDI	In-depth Interview
JMP	Joint Monitoring Programme
M&E	Monitoring and Evaluation
MIS	Management Information System
NGO	Nongovernmental Organization
OCHA	Office for the Coordination of Humanitarian Affairs
ODF	Open-Defecation Free
OR	Odds Ratio
PP	Percentage Point
RCMRD	Regional Centre of Mapping of Resources for Development
RCT	Randomized Controlled Trial
RING	Resiliency in Northern Ghana
SDG	Sustainable Development Goal
UNICEF	United Nations International Children's Emergency Fund
USAID	United States Agency for International Development
W4H	WASH for Health
WASH	Water, Sanitation, and Hygiene
WASHPaLS	Water, Sanitation, and Hygiene Partnerships and Learning for Sustainability
WHO	World Health Organization
WSSCC	Water Supply and Sanitation Collaborative Council
ZSHP	Zambia Sanitation and Hygiene Program

EXECUTIVE SUMMARY

Community-led total sanitation (CLTS) is the most widely employed approach to reduce open defecation in rural areas. It has been implemented in some manner in nearly 60 countries and is part of the national sanitation strategy in approximately half of those countries (Zuin et al., 2019). Both contextual and implementation factors can bear upon CLTS program performance and success, forming a "performance envelope" of factors under which the intervention is more likely to succeed. Examining these factors carefully offers insights for improving decision making on where and how CLTS programs are delivered in the future.

Through the CLTS Performance Envelope research activities, the Water, Sanitation, and Hygiene Partnerships and Learning for Sustainability (WASHPaLS) project examined how local context and program implementation strategies affect CLTS outcomes across multiple countries. The aim of this research is to provide governments, donors, and implementing organizations with insights to i) better target CLTS activities to areas with the highest likelihood of success and ii) adapt implementation strategies to maximize the chances for their success and sustainability.

Our research answered two overarching questions: (1) what contextual factors outside the control of implementers influence CLTS success; and (2) what implementation strategies are successful at achieving and sustaining sanitation gains? For Question 1, we employed a quantitative approach to analyze large CLTS implementation datasets in four countries (Cambodia, Ghana, Liberia, and Zambia). For Question 2, we employed a qualitative approach to allow for in-depth investigation of community-level dynamics in two countries (Cambodia and Ghana). Our research questions have evolved since their initial conception due to data limitations.

Key takeaways. Our quantitative research demonstrated that there is indeed a set of contextual factors associated with CLTS performance (both positive and negative) irrespective of the implementation approach, but that the set of favorable contextual factors is country specific. One exception was small community population size, which was consistently associated with CLTS success in all four study countries. Similarly, in our qualitative research, we found that successful implementation strategies leading to sustained sanitation improvements varied substantially between the two case study countries, and that strategies that have a positive influence in one country can have a negative influence in another, such as the involvement of community leaders.

Quantitative analysis. WASHPaLS acquired six large community monitoring and evaluation datasets from CLTS programs in rural Cambodia, Ghana, Liberia, and Zambia. Following data cleaning and processing, we coupled these datasets with publicly available information derived from satellite imagery, surveys, and hydrogeological models to quantify associations between 18 contextual factors and open-defecation free (ODF) achievement. In one country—Zambia—we also included one implementation factor (the number of reporting periods over the longitudinal record). We also examined correlations between contextual factors and ODF sustainability in Zambia. We found that the contextual predictors of CLTS performance varied among countries, with the exception of community population size: small communities were more likely to achieve ODF in every country studied. Remoteness and literacy were associated with CLTS outcomes, but the direction of association differed across the four countries, though higher remoteness was generally favorable in all three African countries. A detailed technical description of this work is provided in Stuart et al. (2021).

To translate findings into practical guidance for CLTS implementers, WASHPaLS identified favorable contextual conditions derived from "split point" values. Split points are estimated threshold values for favorable contextual factors. To improve cost-effectiveness, implementers can use split point values to

identify areas where CLTS interventions are more likely to have the highest probability of success (Radin et al., 2019), and can consider other approaches in areas likely to have lower probability of success.

Qualitative analysis. We qualitatively examined community-level implementation factors linked to high latrine coverage and consistent use in communities that participated in CLTS programs at least two years prior in Cambodia and Ghana. We applied fuzzy-set Qualitative Comparative Analysis (fsQCA) to data collected from 13 communities in Cambodia and 15 communities in Ghana to understand successful CLTS implementation strategies related to follow-up, involvement of local leaders, and pro-poor support. In Cambodia, latrine coverage was highest in communities whose commune officials and traditional leaders combined active engagement with less prescribed and gentler strategies for promoting latrine construction. Latrine use was less consistent among communities with intense pressure from commune and traditional leaders, less follow up, and more external financial support. In contrast, in Ghana, very active traditional and natural leaders (community members who volunteer to be "champions" for CLTS), high follow-up by CLTS program facilitators, high levels of internal support, and continued follow-up activities by natural leaders were all linked to higher latrine coverage and use. Marked differences in responses to CLTS programming between Cambodia and Ghana indicate that rural communities do not react equally to sanitation behavior change interventions. Understanding and accounting for community reactions to CLTS implementation strategies is therefore critical for fostering long-term sustainability beyond short-term achievements. Further description of this work is published in Tribbe et al. (2021).

The exact analyses conducted in this study may not be practical for implementers to recreate without reliable, clean data on program outcomes and the capacity to conduct rigorous statistical analysis. However, this study proves that this analysis is possible and offers opportunities for more context-specific programming using data. The country-specific nature of favorable contexts and implementation strategies should encourage sanitation planners, funders, and implementers to more carefully collect and utilize monitoring data along with contextual data to maximize CLTS performance in their specific country context. It is equally important to tailor implementation strategies to those contexts. Implementers should pay particular attention to the collection of baseline data (prior to triggering events) and include Global Positioning System (GPS) locations and dates along with all records. WASHPaLS built the SanPlan Tool to help implementers assess the contextual situations in their project areas. SanPlan is an interactive web tool that overlays map data from 13 high-resolution indicators. In the absence of recreating the quantitative analysis described in this report, the user can use their anecdotal, localized knowledge to filter the map and locate the areas of interest, budget, and design their sanitation programs.

1.0 BACKGROUND

1.1 COMMUNITY-LED TOTAL SANITATION (CLTS)

The United Nations Sustainable Development Goal (SDG) 6.2 calls for ending open defecation globally by 2030. Improving access to, and use of, sanitation facilities is critical for improving public health and enhancing the privacy, safety, dignity, and well-being of individuals, particularly women (Sahoo et al., 2015; Schmidt, 2014). Since 2015, the proportion of the global population practicing open defecation has decreased from 10 percent to 9 percent (World Health Organization [WHO]/United Nations International Children's Emergency Fund [UNICEF] JMP, 2021). Despite this progress, as of 2020, approximately 494 million people still practiced open defecation, 92 percent of whom resided in rural areas of Sub-Saharan Africa and Asia (WHO/UNICEF JMP, 2021). While investments in sanitation must accelerate to remain on track to achieve SDG 6.2, increasing the effectiveness of rural sanitation policies and programs is equally critical for meeting United Nations SDG targets and improving public health.

CLTS is the most widely employed approach to reduce open defecation in rural areas. CLTS has been implemented in some manner in nearly 60 countries and is part of the national sanitation strategy in approximately half of those (Zuin et al., 2019). Although the approach has been credited with the achievement of open-defecation free (ODF) districts and regions in sub-Saharan Africa and Asia (Zuin et al., 2019), two meta-analyses that summarized the impact of CLTS and related sanitation interventions on latrine coverage and open defecation found that the gains attributable to CLTS are modest. Garn et al. (2016) found an average increase in latrine coverage of 12 percentage points (pp) (95 percent confidence interval [CI]: -2pp, 17pp) across seven studies, and a more modest, but statistically significant, 6pp increase (95 percent CI: 1pp, 11pp) in three studies that combined CLTS with another intervention (Garn et al., 2016). Whittington, Radin, and Jeuland (2020) found an average increase in latrine coverage of 16pp across 11 CLTS or CLTS-inspired interventions and an average reduction in open defecation of 13pp (reported in eight of the 11 studies) (Whittington et al., 2020). Given these limited gains in latrine coverage and use, researchers and implementers have been investigating how to adapt CLTS programming to improve outcomes, including combining with other approaches (USAID, 2018b; Venkataramanan et al., 2018; Mukherjee, 2011).

Prior studies have identified several aspects of CLTS program implementation as critical to both achieve and sustain ODF communities; among them: (i) the involvement of local and community leaders, meaning the role that Village Chiefs, traditional leaders, or natural leaders play in persuading households to stop open defecation and construct latrines; (ii) intensity and duration of post-triggering follow-up (that is, the frequency and strategies used when actors involved in CLTS implementation return to households to convince them to construct or maintain latrines); (iii) financial and in-kind support to poor and vulnerable households to help them construct or maintain latrines; and (iv) access to nearby supply chains (USAID, 2018b; Kullmann et al., 2011). More generally, practitioners and researchers agree that the performance of CLTS varies greatly depending on community characteristics, the implementation strategies employed, and the enabling environment (USAID, 2018b; Venkataramanan et al., 2018; Kullmann et al., 2011). Refining our understanding of how context and program implementation affect CLTS outcomes would allow governments, donors, and implementing organizations to better target CLTS activities to areas with the highest likelihood of success and adapt implementation strategies to maximize the likelihood that gains from CLTS programs are sustained.

1.2 RESEARCH OBJECTIVES AND APPROACH

Both contextual and implementation factors can bear upon CLTS program "performance." Examining those factors carefully can improve how future CLTS and related rural sanitation programs are delivered.

The United States Agency for International Development's (USAID) Water, Sanitation, and Hygiene Partnerships and Learning for Sustainability (WASHPaLS) project conducted in-depth quantitative research in four countries (Cambodia, Ghana, Liberia, and Zambia) and qualitative research in two of them (Cambodia and Ghana) to add to the knowledge base on the CLTS performance envelope and support global efforts to achieve SDG 6.2. In the context of this research, the term "Performance Envelope" refers to a set of enabling factors influencing the ability of CLTS to reduce open defecation. These factors include characteristics of the community and of the broader local environment (i.e., exogenous factors that are beyond the capacity of program implementers to control), as well as modalities of program implementation that are controllable.

WASHPaLS' CLTS performance envelope research was designed to address the two research questions described below (more information can also be found in the study's inception report [USAID, 2018a]). We note how the final methods and results deviated from our original intentions.

First: what is the relative importance of contextual characteristics compared to program implementation for ODF achievement? Given that many programs now use CLTS as a region-wide approach, this question is timely and policy relevant. We hypothesized that contextual factors outside the control of implementers (e.g., poverty level, demographics, accessibility, hydrogeology, baseline latrine coverage, and water scarcity) can affect CLTS performance independent of implementation quality.

We translated this broad research question into the following two operational questions:

Question 1a. Are some contextual characteristics strong predictors of ODF achievement?
Question 1b. In instances where CLTS succeeded despite unfavorable contextual conditions, what implementation strategies were utilized to mitigate the context?

To answer Question 1a, we analyzed large datasets from CLTS programs in Cambodia, Ghana, Liberia, and Zambia in combination with publicly available information derived from satellite imagery, surveys, and hydrogeological models to quantify associations between contextual factors and CLTS program outcomes. Because we relied on large-scale (and sometimes multi-program) datasets likely capturing various degrees of implementation quality, our statistical analysis allowed identifying contextual predictors that emerged without consideration of varying implementation quality.

Due to data limitations specifically for implementation quality, the research question was modified to be, *"What contextual factors outside the control of implementers influence CLTS success*"? Additionally, we had hoped to use qualitative phone interviews with program implementers to address question Q1b, but the information that we collected unfortunately did not allow us to answer it adequately. This report, therefore, does not address this question.

This is the first effort to directly measure the effect of contextual (non-program) factors on specific quantitative measures of CLTS performance. Past studies have been largely based on anecdotal evidence rather than in-depth statistical analyses.

Second: What are the most successful implementation strategies to achieve and sustain ODF and promote the construction of durable latrines? Several aspects of program implementation have been identified as crucial to both achieving and sustaining ODF. However, the diversity of strategies that have been used and their relative effectiveness have not been well investigated.

This broad research question was translated into the following three operational questions:

Question 2a. What strategies do local leaders use to mobilize their communities?
Question 2b. What type of follow-up is needed to achieve and maintain ODF status in a community?
Question 2c. What approaches to pro-poor support are the most successful?

To assess the effectiveness of CLTS implementation strategies related to involvement of local leaders, follow-up, and pro-poor support, we applied fuzzy-set Qualitative Comparative Analysis (fsQCA) to in-depth qualitative data collected from 13 communities in Cambodia and 15 communities in Ghana triggered under a CLTS intervention at least two years prior. We focused on latrine coverage and use but were not able to investigate latrine durability as initially proposed in the above research question because we only found durable latrines in one country (Cambodia), and their construction could not be directly attributed to CLTS due to the presence of numerous market-based sanitation programs.

1.3 PARTNER PROGRAMS

This research was made possible thanks to collaborations with six rural sanitation programs in four countries who responded to our global call for data. Table 1 details key statistics for the study programs aggregated per country. In many of these sanitation programs, the organizing entity relied on multiple implementers (nongovernmental organizations [NGOs] and/or local government). While the intention was for implementers within each program to follow the same tactics, we understand that variation in implementation factors was introduced from the array of implementing organizations.

In Cambodia, we partnered with Plan International Cambodia, the executing agency for the Cambodia Rural Sanitation and Hygiene Improvement Programme (CRSHIP), a Global Sanitation Fund program funded by the Water Supply and Sanitation Collaborative Council (WSSCC). This data set includes CLTS interventions delivered by 11 different implementers.

In Ghana, our first partner was the international NGO Global Communities (GC), who implemented CLTS activities through two USAID-funded initiatives: Water, Sanitation, and Hygiene (WASH) for Health (W4H) and Resiliency in Northern Ghana (RING). The RING project included CLTS as one component of an intervention to improve the nutrition and livelihood status of vulnerable households in the country's Northern Region. The W4H program aimed to increase sanitation access and, in some communities, included a supply component that worked with the private sector to supply discounted latrine construction materials. Our second partner in Ghana was UNICEF, who provided data on its joint CLTS program with the Government of Ghana in 53 districts. UNICEF and GC worked with district government staff to implement CLTS in Ghana.

In Liberia, we obtained data from GC for communities enrolled in the USAID-funded Improved Water, Sanitation, and Hygiene (IWASH) and Partnership for Advancing Community-Based Services programs (Sticklor, 2016). GC implements CLTS in Liberia as a three-pronged approach, which emphasizes low-cost, locally sourced materials, collaboration with traditional leaders and government agencies, and the development of Natural Leadership Networks (Sticklor, 2016).

Finally, in Zambia, we partnered with Akros and the Ministry of Water Development, Sanitation, and Environmental Protection, which tracks the progress of Zambia's Sanitation and Hygiene Program's (ZSHP) CLTS activities through the WASH Management Information System (MIS). 1,500 volunteer "Community Champions," who attended five-day training sessions, conducted data collection. The WASH MIS uses District Health Information System's mobile-to-web platform whereby Community Champions enter CLTS data via phones to populate an online database. Select chiefs were sensitized to CLTS and educated on the importance of achieving 100 percent sanitation coverage and the sanitation access rates of villages within their chiefdom and those of neighboring chiefdoms. While WASHPaLS also originally planned to conduct the qualitative research in Zambia, this was not possible due to

ongoing internal evaluations of the ZSHP program that would have resulted in overlapping fieldwork. We discussed all results with implementing partners and solicited their input to interpret findings.

Table 1. Key statistics of CLTS program datasets.

	CAMBODIA	GHANA	LIBERIA	ZAMBIA
# Communities before data cleaning	2,301	5,909	2,095	30,177
# Communities after data cleaning	2,234	2,038	2,011	9,017
% ODF achievement in cleaned datasets [a]	32%	49%	57%	35%
% ODF sustainability in cleaned datasets (among achieving communities) [b]	NA	NA	NA	30%
Geographic representation of the datasets	50 communes out of 1431 nationally	77 districts (72 after cleaning) out of 216 nationally	151 clans out of 815 nationally	803 wards (434 after cleaning) out of 1287 nationally
Specificity of contextual factor definition	Commune averages	Global Positioning System (GPS)	GPS	GPS
# CLTS programs covered	1 program (2 phases)	3 programs	1 program	1 program
Period covered by the dataset	2012-2018	2014-2019	2015-2018	2013-2018
Administrative identifiers provided in datasets (from largest to smallest)	Province, district, commune	Region, district	County, district, clan	Province, district, ward
Programmatic additions/variations to traditional CLTS [c]	Market-based sanitation (in a subset of communities)	RING program: nutrition programming W4H program: hardware subsidies	Natural Leader Networks, local institution integration, localized WASH technologies	CLTS with a unique mobile-to-web service delivery and monitoring system

[a] In Ghana and Liberia, we determined ODF achievement based on ODF certification information provided in the program dataset. In Cambodia and Zambia, where this information was not available, we determined ODF achievement based on latrine coverage using thresholds of 85% and 100%, respectively, according to national guidelines (Zambia Ministry of Local Government and Housing, 2013; Venkataramanan, 2014). ODF achievement after cleaning but prior to the removal of communities without GPS coordinates was 34% in Cambodia (2,273 communities), 49% in Ghana (5,059 communities), 56% in Liberia (2,026 communities), and 38% in Zambia (20,398 communities).
[b] Among communities that achieved ODF, a community was considered to have "sustained ODF" if latrine coverage equaled or exceeded 90% in all follow-up reports posterior to ODF achievement. Follow-up reports ranged from 1-57 months from the first record of ODF achievement.
[c] Programmatic additions applied to all communities in a program unless otherwise specified.

2.0 METHODS

2.1 QUANTITATIVE STUDY METHODS

General approach. To better understand if and how local conditions influence CLTS outcomes, we acquired: (i) six large CLTS program datasets from four countries (Cambodia, Ghana, Liberia, and Zambia); and (ii) data on 18 georeferenced contextual factors from either publicly available sources or derived directly from the program data. We used statistical analysis to examine the relationships between these contextual factors and two metrics of CLTS program performance: ODF achievement in all four countries and sustained ODF (among communities that achieved ODF) in Zambia (data on ODF sustainability was not available in the other three countries). We complemented this analysis with phone interviews of program implementers to validate preliminary results and gain insight into mitigation methods in difficult contexts. To translate our findings into practical guidance for CLTS implementers, we identified a "split point" for each contextual factor significantly associated with ODF achievement, which can be understood as the threshold value above which the contextual factor is shown to be more favorable for ODF achievement, for instance, in a given setting, ODF achievement is more likely where the community has fewer than 'y' households. We also identified the combination of contextual factor threshold values leading to a minimum probability of ODF achievement in each country.

CLTS data overview and cleaning. We obtained datasets covering a combined 40,482 communities before data cleaning (Table 1). Across the six datasets, data cleaning reduced the number of communities from 40,482 to 15,300 (Table 1). For each dataset, we matched location names (e.g., province, district, and ward) provided in the CLTS datasets with identifiers from governmental maps. Where possible, we utilized GPS coordinates to facilitate the match. We excluded communities that lacked recognizable identifying information, had less than five households, lacked ODF status information, were duplicate or unverified according to implementing partners, or already met ODF coverage requirements at baseline. Additionally, almost all (99 percent) of the excluded records came from the Zambia and Ghana datasets and were largely the result of our eliminating communities without GPS coordinates. Where possible, we decided to limit the datasets to communities with GPS coordinates, which allowed defining contextual variables with higher resolution. This was not possible for the Cambodia dataset, which did not contain GPS information for any community. In Zambia, we examined month-to-month latrine coverage trends and removed communities that failed quality checks, such as inconsistent spikes or dips in latrine coverage or household counts (Stuart et al., 2021). Overall, we recognize that our data cleaning steps may have biased the datasets, for example towards communities with higher quality of program implementation that are more easily accessible, or that are more developed. Additionally, we recognize that our Cambodia analysis, which relied on lower-resolution variables, may have overlooked some correlations. A deeper exploration of the CLTS program data, associated contextual variables, and study limitations is available in Stuart et al. (2021).

Outcome variables and their computation. We assessed CLTS performance based on whether a community had achieved ODF status ("ODF achievement") using ODF certification dates contained in the CLTS program dataset (Ghana and Liberia), or using latrine coverage data where certification information was unavailable (Cambodia and Zambia). In Cambodia and Zambia, we defined a community as ODF if, in a follow-up report, the latrine coverage equaled or exceeded the threshold of 85 percent and 100 percent, respectively, as delineated in the country's national CLTS guidelines (Venkataramanan, 2014; Government of Zambia, 2013). After data cleaning, ODF achievement among study communities was 32 percent in Cambodia, 57 percent in Liberia, 49 percent in Ghana, and 35 percent in Zambia (Table 1). Within each country, ODF achievement varied widely across districts (min: 0 percent, max: 100 percent).

The Zambia dataset allowed for an additional CLTS performance outcome, which we call "ODF sustainability," indicating whether an ODF-declared community had sustained its ODF status over the data record (a binary, or yes/no, outcome variable). We operationally defined sustainability as the equaling or exceedance of 90 percent latrine coverage in all reports following ODF achievement, regardless of the length of the data record or duration of sustained ODF. For example, if a community achieved ODF status in month three of programming, but follow-up reporting in month 15 showed less than 90 percent latrine coverage, then the community did not sustain ODF.

Contextual factors and source datasets. We examined 18 georeferenced contextual factors from either publicly available sources or derived directly from the program data. We acquired publicly available, geospatial datasets on 14 demographic, socioeconomic, health, accessibility, and environmental variables plausibly influencing CLTS program performance based on the literature. We used communities' geographic positions to assign them a value for each contextual variable. Additionally, we computed the average population density for each commune (Cambodia), district (Ghana), clan (Liberia) and ward (Zambia) in the CLTS program datasets. This "area-wide" population density variable was used as a proxy for the presence of market centers in the vicinity of communities. The Cambodia dataset, which lacked GPS coordinates, did not allow for explanatory variables to be defined at the community level, and so we applied commune averages to each community, thereby reducing the resolution and data variability for these variables. Detailed methodology for variable computation is found in Stuart et al. (2021).

We derived four additional variables directly from the CLTS program datasets: (i) community size, defined as the number of households; (ii) baseline latrine coverage (Cambodia, Liberia); (iii) baseline 30-day diarrhea prevalence, defined as the number of people in a 30-day period with reported diarrhea divided by the number of households per community (Liberia); and (iv) number of improved water sources (Zambia). A list with rationale for considering each of these variables, their sources, definitions, and resolutions is provided in Table 2. Further, we calculated "time since triggering" for each community to capture the length of exposure to programming in the models. This corresponded to the number of years (Cambodia and Zambia) or months (Ghana and Liberia) between the triggering event (Zambia and Liberia) or baseline data collection date (Cambodia and Ghana, where triggering dates were unavailable) and the last follow-up data point. Lastly, in Zambia, our models controlled for the "number of reports," because we were more likely to identify both ODF achievement and "slippage" in communities with more monitoring visits.

Several variables with potential influence on CLTS were not available at sufficient resolution to be included in this analysis, including hydrogeological characteristics, flood burden, prior history of WASH programming, demographic characteristics (such as age, gender, religion), and in some cases, baseline latrine coverage and poverty level. As noted, this analysis did not include commitment of local leaders, quality of program implementation, and history of WASH subsidies due to a lack of data on these factors. Thus, the relationships reported in results may reflect influences from unaccounted for variables.

Analytical approach. We then defined a unique model for each contextual factor and CLTS outcome in each country. Additional details regarding model formulation are published elsewhere (Stuart et al., 2021). For those models with statistically significant outcomes (p values less than or equal to 0.05), we derived an operational split point to estimate favorable ranges for the factor. Using these split points, we identified areas within each country which could be predicted to achieve a target rate of ODF achievement. See Annex B for additional details on defining and layering split points.

2.2 QUALITATIVE STUDY METHODS

General approach. The qualitative study examined community-level implementation factors that influence latrine coverage and consistent latrine use in communities that participated in CLTS triggering in Cambodia and Ghana at least two years prior. We analyzed implementation factors under three areas of interest: (i) involvement of community leaders; (ii) level of post-triggering and post-ODF follow-up (or continued, long-term follow-up in the case of non-ODF communities); and (iii) magnitude of financial support to poor and vulnerable households. We applied fsQCA to identify combinations of these factors that influenced sanitation outcomes post-CLTS and compared country results to see how CLTS implementation varied across country contexts. For an overview of study design, see Figure 1.

Sampling strategy. The qualitative study took place in Cambodia and Ghana from November 2018 to July 2019. We selected two rural provinces in Cambodia (Kampong Cham and Kampong Speu) and four rural districts in Ghana (Sawla Tuna Kalba, West Mamprusi, East Mamprusi, and Nanumba North) where partners CRSHIP and GC, respectively, have been operating CLTS programs. In the case of CRSHIP, several organizations implemented the intervention, while in Ghana, CLTS was implemented by GC directly or by district government staff. Within the identified provinces and districts, we identified communities that had been triggered at least two years prior to data collection and with varying CLTS implementation strategies and success of ODF achievement. To establish variability in our outcomes of interest (required for fsQCA), we conducted purposive sampling to include three categories of success: (i) communities that achieved and sustained ODF (i.e., declared ODF at least 12-15 months prior to data collection according to the respective national definitions and maintained sufficient latrine coverage to meet the national definition); (ii) communities that achieved ODF according to national criteria but did not sustain (i.e., declared ODF at least 12-15 months prior, but no longer had sufficient latrine coverage to meet the national definition as self-reported by community leaders); or (iii) communities that never achieved ODF (i.e., triggered at least two years prior but never declared ODF). In both countries, we also purposively selected communities to ensure variability across three categories of implementation factors of interest: local leadership, follow-up intensity, and pro-poor support.

In each selected community, we conducted transect walks, in-depth semi-structured interviews, and focus group discussions (FGDs) until we reached information saturation (i.e., no new information was collected with additional data collection). We provide more details on the specific sampling strategy and methods in Tribbe et al. (2021).

Data collection. With the assistance of key informants, we identified participants for in-depth interviews and FGDs, which included: individuals responsible for triggering activities, district and provincial officials, traditional and natural leaders, and households (early and late toilet adopters and poor and vulnerable households). We established equal participation of men and women for individual interviews and FGDs where possible. Members of our research teams conducted interviews in local languages or in the participants' language of preference. In Cambodia, the research team conducted 186 semi-structured individual interviews and 13 FGDs. In Ghana, the research team conducted 154 semi-structured individual interviews and 15 FGDs.

Ethical considerations. Researchers obtained informed verbal consent from all interview and FGD participants prior to beginning each interview and audio-recording. Our study protocol was determined to be exempt from full review by the Western Institutional Review Board (under 45 CFR §46.101(b)(2) of the Federal Common Rule in the U.S.) and Cambodia's National Ethics Committee for Health Research. In Ghana, our study protocol was approved by the Council for Scientific and Industrial Research (RPN 002 CSIR-IRB 2019).

Data analysis and definition of outcomes. We defined latrine coverage (our first outcome) as the number of functioning latrines divided by the number of compounds (a grouping of households often enclosed by a wall and sharing space and a latrine) in Ghana and as the number of latrines divided by the

number of households in Cambodia. We relied on responses from community leaders and interviewed households to estimate these ratios. When conducting QCA, we established the threshold for determining "high" latrine coverage at 85 percent in Cambodia and 75 percent in Ghana.

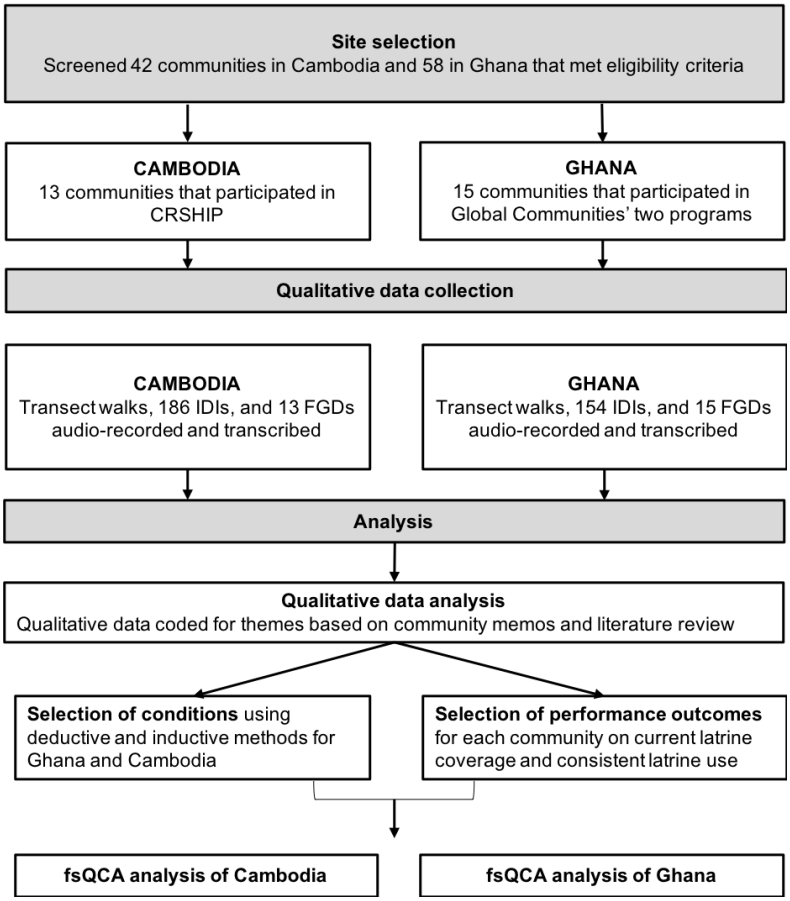


Figure 1. Study design overview *(IDIs = in-depth interviews)*

To define latrine use (our second outcome), we examined the extent to which households used latrines rather than practicing open defecation. We also considered whether households preferred to share latrines or practice open defecation when their latrine was occupied or collapsed/broken. We assessed consistent latrine use as a categorical variable on a four-point scale based on our qualitative data. In Cambodia, we conducted the fsQCA on inconsistent latrine use, the inverse of consistent latrine use, as only three communities in our sample demonstrated consistent latrine use.

Table 2. List of explanatory contextual variables identified as potentially influential for CLTS performance.

CAT.	FACTOR	AVAILABLE VARIABLES	POSSIBLE LINK TO CLTS PERFORMANCE	SOURCE(S)	ORIGINAL RES.	MODEL RES. [a]
Demographic	Community size	Number of households (#)	The number of households and their demographic characteristics can affect social cohesion and amenability to behavior change (Crocker, Shields, et al., 2016; Venkataramanan, 2016).	Zambia MOH/Akros, CRSHIP, GC Ghana, UNICEF Ghana, GC Liberia	Comm.	Comm.
	Decision-maker demographics (income source, religion, age and gender of household head)	*Unavailable*		*NA*	*NA*	*NA*
Environmental	Nearby environmental shelter for OD	Average distance to inland waterways (km)	Forests, bushes, and waterbodies can provide shelter for open defecation and slow down its eradication (Mukherjee, 2011; Kreisel, 1991). Latrine pits may be more or less easy to dig and maintain depending on the local hydrogeology (Venkataramanan, 2016; Lawrence et al., 2016). Flooding can damage latrines, and can be more common near waterways (Harter et al., 2018).	RCMRD (RCMRD, 2015), OCHA (United Nations Office for the Coordination of Humanitarian Affairs, 2018)	100m	1km
		Forest coverage (%)		University of Maryland (Hansen et al., 2013)	30m	1km
		Shrubland (bush) coverage (%)		Copernicus Climate Change Service (Corpenicus & ECMWF, 2019)	300m	1km
	Hydrogeology: water table depth, soil type, flood burden	*Unavailable*		*NA*	*NA*	*NA*
Accessibility	Population density	Average # of people per hectare (pp/km^2)	Accessibility may affect several factors linked to CLTS success: availability of materials, markets, local masons and information; and ease of triggering and follow-up for NGOs (Venkataramanan, 2016).	WorldPop (WorldPop Project, n.d.)	100m	1km [b]
	Remoteness of community	Time to cities (hr)		Malaria Atlas Project (Weiss et al., 2018)	1km	1km
		Distance to major roads (km) [c]		Open Street Maps (United Nations Office for the Coordination of Humanitarian Affairs, 2020; Cambodia Road Network (Main Roads), 2018; World Food Programme, 2018; United Nations Office for the Coordination of Humanitarian Affairs, 2019)	100m	1km
	Access to construction materials	*Unavailable*		*NA*	*NA*	*NA*
Socioeconomic	Literacy	Men/women who can read all or part of a sentence (%)	Poverty and literacy are indicators of socioeconomic development, which can affect ability to pay for sanitation and health knowledge. Baseline OD reflects prevailing behaviors before CLTS and may affect a community's responsiveness to the approach (Crocker et al., 2016; Venkataramanan, 2016). Social cohesion and peer pressure can inspire collective action.	Demographic and Household Survey (Spatial Data Repository, 2020)	5km	5km
	Baseline OD	Households with latrines at baseline (%)		CRSHIP, GC Liberia	Comm.	Comm.
	Poverty	Population living below the national poverty line (%)		Ghana Statistical Service (Ghana Statistical Service, 2015)	District	District
	Social dynamics (social cohesion, peer pressure)	*Unavailable*		*NA*	*NA*	*NA*
Water availability	Water supply	Households having access to improved water (%)	Access to water supply eases latrine construction, repair, and cleaning (Tyndale-Biscoe et al., 2013). Extreme	Demographic and Household Survey (Spatial Data Repository, 2020)	5km	5km
		Number of improved water sources (#)		Zambia MOH/Akros	Comm.	Comm.

CAT.	FACTOR	AVAILABLE VARIABLES	POSSIBLE LINK TO CLTS PERFORMANCE	SOURCE(S)	ORIGINAL RES.	MODEL RES. [a]
		Rural population served by a water supply system (%)	water scarcity can affect behavior patterns within a community (Odagiri et al., 2017).	District League Table (UNICEF and CDD Ghana, 2016)	District	District
	Water scarcity	The ratio of water use and water availability per area		Water Footprint Network (Mekonnen and Hoekstra, n.d.)	60km	60km
Health	Waterborne disease burden	Diarrhea prevalence at baseline (%)	Awareness of waterborne diseases may increase receptivity to health messaging (Kar and Chambers 2008)	GC Liberia	Comm.	Comm.
		Predicted cholera incidence (cases/100,000pp)		Infectious Disease Dynamics (Lessler et al., 2018)	20km	20km

[a] All variable values were extracted at the community location; variables where data resolution was <1km were aggregated within 1km diameter of community location.
[B] An additional variable, "area-wide population density" was defined at the smallest administrative boundary level for each country: commune (Cambodia), district (Ghana), clan (Liberia), ward (Zambia).
[c] "Major roadways" include trunk, primary, secondary and tertiary road types as defined by Open Street Maps.

Data analysis. We analyzed the data using fsQCA, a semi-quantitative method that identifies combinations of factors that influence an outcome of interest (Rihoux and Ragin, 2009; Jordan et al., 2011, 2016). We examined two community-level outcomes: latrine coverage and consistent latrine use. We selected these two outcome variables because latrine coverage does not necessarily indicate latrine use (Vernon & Bongartz, 2016; USAID, 2018b). We further examined implementation factors (six in Cambodia and six in Ghana) that could influence these outcomes based on hypotheses drawn from the literature and on themes that emerged through our qualitative research (Table 3). We then scored each community with respect to the strength of each factor employing information collected during interviews with village leaders and households. We used the scores to examine relationships among different combinations of factors and outcomes via fsQCA software.

Table 3. Outcome and factor definitions used for analysis in Cambodia and Ghana.

Category	Outcomes/ Conditions	Scale	Cambodia Definition	Ghana Definition
Category 1: Community Leadership	Commune Engagement	Four-point	Level of engagement of commune council members in sanitation at the community level post-triggering.	N/A (no communes in Ghana.)
	Traditional Leader Pressure (Cambodia)/ Traditional Leader Engagement (Ghana)	Four-point	Intensity of pressure applied by community leaders to households post-triggering (includes Village Chief, Deputy Chief, or Village Focal Point).	Activity level of traditional leaders, namely the Village Chief, in sanitation activities post-triggering.
	Natural Leader Engagement	Four-point	N/A (no natural leaders in Cambodia).	Activity level of natural leaders in sanitation activities post-triggering.
Category 2: Follow-up Activities	NGO (Cambodia)/ CLTS Facilitator follow-up (Ghana)	Four-point	Intensity of follow-up by NGOs post-triggering (not limited to CLTS implementing partner).	Intensity of follow-up by CLTS facilitators or other external actors post-triggering.
	Internal follow-up post-ODF (Ghana)	Four-point	N/A (this condition was dropped due to insufficient variability).	Activity level of natural leaders or traditional leaders, or both, post-ODF (or at the time of the research in the case of non-ODF communities).
Category 3: Financial/ Pro-poor Support	Financial Support	Four-point	Amount of financial support, such as subsidies, latrine materials or loans, received by the community (pre- or post-ODF; does not include sanitation marketing offers of low-cost latrines).	N/A (this condition was dropped due to insufficient variability).
	Pro-poor support (Cambodia)/Internal Support (Ghana)	Four-point	Extent to which financial support or other strategies were intentionally targeted to poor or vulnerable households.	Level of engagement of community members in sanitation activities, including supporting neighbors to construct latrines, or ensuring that poor and vulnerable households were supported.
	Subsidies before triggering	Binary	Presence of subsidies in the community prior to CLTS.	N/A (no communities had received previous subsidies).
Other	Women engaged in sanitation	Four-point	N/A (this condition was dropped due to insufficient variability).	Engagement of women in sanitation activities such as triggering, the decision to construct latrines, maintaining latrines over time, or in leadership positions (i.e., natural leaders).

Category	Outcomes/ Conditions	Scale	Cambodia Definition	Ghana Definition
Outcomes	Outcome 1: Current Latrine Coverage	Continuous	Current number of latrines divided by number of households.	Current number of latrines divided by number of compounds.[a]
	Outcome 2: Consistent Latrine Use	Four-point	Prevailing latrine use behaviors in the community compared to open defecation behaviors, including whether or not households repair broken latrines, or are willing to share latrines rather than practice open defecation.	

2.3 LIMITATIONS

Our quantitative research had several limitations stemming from constraints with the datasets. First, we aggregated CLTS data with inconsistent levels of detail from multiple implementing partners, including some datasets without data on ODF achievement. In Cambodia and Zambia, we relied solely on latrine coverage estimates to assign ODF status based on the official government minimum latrine coverage requirement for ODF (85 percent in Cambodia and 100 percent in Zambia; Venkataramanan, 2016; USAID, 2018b), while in Ghana and Liberia we had data on each community's official government-defined ODF status, which also relies on a minimum level of latrine coverage (80 percent in Ghana and 100 percent in Liberia [USAID, 2018b; Liberia County Manager, 2019] but may also capture other factors such as acceptable disposal of excreta and lack of visible OD. In practice, ODF definitions vary by country, and ODF status is often not an indication of the total elimination of OD, not only because the qualifying ODF threshold can allow for some OD, but also because open defecation levels can be difficult to document reliably. These dataset differences may have contributed to the differing variable associations we observed among countries.

Second, the datasets required significant cleaning, including the removal of communities missing GPS data (40 percent across the five datasets), except for Cambodia where no communities had GPS data. This is likely to have biased the sample, for example, toward more accessible communities or those with higher-quality program implementation. A comparison of cleaned study communities with national medians showed that the programs in Cambodia, Ghana, and Zambia differed significantly for some variables (higher literacy and lower forest coverage in Cambodia, lower literacy and more densely populated districts in Ghana, and higher access to improved water in Zambia) as a result of program community selection criteria and/or data cleaning. A deeper analysis of these biases is found in Stuart et al. (2021). Third, because the Cambodia dataset lacked sufficient geospatial information to locate communities below the commune level, we used the commune-level average for geospatial explanatory variables, which affects results by reducing variability and specificity in the dataset. Fourth, we were unable to oversee data collection or validate any community-specific information provided in program datasets and relied on partners to identify unverified components of the datasets. Fifth, the set of contextual factors analyzed against outcomes varied across the four countries due to data availability, with a number of factors available only for one or two countries and socioeconomic factors least consistently available (Stuart et al., 2021). This limits our ability to evaluate if these factors are consistently impactful across countries.

Our qualitative approach also had several limitations. First, although QCA seeks to determine cause and effect, it cannot enable causal inferences in the same way that a randomized controlled trial (RCT) can. Second, QCA does not permit analysis of every possible explanatory variable; there may be other factors that we did not examine that influenced the outcomes of interest. Third, latrine coverage outcomes in this study were not measured by visiting every household in each community, but instead relied on estimates made by local researchers based on multiple household and community leader

[a] In Ghana, a compound is grouping of households; the number of households per compound varied per community.

interviews. Fourth, the research team completed data collection in Ghana at the beginning of the rainy season, which may have contributed to lower-than-average latrine coverage due to recent latrine collapse. Finally, the abundance of sanitation programs in Cambodia made it difficult to assess the activities and strategies of CLTS programs independently, since households often could not distinguish between multiple similar sanitation program interventions.

3.0 FINDINGS

3.1 SUMMARY TAKEAWAYS

CLTS success depends on country- or region-specific combinations of favorable contextual factors and implementation strategies that can help improve practice.

No set of contextual and implementation factors were favorable to CLTS success across all study countries. In Ghana, for example, our quantitative research found that remote communities, typically associated with strong social cohesion and traditional values, were more prone to ODF achievement (Section 3.2). The qualitative research confirmed the importance of social cohesion in Ghana; it showed that active community leaders who followed up and engaged with households, and internal support (i.e., neighbors helping neighbors), were key ingredients for communities to maintain high latrine coverage and use (Section 3.3). Conversely, in Cambodia, ODF achievement was more likely in less remote communes characterized by higher literacy rates (Section 3.2). These types of communities often have higher socioeconomic development, incomes and access to markets and sanitation businesses. Successful implementation strategies also differed from Ghana; in Cambodia, communities with high latrine coverage had generally received less intensive or "light touch" CLTS implementation (Section 3.3).

In all three African study countries, remote communities with low population density were generally more likely to achieve ODF status, irrespective of program; however, the influence of socioeconomic and environmental conditions was country specific (Figure 2).

Factors that have a positive impact on ODF achievement in the short term might not support ODF sustainability in the long term.

In Zambia, our quantitative research indicated that the favorable conditions for ODF achievement can differ from those required for sustainability. Targeting communities most likely to sustain sanitation gains may thus require longer program time scales and more financial resources, compared to solely focusing on ODF achievement.

Similarly, our qualitative research demonstrated that high latrine coverage does not always translate to consistent use. Furthermore, implementation strategies that promote latrine coverage can sometimes have *negative* effects on latrine use: in Cambodia, we found that excessive pressure to build latrines prior to the ODF declaration could lead to high latrine coverage and inconsistent latrine use simultaneously (Section 3.3).

3.2 QUANTITATIVE ANALYSIS TAKEAWAYS

Box 1. QUANTITATIVE FINDINGS AT A GLANCE

What contextual factors outside the control of implementers influence CLTS success?

- We found that the likelihood of ODF achievement varies depending on several contextual characteristics outside the control of implementers.
- In each study country, we identified four to seven contextual predictors of ODF achievement. In Zambia, we also identified predictors of ODF sustainability.
- The only consistent predictor across all four study countries was small community population size.
- In Ghana, Liberia, and Zambia, ODF achievement was generally correlated with low localized population density and high remoteness, but relationships were not always significant ($p<0.05$).

What is the importance of contextual characteristics as compared to program implementation for ODF achievement?

- The datasets did not allow for direct comparison of the relative importance of context and program implementation quality due to a lack of community-level data on implementation characteristics (e.g., quality of the facilitator, quality of the triggering event, involvement of local leadership).
- However, because we used large-scale (and sometimes multi-program) datasets likely capturing various degrees of implementation quality, our analysis suggests that contextual characteristics can influence CLTS outcomes irrespective of implementation quality.

This research showed that program data and publicly available datasets can be leveraged to identify favorable and unfavorable contexts for CLTS.

Community population size is the most generalizable predictor of CLTS program success.

The smaller the community population, the higher the likelihood of ODF achievement. Small community size had a positive association with ODF achievement ($p<0.001$) in all four countries (Figure 2, Table A-1). This may be because communities with fewer households are easier to engage during triggering events and follow-up visits, increasing the potential for facetime with community members (Cambodia Project Coordinator, 2019; Zambia Deputy Program Manager, 2019; Ghana WASH Programme Coordinator, 2019; Liberia County Manager, 2019). Additionally, smaller communities may have higher social cohesion, particularly as households are more likely to be related to neighbors, as well as have stronger local leadership and higher socioeconomic homogeneity. Strong social cohesion in small communities may also manifest in more widespread information sharing among households as well as stronger peer pressure (Mukherjee & Robiarto, 2012; Venkataramanan et al., 2018; Ghana Environmental Health Officer, 2019; WaterAid/Causal Design, 2017). Finally, smaller communities require less overall latrine construction to reach ODF requirements.

Other contextual factors, such as accessibility and socioeconomic development (as measured via different proxies), often meaningfully affect CLTS program performance.

Figure 2 graphically depicts the differing association magnitudes and strengths for all factors across countries. Numerical results are presented in Table A-1.

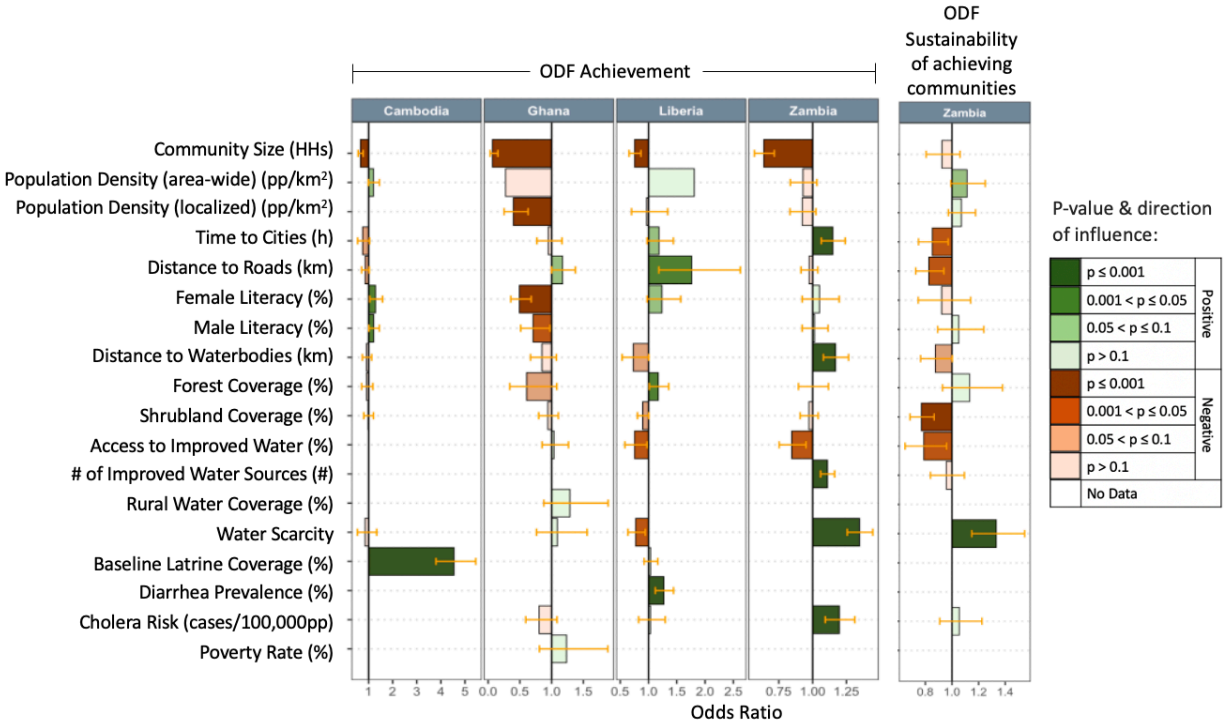


Figure 2. Outputs of logistic regression models in terms of odds ratios (OR). *Each bar represents the output of a specific multivariate model, derived for the standardized explanatory variable of interest (rows) by country (columns). Results are displayed as Odds Ratios (length of the bar), p-values (shade, darker=more significant, lighter=less significant), direction of impact (color, green=positive, red=negative), and 95% confidence intervals (in gold). Confidence intervals for area-wide population density were removed for clarity (Ghana: 0.03-2.93, Liberia: 0.61-5.34). See Table 2 for additional details on variables and their resolutions, and Table A-1 for numerical results. All results with p<0.001 met the significance test when considering post-hoc Bonferroni corrections.*

While the CLTS Handbook and a number of studies have suggested that remote areas may be more receptive to the CLTS approach (Crocker et al., 2016; WaterAid et al., 2017; Venkataramanan & Shannon, 2016; Russpatrick et al., 2017; Kar & Chambers, 2008), other authors have pointed out that proximity to supply chains of construction materials may favor toilet construction (Mukherjee, 2011; Burr et al., 2017). In this study, we used two indicators of remoteness: distance to roads and travel time to cities, complemented by a third indicator, area-wide population density, as a proxy to indicate the presence of supply chains. In the three African countries (where our analysis relied on high-resolution contextual variables), we found indications that remoteness, as indicated by distance to roads (Ghana and Liberia) or travel time to cities (Liberia and Zambia) had a positive association with ODF achievement; the more remote, the better the ODF achievement (Figure 2). This is potentially because remote communities have stronger social cohesion, higher socioeconomic homogeneity, and have been exposed to fewer subsidy-driven sanitation programs in the past (Kar & Chambers, 2008; Venkataramanan, 2016; Mukherjee, 2011). Our implementing partners have also observed that urbanized communities were more challenging because social cohesion was weaker, inhabitants had less time for community activities, expected assistance from NGOs, and/or faced space and land tenure constraints (Liberia County Manager, 2019; Ghana WASH Programme Coordinator, 2019).

In contrast, in Cambodia, there were weak indications that communities were more likely to achieve ODF in communes that were more densely populated and less remote (Table A-1). However, we note that this analysis relied on lower-resolution proxies for remoteness because we did not have GPS information for study communities. Such communities may have easier access to market centers and materials, facilitating the construction of high-quality pour-flush latrines, which Cambodian households

tend to prefer over traditional latrines built with local materials (Cambodia Project Coordinator, 2019). High population density may also promote latrine construction, as there are fewer suitable locations for open defecation (USAID, 2021), although the absence of GPS information prevented us from analyzing this at community level.

Our results further indicate that socioeconomic development is associated with CLTS performance independent of remoteness, though the direction and strength of impact may differ depending on other contextual factors. In Cambodia, ODF achievement was associated with higher literacy, while in Ghana, we observed the opposite relationship. If we consider that literacy is correlated with wealth, we could consider these differences in light of their cultural preferences and the historical context. In Cambodia, a parallel study identified strong cultural preferences for more expensive pour-flush toilets with cemented superstructures, while rudimentary dry latrines made of local materials were stigmatized (USAID, 2021). In contrast, rudimentary latrines are generally acceptable in rural Ghana. Thus, poorer, remote communities with easy access to traditional construction materials (mud, thatch, sand, and wood) may be more likely to reach ODF quickly. This interpretation is consistent with prior research in Ghana that showed superior CLTS performance in remote, poorer areas (Crocker et al., 2016) and aligns with our findings for remoteness factors, detailed above.

We also found inconsistent associations with environmental and health indicators. The CLTS Handbook proposed that the lack of vegetation cover in the surrounding area, unprotected polluted water supplies, and high incidence of waterborne diseases constitute a favorable environment for CLTS (Kar & Chambers, 2008). Our results provide limited evidence for these assertions. Forest cover had a positive association with ODF achievement in Liberia, a weak, negative association in Ghana, and no association in Zambia. In Cambodia, no associations were found with vegetation cover; however, the evidence is weak, as data did not allow for community-level analyses. Distance to major waterbodies was only significant in Zambia, and lower access to improved water was associated with higher ODF achievement in Zambia and Liberia, but not in Ghana. CLTS was indeed more successful in areas with high diarrhea prevalence in Liberia and high cholera risk in Zambia, but no other association for cholera risk was detected. Additionally, we found that water scarcity was positively associated with ODF achievement in Zambia, negatively associated in Liberia, and had no association in Cambodia and Ghana.

Integrating CLTS program monitoring data with contextual data on a widespread basis requires improving how programs do basic program tracking (such as consistent documentation of the location and timing of CLTS activities).

Overall, across the six datasets we analyzed, data cleaning reduced the number of communities included by 62 percent, from 40,482 to 15,300 (Table 1). The majority of removed communities (approximately 64 percent) were removed because they lacked GPS coordinates. Improved data management can ensure maximal utilization of implementer data for both internal monitoring and evaluation (M&E) as well as external analyses, and we have developed recommendations for data collection and maintenance for implementers' consideration (see Section 4.1).

Sustainability is difficult to assess: the development of cost-effective methods for monitoring changes in latrine coverage over time should be prioritized in CLTS and rural sanitation programs more generally.

Our analysis of the Zambia dataset found that some favorable conditions for the achievement of ODF status may be unfavorable for maintaining that status over time. We found that remote communities were more likely to achieve ODF, but among these more remote communities, those relatively closer to cities or towns were more likely to sustain ODF (Figure 2). Access to markets and supply chains may facilitate construction and repairs in the years following ODF achievement (Kullmann et al., 2011). More post-ODF data is needed to better understand the nuances in favorable contexts for ODF sustainability versus ODF achievement.

Detailed country-specific results are provided in the research briefs for Cambodia, Ghana, Liberia, and Zambia.

3.3 QUALITATIVE ANALYSIS TAKEAWAYS

Box 2. QUALITATIVE FINDINGS AT A GLANCE

What are the most successful implementation strategies to achieve and sustain ODF?

- We could identify no single strategy that resulted in sustained latrine coverage and use multiple years after CLTS implementation. Among our case study communities, strategies that were effective in Ghana were not necessarily effective in Cambodia (and vice versa), reflecting contextual and community dynamic differences between the two countries.
- In Ghana, remote, rural communities without prior sanitation interventions responded positively to traditional CLTS approaches and demonstrated lasting behavior change.
- In Cambodia, most of our study communities had experienced multiple sanitation interventions. Coverage of high quality latrines was high, but there were still challenges maintaining consistent use among growing communities and households that share.

a. What strategies do local leaders use to mobilize their communities?

- Strong leadership was effective in motivating latrine construction in both Ghana and Cambodia, but consistent latrine use required more community-led approaches. In Cambodia, aggressive tactics and threats were not effective at sustaining ODF.

b. What type of follow-up is needed to achieve and maintain ODF status in a community?

- The type of follow-up required to support a community to achieve ODF may vary based on access to markets and skills, toilet preferences, and previous community exposure to sanitation interventions.
- In both countries, follow-up by external actors, such as government or implementing organizations, stopped as soon as communities achieved ODF status. However, in Ghana, communities performed better when some follow-up activities were continued by internal actors (i.e., natural leaders).

c. What approaches to pro-poor support are the most successful?

- Where internal support mechanisms exist culturally (as was the case in our Ghana study communities), such as neighbors helping neighbors to construct and repair latrines, they proved to be effective in sustaining latrine use across the entire community (including, but not specifically targeting, poor and vulnerable households). In both countries, financial

Different effective strategies in Cambodia as compared to Ghana reflect differences in context and community dynamics between the two countries.

In Ghana, remote, rural communities without prior sanitation interventions responded positively to traditional CLTS approaches and demonstrated lasting behavior change. The main challenge was the limited availability of construction materials in Northern Ghana: most latrines in the communities in this study were made of local materials (e.g., logs, mud, thatch, and occasionally cement for plastering) and were susceptible to damage and collapse, especially during the rainy season. In Ghana, households in communities with consistent latrine use typically rebuilt or repaired latrines when they collapsed or broke, felt comfortable sharing latrines with neighbors, and had awareness of potential sanctions for open defecation.

In Cambodia, most of our study communities had experienced multiple sanitation interventions in addition to CLTS and had better access to markets. Most maintained high levels of latrine coverage due to investments in durable pour-flush latrines with high quality superstructures (including cement or tiled slabs, handwashing facilities, and cement or brick superstructures). There, the main challenges were lack of latrines among poor households, sustaining use among households that shared facilities, and maintaining coverage and use as communities grew in population over time. New households would often delay latrine construction until they could save enough money for a higher "status" (aspirational) latrine, such as a pour-flush latrine with cement and tiled superstructure. While many of these households claimed to share latrines with relatives, the practice in Cambodia is generally not preferred and only socially acceptable among close family relatives (Plan International, WaterAid, & WSSC, 2019).

Community leaders play an important role in achieving and maintaining ODF status, but *how* they interact with households is important.

Among successful communities in Ghana (i.e., with high latrine coverage and consistent latrine use), natural and traditional leaders were active post-triggering and remained active after the declaration of ODF status. Women were also engaged during triggering and participated as natural leaders in these communities. In Cambodia, high latrine coverage was more common when leaders were engaged but did *not* apply intense pressure to construct latrines during the post-triggering period. (Their gentler encouragement involved, for example, informal chats with households.)

Among communities with inconsistent latrine use in Cambodia, leaders were either not involved or placed intense pressure on households to construct latrines. Intense pressure often took the form of visiting households every day and/or threatening sanctions, such as the refusal to issue marriage licenses or process loan applications. This result contrasted with our findings in Ghana, where sanctions or by-laws for open defecation were widely accepted by community members and were viewed as critical for ensuring latrine coverage and use. There is other evidence indicating that by-laws designed in a participatory fashion can be effective (UNICEF WCARO, 2011; Hydroconseil et al., 2014), whereas top-down sanctions may be less effective (Venkataramanan, 2016). Previous literature has also raised concerns that sanctions, when actually enforced, may disproportionately affect the poor (Venkataramanan, 2016).

The type of follow-up required depends on the needs of the community, their exposure to previous interventions, and their access to markets.

In Ghana, active leaders and regular follow-up, combined with internal (neighbors helping neighbors) support, were characteristics shared by most post-ODF communities with consistent latrine use. This runs counter to the findings in Cambodia, where higher engagement from leaders and NGOs led to *less* consistent latrine use.

Among successful communities in Ghana, CLTS facilitators maintained regular engagement post-triggering and passed on critical technical skills to households and natural leaders on how to construct and repair latrines. Natural leaders continued engagement after ODF achievement and played a critical role in maintaining ODF status after ODF achievement.

In Cambodia, communities with high latrine coverage were generally those that received "light touch" implementation: lower levels of financial or pro-poor support, lower levels of follow-up by external actors after triggering, and less intense pressure from community leaders. In Cambodia, where markets are relatively accessible and sanitation marketing businesses abound, it is possible that non-poor households were less reliant on NGOs for obtaining latrine materials or for latrine construction. The sheer number of sanitation actors in Cambodia may have resulted in "intervention fatigue" at the community level, compounded by aggressive tactics used by leaders.

Support to poor households was not well targeted in either country, but community-wide internal support emerged as a necessary factor for consistent latrine use in Ghana.

Most study communities in Ghana did not receive any external subsidies, but neighbors helping neighbors with latrine construction was a common strategy used to increase latrine coverage across communities that maintained consistent latrine use. This type of internal support mechanism did not solely focus on poor and vulnerable households but still led to better community outcomes.

We found no evidence of neighbors helping neighbors to construct latrines in Cambodia. Instead, communities were exposed to a range of external subsidy and pro-poor programs, but increased access to subsidies did not necessarily encourage higher coverage or consistent latrine use. Programs did not appear to be well targeted or tailored to the needs of poor households and were often executed in combination with the use of intense pressure and follow up by local leaders that did not inspire behavior change among community members.

Detailed country-specific results can be found in the research briefs for Cambodia and Ghana.

4.0 IMPLICATIONS FOR CLTS PROGRAMS

4.1 RECOMMENDATIONS FOR DATA COLLECTION AND MANAGEMENT

As a result of the data cleaning efforts made in preparation for this research, we developed recommendations for data collection and management for implementers. Improved data management can ensure maximal utilization for both internal M&E as well as external analyses. Higher-quality CLTS implementation data can improve the accuracy and confidence of statistical models and ultimately allow for a more complete understanding of favorable contexts (including the production of maps for sanitation planning). As noted above, across the six datasets, data cleaning reduced the number of communities included in analyses by 62 percent, from 40,482 to 15,300. Most communities were removed for lacking GPS coordinates.

Importance of GPS coordinates. Increasingly, maps of contextual variables are being produced at high spatial resolution and being made publicly available. The high spatial precision of these datasets is only useful if the location of communities is known with similar precision. This allows identifying values of contextual variables at precise community locations, rather than values averaged to the smallest administrative boundary (i.e., district, clan, commune, etc.) in which a community was located. Models using high-resolution variables may be more robust, indicating that GPS coordinates are important. GPS coordinates can also be used to catch and correct errors in identifying information, such as typos in names of administrative boundaries (region, county, district, etc.). Administrative boundaries invariably are changed over time, and when they do, GPS can be used to update identifying information and ensure the longevity of the dataset.

GPS coordinates can be captured by most smartphones, without the need of a sophisticated GPS device. If obtaining GPS coordinates is not possible, special attention should be paid to fixing typos in administrative boundary names and to ensuring consistency in spelling throughout the dataset.

Baseline data. To accurately track progress, accurate and complete baseline data is required. For example, to evaluate metrics such as change in latrine coverage or time to ODF achievement, baseline latrine and household counts as well as the date of baseline data collection are necessary. Collecting data for more indicators at baseline can create opportunities for analyzing additional performance metrics. This is important to consider, as program objectives can change over time. For example, some partners collected baseline data on diarrhea prevalence, the number of improved water sources, and the number of handwashing stations. Implementers can also consider noting the quality or type of surveyed infrastructure, such as distinguishing between improved and unimproved latrines or drinking water sources.

We also recommend that follow-up data collection is consistent with baseline data collection; the indicators measured at baseline should also be collected at all follow-up visits, if possible. For example, for some programs in this study we were unable to calculate endline latrine coverage because although updated latrine counts were available, household counts were only collected at baseline.

Logging dates with all data collected. It is extremely useful to track dates along with *all* incoming data, not just dates of field visits. For example, to accurately study ODF sustainability, one requires the date of ODF certification (not just whether the community is declared ODF). Logging dates for all data can also protect against unforeseen challenges that may arise. Dates of ODF certification are also invaluable in situations where national guidelines for ODF certification criteria (e.g., the required latrine coverage threshold) changes. In some cases, dates of data input (into Excel, for example) are confused with the date of data collection. Tracking the exact dates, as opposed to only the month and year, allow for the most flexibility and accuracy in analyses.

Ongoing data management and quality control checks. Data entry errors are common and can be easily rectified if caught in a timely manner. Depending on the frequency and severity of the data entry errors, entire communities may be removed from analyses, possibly biasing final results. In our study, more than 5,000 communities were removed for containing "suspicious" data reports (such as household counts that differed by +/- 25 percent from one month to the next, or latrine coverage reports well over 100 percent). Formatting rules can be defined in most data entry tools that disqualify entries outside of reasonable, user-defined ranges. We recommend running quality checks after each reporting period. Numerical data can be checked by comparing values to previous entries. Trend plots will clearly display unusual spikes or drops in indicators, such as latrine coverage.

4.2 FROM DATA ANALYTICS TO PRACTICAL GUIDANCE FOR IMPLEMENTATION

We employed two approaches to translate findings into actionable tools for implementers. For the four study countries, we calculated "split points" or "optimal thresholds" for each of the significant indicators. We also developed an interactive web tool for quick localized situational analyses, usable by implementers from any supported country (not only study countries). The tool allows implementers to select the desired context(s) based on their own knowledge of favorable factors without conducting the same rigorous analyses described in this report. They can then use the SanPlan tool to plan, target, and budget programming to areas fitting this criterion.

Split Point Analysis. Anticipating challenges prior to implementation can improve program success and decrease costs. To aid implementers, we identified "split points" to help delineate favorable from challenging community characteristics in our study countries (see Annex B, Box B-1). A full list of split points is available in Table 4.

In the four study countries, the split points with the largest potential effect on differentiating favorability for ODF achievement were community size in Ghana, Liberia, and Zambia, and baseline latrine coverage in Cambodia. In Ghana, among communities with fewer than 40 households, the ODF achievement rate was 41pp higher than the rate among communities with greater than 40 households. In communities in Liberia with fewer than 61 households, ODF achievement was 20pp higher than among larger communities, and in those with fewer than 74 households in Zambia, ODF achievement was 18pp higher than in larger communities. In Cambodia, in communities with latrine coverage higher than 34 percent at baseline, ODF achievement was 33pp higher than in those with lower baseline coverage (Table 4).

We used the same methodology with multiple key factors for which data are publicly available to identifying contextual conditions favorable for ODF achievement. To be able to map the target probability of achievement over the entire country, variables which were community-specific (variables coming from implementers' field data collection as opposed to publicly available datasets) must be removed from the analysis since spatial data is unavailable. For example, in Cambodia, the significant factors were male and female literacy, baseline latrine coverage, and community size, of which only the literacy factors are mapped across the country. Therefore, the favorability map of areas with 57 percent probability of success was derived only with literacy (male literacy greater than or equal to 85 percent). Figure 3 depicts maps of areas within each of the four countries which are likely to achieve or exceed a target level of ODF achievement: 50 percent in Cambodia and Zambia and 70 percent in Ghana and Liberia.

Table 4. Split points for variables significantly associated with ODF achievement (Stuart et al. 2021).[a] One split point (access to improved water in Liberia) had a Wilcoxon p-value>0.05 and is not listed. Split points were derived using bivariate analyses.

EXPLANATORY VARIABLE	SPLIT POINT	% ODF ACHIEVEMENT [b] (Proportion of communities on each side of the split point)		PERCENTAGE POINT DIFFERENCE IN ODF ACHIEVEMENT ACROSS SPLIT POINT
		BELOW SPLIT POINT	ABOVE SPLIT POINT	
CAMBODIA				
Baseline latrine coverage	≧ 34%	16 (50)	49 (50)	33
Community size	< 110 HH	40 (28)	29 (72)	11
Female literacy	≧ 68%	20 (12)	34 (88)	14
Male literacy	≧ 85%	29 (89)	57 (11)	28
GHANA				
Community size	< 40 HH	61 (70)	20 (30)	41
Female literacy	< 57%	56 (81)	18 (19)	38
Male literacy	< 35%	62 (28)	43 (72)	19
Population density (localized)	< 280 people/km^2	57 (78)	22 (22)	35
LIBERIA				
Community size	< 61 HH	60 (82)	40 (18)	20
Diarrhea prevalence	≧ 25%	55 (89)	73 (11)	18
Distance to roads	≧ 16 km	48 (12)	58 (88)	10
Forest coverage	≧ 51%	50 (22)	59 (78)	9
Water scarcity	< 1.4	65 (42)	52 (58)	13
ZAMBIA				
Access to improved water	< 95%	36 (90)	26(10)	10
Cholera risk	≧ 0.83	27 (30)	38 (70)	11
Community size	< 74 HH	37 (90)	19 (10)	18
Distance to major waterbodies	≧ 12 km	27 (20)	37 (80)	10
Number of improved water sources	≧ 1.4	33 (28)	36 (72)	3
Time to cities	≧ 0.6 hrs.	23 (23)	38 (77)	15
Water scarcity	≧ 0.053	33 (78)	43 (22)	10

[a] **We identified split points using a Classification and Regression Tree (CART) approach. The split point is the value of the variable defining the greatest homogeneity in ODF achievement on one side of the value and the greatest homogeneity in non-achievement on the other side.**

[b] **Wilcoxon tests confirmed that the difference in ODF achievement below and above split points was statistically significant (*p*<0.05).**

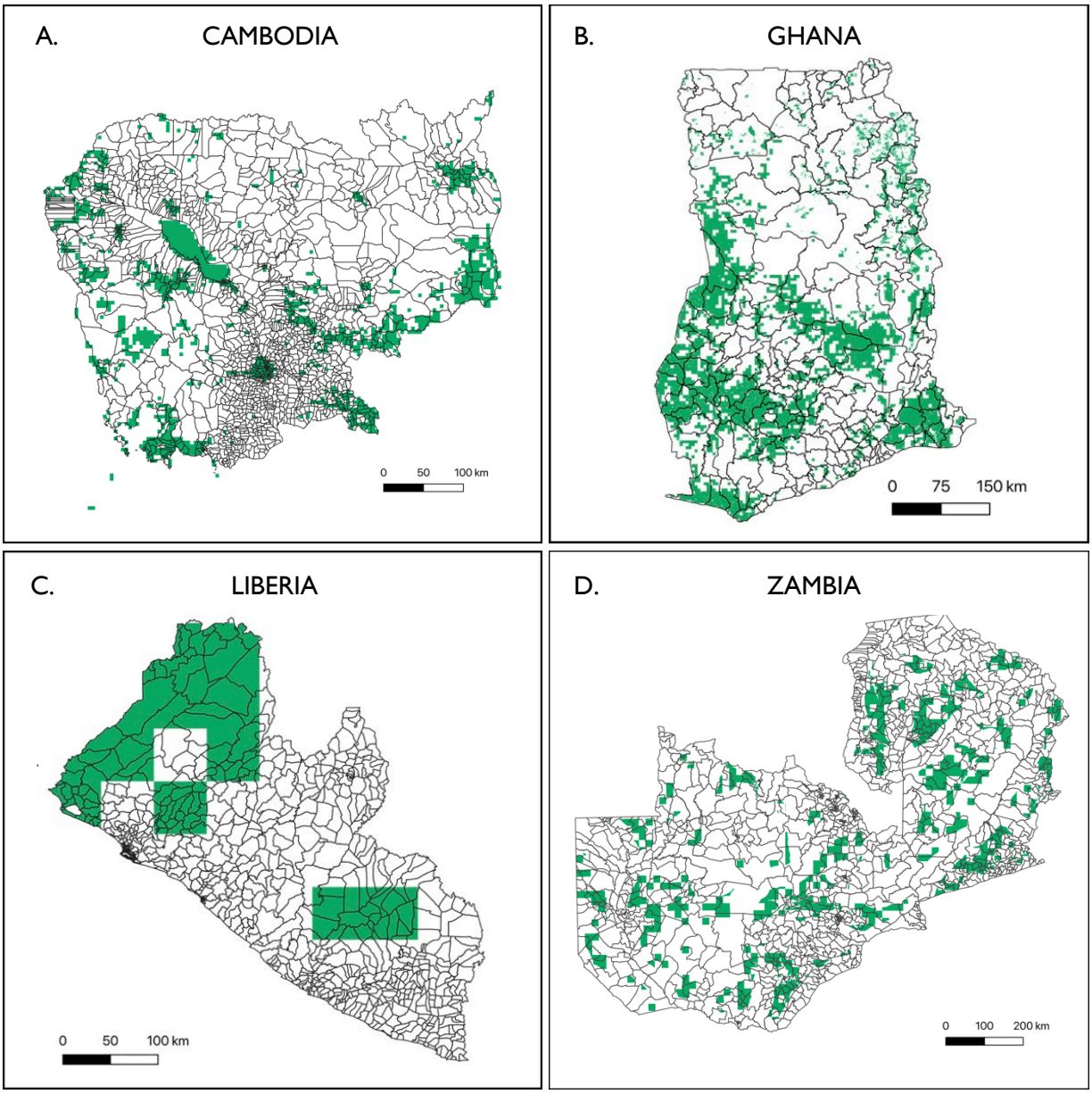


Figure 3. Maps of areas meeting target ODF achievement probabilities *(50% in Cambodia and Zambia, 70% in Ghana and Liberia) based on contextual factors for which data are publicly available. Pixel resolutions are determined by raw datasets, resolutions for variables are listed in Table 2. A) Cambodia - shaded areas indicate areas with 57% probability of ODF achievement, determined having =>85% male literacy. B) Ghana - shaded areas indicate areas with 72% probability of ODF achievement, determined by either areas with <57% female literacy, < 28 pp/km2 (localized density), & >= 67% male literacy OR areas with <57% female literacy, 1.4-4.7 pp/km^2 (localized density), & <35% or >=67% male literacy, C) Liberia – shaded areas indicate areas with 76% probability of ODF achievement, determined by water scarcity index of 1.1-1.4. D) Zambia - shaded areas indicate areas with 52% probability of ODF achievement, determined by >=34 minutes from cities AND >= 27km from waterbodies AND 0.83-3.9 cholera cases/100,000.*

Rural sanitation community classification tool. Through the Performance Envelope research, WASHPaLS identified an opportunity to develop a web-based community classification tool, which would later become "SanPlan" (www.sanplan.app), to support the grouping and exploration of communities according to contextual factors of interest, displaying this information within country maps. The webtool was built with inputs and feedback from our research partners in Cambodia, Ghana, and Liberia and key stakeholders at WaterAid and UNICEF.

SanPlan integrates data on contextual factors that are thought to influence sanitation program success, allowing users to identify areas that meet their desired characteristics or to determine what interventions may best suit a particular geographic area of interest. SanPlan uses existing publicly available data and links it to a specific location on the map. This allows users to click anywhere on the map and access information on key contextual factors. To create the map, values for each pixel area are pulled from each variable layer. The tool offers five main functionalities (Figure 4): (i) rural typology classification (this automatically assigns communities to one of four rural typologies—rural remote, rural, on-road, rural mixed, or urban—based on pre-defined rules for three variable layers: time to cities, distance to roads, and distance to towns, at either 1km or 5km resolution); (ii) 5km area pixel-level contextual analysis with 13 variables; (iii) administrative boundary-level contextual analysis; (iv) user-added community situating (using user-uploaded community locations); and (v) estimated settlement mapping. Currently, the tool does not allow users to conduct the same quantitative analysis used in this study to establish influential factors in a more rigorous way because reliable outcome data is not available for all programs or countries included in the tool.

SanPlan is intended for use for sanitation projects at national, regional, or local scales. Users in the planning or budgeting phases can use the spatial information to select and target interventions based on the characteristics of a particular geographic area. Similarly, someone in the monitoring and reporting phase could use the tool to compare the local context of their program area to the rest of the country. Program implementers, funders, and government institutions, and researchers are all intended users. WASHPaLS intends to make this tool publicly available.

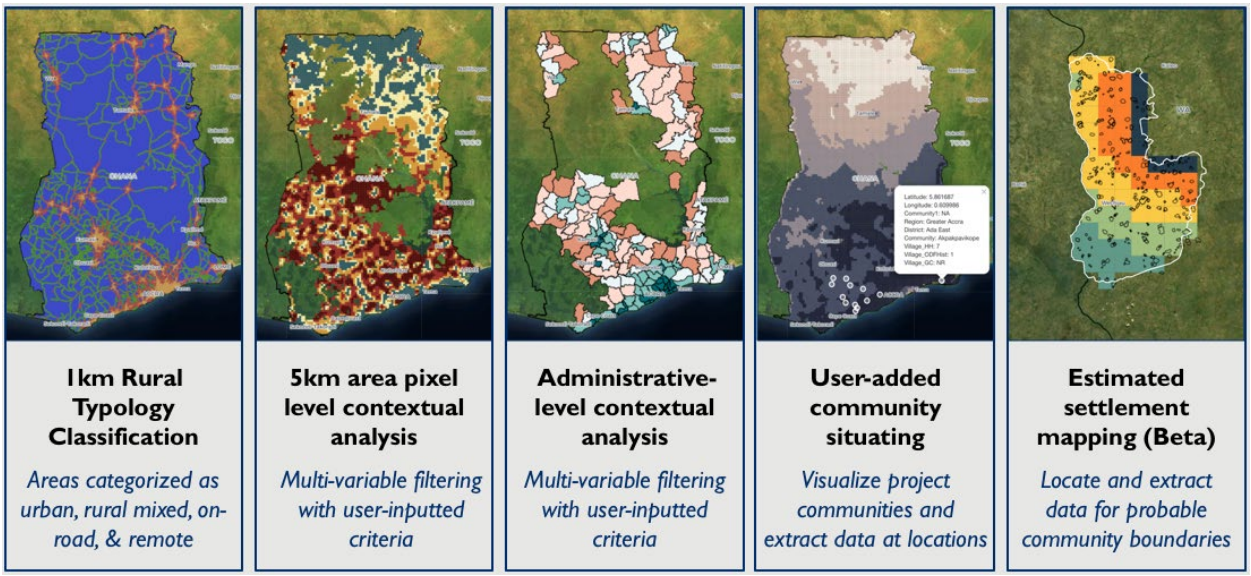


Figure 4. Main five features of the SanPlan Web Tool.

4.3 SUSTAINABILITY CONTINUES TO BE THE MAIN CHALLENGE FOR CLTS

Some level of open defecation still occurs in most ODF-declared communities. In the qualitative case study communities in Ghana, this was primarily due to latrines that collapsed and were not rebuilt, not

because households preferred open defecation. Among the qualitative case study communities in Cambodia, where toilet structures were more robust in general, newly constructed houses in ODF-declared communities were not always choosing to build toilets. Continued open defecation among ODF-declared communities was largely supported by the quantitative work which found that approximately 70 percent of communities that had achieved 100 percent latrine coverage in Zambia had slipped at least once afterwards.

Our research also found that, in some cases, factors that are conducive to achievement may create challenges for sustainability. For example, in some contexts, remote communities may be more likely to achieve ODF, but very remote communities in turn may be less likely to sustain ODF. In addition, implementation strategies that encourage rushed latrine constructions may result in inconsistent use over the longer term.

To gain insight into the drivers of ODF sustainability, data collection needs to continue post-ODF certification. As discussed above, we were only able to examine factors associated with ODF sustainability in one of the study countries (Zambia). We found discrepancies between the predictors of ODF sustainability and ODF achievement, hinting toward an optimal middle ground conducive to both, which requires additional research to define. From our analysis in Zambia, we confirmed that households may revert to open defecation even years after ODF achievement (our data included reports from 2013-2018), demonstrating the need for long-term M&E.

In addition to monitoring latrine coverage targets, monitoring the feedback of community members throughout implementation will help implementers assess the likelihood of sustainability. Implementers should identify opportunities to reinforce community-led mechanisms for success, such as encouraging neighbors to help one another with construction where this kind of mutual-aid is practiced, and building capacity of natural leaders who can continue to support ongoing monitoring and maintenance.

5.0 REFERENCES

Burr, P., Pinfold, J., Sackeyfio, C., Tincani, L., Amissah, G. A., & Dotse, M. (2017). Water and Sanitation Sector Equity Analysis for Ghana.

Cambodia Project Coordinator. (2019). Phone Interview. Plan International.

Cambodia Road Network (Main Roads). (2018). https://geonode.wfp.org/layers/ogcserver.gis.wfp.org%3Ageonode%3Azmb_trs_roads_osm.

Cameron, L. A., & Shah, M. (2017). Scaling Up Sanitation: Evidence from an RCT in Indonesia. Cambridge, MA. https://www.povertyactionlab.org/sites/default/files/publications/3855_Scale_Up-Sanitation-Evidence-from-an-RCT-in-Indonesia_LisaCameron_Jan2017.pdf.

Corpenicus & ECMWF. (2019). Land Cover Classification Gridded Maps from 1992 to Present Derived from Satellite Observations. https://cds.climate.copernicus.eu/cdsapp#!/home.

Crocker, J., Abodoo, E., Asamani, D., Domapielle, W., Gyapong, B., & Bartram, J. (2016). Impact Evaluation of Training Natural Leaders during a Community- Led Total Sanitation Intervention: A Cluster-Randomized Field Trial in Ghana. *Environmental Science & Technology, 50,* 8867–75. https://doi.org/10.1021/acs.est.6b01557.

Crocker, J., Geremew, A., Atalie, F., Yetie, M., & Bartram, J. (2016). Teachers and Sanitation Promotion: An Assessment of Community-Led Total Sanitation in Ethiopia. *Environmental Science & Technology 50*(12), 6517–25. https://doi.org/10.1021/acs.est.6b01021.

Crocker, J., Shields, K. F., Venkataramanan, V., Saywell, D., & Bartram, J. (2016). Building Capacity for Water, Sanitation, and Hygiene Programming: Training Evaluation Theory Applied to CLTS Management Training in Kenya. *Social Science & Medicine, 166*, 66–76. https://doi.org/http://dx.doi.org/10.1016/j.socscimed.2016.08.008.

Garn, J. V., Sclar, G. D., Freeman, M. C., Penakalapati, G., Alexander, K. T., Brooks, P., Rehfuess, E. A., Boisson, S., Medlicott, K. O., & Clasen, T. F. (2016). The Impact of Sanitation Interventions on Latrine Coverage and Latrine Use: A Systematic Review and Meta-Analysis. *International Journal of Hygiene and Environmental Health, 220*(2), 329–40. https://doi.org/10.1016/J.IJHEH.2016.10.001.

Ghana Environmental Health Officer. (2019). Phone Interview. Government of Ghana.

Ghana Senior WASH Coordinator. (2019). Phone Interview. Global Communities Ghana.

Ghana Statistical Service. (2015). Ghana Poverty Mapping Report. https://www2.statsghana.gov.gh/docfiles/publications/POVERTY%20MAP%20FOR%20GHANA-05102015.pdf

Ghana WASH Programme Coordinator. (2019). Phone Interview. Global Communities Ghana.

Government of Zambia, Ministry of Local Government and Housing. (2013). National Procedure for Verification and Certification of ODF.

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S. V., Goetz, S. J., Loveland, T. R., Kommareddy, A., Egorov, A., Chini, L., Justice, C. O., & Townshend, J. R. (2013). High-resolution global maps of 21st-century forest cover change. *Science, 342*(6160), 850–853. https://doi.org/10.1126/science.1244693

Harter, M., Lilje, J., & Mosler, H.-J. (2019). Role of implementation factors for the success of community-led total sanitation on latrine coverage. A case study from rural Ghana. Environmental Science & Technology, 53(9), 5466–5472. https://doi.org/10.1021/acs.est.9b01055

Harter, M., Mosch, S., & Mosler, H.-J. (2018). How does community-led total sanitation (CLTS) affect latrine ownership? A quantitative case study from Mozambique. *BMC Public Health*, *18*(1). https://doi.org/10.1186/s12889-018-5287-y

Hydroconseil, Ecopsis, and WEDC. (2014). Evaluation of the WASH Sector Strategy: Community Approaches to Total Sanitation (CATS).

Jordan, E., Gross, M. E., Javernick-Will, A. N., & Garvin, M. J. (2011). Use and misuse of qualitative comparative analysis. *Construction Management and Economics*, *29*(11), 1159–1173. https://doi.org/10.1080/01446193.2011.640339

Jordan, E., Javernick-Will, A., & Tierney, K. (2016). Post-tsunami recovery in Tamil Nadu, India: Combined social and infrastructural outcomes. *Natural Hazards*, *84*(2), 1327–1347. https://doi.org/10.1007/s11069-016-2489-4

Chambers, R. & Kar, K. (2008) Handbook on Community-Led Total Sanitation, Brighton: IDS

Kreisel, W. (1991). Water-Quality and Health. *Water Science and Technology, 23*(1–3), 201–9.

Kullmann, Craig, Rokeya Ahmed, Suzanne Hanchett, Laurie Krieger, and Mohidul Hoque Kahn. 2011. "Long-Term Sustainability of Improved Sanitation in Rural Bangladesh." WSP Research Brief.

Lawrence, J. J., Hamer, D. H., Ram, P. K., Osbert, N., Yeboah-Antwi, K., Sabin, L. L., & Biemba, G. (2016). Beliefs, behaviors, and perceptions of community-led total sanitation and their relation to improved sanitation in rural Zambia. *The American Journal of Tropical Medicine and Hygiene*, *94*(3), 553–562. https://doi.org/10.4269/ajtmh.15-0335

Lessler, J., Moore, S. M., Luquero, F. J., McKay, H. S., Grais, R., Henkens, M., Mengel, M., Dunoyer, J., M'bangombe, M., Lee, E. C., Djingarey, M. H., Sudre, B., Bompangue, D., Fraser, R. S., Abubakar, A., Perea, W., Legros, D., & Azman, A. S. (2018). Mapping the burden of cholera in sub-saharan Africa and implications for control: An analysis of data across geographical scales. *The Lancet*, *391*(10133), 1908–1915. https://doi.org/10.1016/s0140-6736(17)33050-7

Liberia County Manager. (2019). Phone Interview. Liberia: Global Communities.

Mekonnen, M. M., & Hoekstra, A. Y. (2016). Four billion people facing severe water scarcity. *Science Advances*, *2*(2). https://doi.org/10.1126/sciadv.1500323

Mukherjee, N. (2011). Factors Associated with Achieving and Sustaining Open Defecation Free Communities: Learning from East Java. *WSP Research Brief*.

Mukherjee, N. & Robiarto, A. (2012). Monitoring Progress and Program Performance, and Sequencing of CLTS and Sanitation Marketing. IDS Workshop on Monitoring CLTS, 32 pp. Malawi: Water and Sanitation Program.

Odagiri, M., Muhammad, Z., Cronin, A., Gnilo, M., Mardikanto, A., Umam, K., & Asamou, Y. (2017). Enabling factors for sustaining open defecation-free communities in rural Indonesia: A cross-sectional study. *International Journal of Environmental Research and Public Health*, *14*(12), 1572. https://doi.org/10.3390/ijerph14121572

Plan International, WaterAid, & WSSCC. (2019). Shared Latrine Use and Dynamics in Rural Cambodia: Full Report.

R Core Team. (2019). R: A Language and Environment for Statistical Computing. *R Foundation for Statistical Computing*.

Radin, M., Jeuland, M., Wang, H., Whittington, D., Robinson, L., Hammitt, J., Wong, B., & Smith, V. K. (2019). Benefit-Cost Analysis of Community-Led Total Sanitation: Incorporating Results from Recent Evaluations. https://sites.sph.harvard.edu/bcaguidelines/

RCMRD. (2015). Africa Water Bodies. http://geoportal.rcmrd.org/layers/servir%3Aafrica_water_bodies.

Rihoux, B. & Ragin, C. (2009). Qualitative Comparative Analysis Using Fuzzy Sets (FsQCA). *Configurational Comparative Methods: Qualitative Comparative Analysis (QCA) and Related Techniques*. https://doi.org/https://dx.doi.org/10.4135/9781452226569.n5.

Russpatrick, S., Tiwari, A., Markle, L., Musonda, E., Mutunda, A., Osbert, N., Pinfold, J., Winters, A., Winters, B., & Larsen, D. A. (2017). Mobility up the sanitation ladder following community-led total sanitation in rural Zambia. *Journal of Water, Sanitation and Hygiene for Development*, *7*(3), 436–444. https://doi.org/10.2166/washdev.2017.111

Sahoo, K. C., Hulland, K. R. S., Caruso, B. A., Swain, R., Freeman, M. C., Panigrahi, P., & Dreibelbis, R. (2015). Sanitation-related psychosocial stress: A grounded theory study of women across the life-course in Odisha, India. *Social Science & Medicine*, *139*, 80–89. https://doi.org/10.1016/j.socscimed.2015.06.031

Schmidt, W.-P. (2014). The elusive effect of water and sanitation on the global burden of disease. *Tropical Medicine & International Health*, *19*(5), 522–527. https://doi.org/10.1111/tmi.12286

Spatial Data Repository, The Demographic and Health Surveys Program. (2020). Modeled Surfaces. https://spatialdata.dhsprogram.com/modeled-surfaces/.

Sticklor, Russell. (2016). A Community Approach to Better Public Health in Rural Liberia. *Global Waters*. https://medium.com/usaid-global-waters/a-community-approach-to-better-public-health-in-rural-liberia-b0357f84a980.

Stuart, K., Peletz, R., Albert, J., Khush, R., & Delaire, C. (2021). Where does CLTS work best? quantifying predictors of CLTS performance in four countries. *Environmental Science & Technology*, *55*(6), 4064–4076. https://doi.org/10.1021/acs.est.0c05733

Therneau, T., Atkinson, B., & Ripley, B. (2019). Recursive Partitioning and Regression Trees. CRAN.

Tiwari, A., Osbert, N., Matimelo, S. M., Larsen, D. A., Winters, B., Russpatrick, S., Soloka, G., Mazimba, S., Winters, A., Nkhata, I., & Hoehne, A. (2017). Assessing the impact of leveraging traditional leadership on access to sanitation in rural Zambia. *The American Journal of Tropical Medicine and Hygiene*, *97*(5), 1355–1361. https://doi.org/10.4269/ajtmh.16-0612

Tribbe, J., Zuin, V., Delaire, C., Khush, R., & Peletz, R. (2021). How do rural communities sustain sanitation gains? qualitative comparative analyses of community-led approaches in Cambodia and Ghana. *Sustainability*, *13*(10), 5440. https://doi.org/10.3390/su13105440

Tyndale-Biscoe, P., Bond, M., & Kidd, R. (2013). ODF Sustainability Study.

UNICEF & CDD Ghana. (2016). The Ghana District League Table (DLT). http://iamawareghana.com/index.php?id=71.

UNICEF WCARO. (2011). Roll-Out Evaluation of 'Community Led Total Sanitation' in West and Centra Africa.

United Nations Office for the Coordination of Humanitarian Affairs. (2018). Cambodia - Rivers. https://data.humdata.org/dataset/cambodia-water-courses-0.

United Nations Office for the Coordination of Humanitarian Affairs. (2019). OpenStreetMap GIS Data on Guinea, Liberia, and Sierra Leone. https://data.humdata.org/dataset/open-street-map-data-on-guinea-liberia-and-sierra-leone.

United Nations Office for the Coordination of Humanitarian Affairs. (2020). HOTOSM Ghana Roads (OpenStreetMap Export). 2020. http://wiki.openstreetmap.org/wiki/Key:name.

USAID. (2018a). Community-Led Total Sanitation (CLTS) Performance Envelope Study: Inception Report. Water, Sanitation, and Hygiene for Partnerships and Learning for Sustainability Project (WASHPaLS).

USAID. (2018b). An Examination of CLTS's Contributions Toward Universal Sanitation. https://www.globalwaters.org/resources/assets/washpals/examination-cltss-contributions-toward-universal-sanitation.

USAID. (2021). Sustaining Latrine Coverage and Use in Rural Cambodia: A Study of the Cambodia Rural Sanitation and Hygiene Improvement Programme (CRSHIP 1). Unpublished Report.

Venkataramanan, V. (2012). Testing CLTS Approaches for Scalability: Systematic Literature Review. https://waterinstitute.unc.edu/files/2015/03/CLTS-Systematic-Literature-Review-Final-Report-Appendix-1-4.pdf.

Venkataramanan, V. (2014). Testing CLTS Approaches for Scalability CLTS Learning Series: Cambodia Country Report. Chapel Hill, NC. http://www.planusa.org/.

Venkataramanan, V. (2016). Testing CLTS Approaches for Scalability CLTS Learning Series: Lessons from CLTS Implementation in Seven Countries. http://www.planusa.org/.

Venkataramanan, V., Crocker, J., Karon, A., & Bartram, J. (2018). Community-led total sanitation: A mixed-methods systematic review of evidence and its quality. *Environmental Health Perspectives*, *126*(2), 026001. https://doi.org/10.1289/ehp1965

Venkataramanan, V. & Shannon, A. (2016). CLTS Learning Series: Lessons from CLTS Implementation in Seven Countries. https://waterinstitute.unc.edu/files/2016/01/CLTS-Learning-Series-Final-Report_011416.pdf.

Vernon, N., & Bongartz, P. (2016). Chapter 1: Going Beyond Open Defecation Free. *Sustainable Sanitation for All*, 1–28. https://doi.org/10.3362/9781780449272.001

WaterAid/Causal Design. (2017). Assessing the Influence of Social Context on Sanitation Uptake: Final Report.

WaterAid, UNICEF, & Plan International. (2017). Rethinking Rural Sanitation Approaches.

Weiss, D. J., Nelson, A., Gibson, H. S., Temperley, W., Peedell, S., Lieber, A., Hancher, M., Poyart, E., Belchior, S., Fullman, N., Mappin, B., Dalrymple, U., Rozier, J., Lucas, T. C., Howes, R. E., Tusting, L. S., Kang, S. Y., Cameron, E., Bisanzio, D., … Gething, P. W. (2018). A global map of travel time to cities to assess inequalities in accessibility in 2015. *Nature*, *553*(7688), 333–336. https://doi.org/10.1038/nature25181

Whittington, D., Radin, M., & Jeuland, M. (2020). Evidence-based policy analysis? The strange case of the randomized controlled trials of community-led total sanitation. *Oxford Review of Economic Policy*, *36*(1), 191–221. https://doi.org/10.1093/oxrep/grz029

WHO/UNICEF JMP. (2019). Progress on Household Drinking Water, Sanitation and Hygiene 2000-2017: Special Focus on Inequalities. Launch Version July 12 Main Report Progress on Drinking Water, Sanitation and Hygiene. https://washdata.org/reports.

World Food Programme. (2018). Zambia Road Network (Main Roads). WFPGeoNode. https://geonode.wfp.org/layers/ogcserver.gis.wfp.org%3Ageonode%3Azmb_trs_roads_osm.

WorldPop Project. (n.d.). Accessed November 14, 2018. http://www.worldpop.org.uk/.

Zambia Deputy Program Manager. (2019). Phone Interview. Akros.

Zambia Ministry of Local Government and Housing. (2013). Community-Led Total Sanitation. National Procedures for Verification and Certification of ODF (Zambia). https://www.communityledtotalsanitation.org/resource/national-procedures-verification-and-certification-odf-zambia.

Zuin, V., Delaire, C., Peletz, R., Cock-Esteb, A., Khush, R., & Albert, J. (2019). Policy diffusion in the Rural Sanitation Sector: Lessons from community-led total sanitation (CLTS). *World Development*, *124*, 104643. https://doi.org/10.1016/j.worlddev.2019.104643

ANNEX A. QUANTITATIVE MODEL RESULTS TABLE

Table A-1. Detailed multilevel logistic regression results. OR=Odds Ratio, CI=95% Confidence Interval. Associations p<0.1 are indicated in bold, and statistically significant associations (p<0.05) are italicized. All results with p<0.001 met the significance test when considering post-hoc Bonferroni corrections. See Table 2 for additional details on variables and their resolutions. A unit increase in the standardized variable corresponds to an increase in the actual variable equal to its standard deviation.

FACTOR	EXPLANATORY VARIABLE (UNIT)	ODF ACHIEVEMENT [a]								ODF SUSTAINABILITY [b]	
		CAMBODIA		GHANA		LIBERIA		ZAMBIA		ZAMBIA	
		OR [95% CI]	*p*-value	OR [95% CI]	*p*-value	OR [95% CI]	*p*-value	OR [95% CI]	*p*-value	OR [95% CI]	*p*-value
Baseline latrine Coverage	Baseline latrine coverage (%)	***4.55 [3.80, 5.45]***	***<0.001***	-	-	1.04 [0.92, 1.16]	0.559	-	-	-	-
Community size	Community size (# HHs)	***0.66 [0.57, 0.77]***	***<0.001***	***0.07 [0.03, 0.15]***	***<0.001***	***0.75 [0.66, 0.87]***	***<0.001***	***0.64 [0.57, 0.72]***	***<0.001***	0.92 [0.81, 1.06]	0.262
Literacy	Men's literacy (%)	***1.21 [1.01, 1.44]***	***0.037***	***0.71 [0.51, 0.97]***	***0.034***	-	-	1.01 [0.92, 1.11]	0.773	1.05 [0.89, 1.23]	0.549
	Women's literacy (%)	***1.28 [1.05, 1.57]***	***0.016***	***0.49 [0.36, 0.68]***	***<0.001***	**1.24 [0.98, 1.57]**	**0.079**	1.05 [0.92, 1.20]	0.453	0.92 [0.75, 1.14]	0.455
Natural environmental shelter	Distance to major waterbodies (km.)	0.91 [0.74, 1.13]	0.392	0.85 [0.67, 1.08]	0.173	**0.73 [0.53, 1.00]**	**0.052**	***1.17 [1.08, 1.27]***	***<0.001***	**0.88 [0.76, 1.00]**	**0.054**
	Forest coverage (%)	0.92 [0.71, 1.18]	0.490	**0.61 [0.34, 1.08]**	**0.090**	***1.17 [1.01, 1.36]***	***0.032***	1.00 [0.90, 1.12]	0.996	1.13 [0.93, 1.38]	0.217
	Shrubland coverage (%)	0.98 [0.80, 1.20]	0.847	0.94 [0.80, 1.11]	0.454	**0.90 [0.80, 1.00]**	**0.056**	0.97 [0.91, 1.04]	0.417	***0.78 [0.69, 0.87]***	***<0.001***
Population density	Population density (Area-wide) (pp/km^2)	**1.20 [0.99, 1.45]**	**0.058**	0.27 [0.03, 2.93]	*0.285*	1.81 [0.61, 5.34]	0.282	0.93 [0.84, 1.03]	0.167	**1.11 [1.00, 1.25]**	**0.069**
	Population density (Localized) (pp/km^2)	-	-	***0.40 [0.25, 0.63]***	***<0.001***	0.97 [0.70, 1.34]	0.841	0.92 [0.83, 1.02]	0.131	1.07 [0.97, 1.18]	0.164
Poverty	Poverty rate (%)	-	-	1.23 [0.81, 1.89]	0.331	-	-	-	-	-	-
Remoteness	Time to cities (hr.)	**0.75 [0.54, 1.04]**	**0.083**	0.95 [0.77, 1.16]	0.600	**1.18 [0.97, 1.44]**	**0.088**	***1.15 [1.06, 1.24]***	***<0.001***	***0.85 [0.75, 0.97]***	***0.016***
	Distance to main roadways (km.)	**0.85 [0.71, 1.02]**	**0.086**	1.17 [1.00, 1.38]	0.050	***1.76 [1.18, 2.63]***	***0.005***	0.97 [0.91, 1.04]	0.420	***0.83 [0.73, 0.94]***	***0.003***
Water availability	Access to improved water (%)	-	-	1.04 [0.85, 1.27]	0.714	***0.75 [0.58, 0.97]***	***0.030***	***0.85 [0.75,0.95]***	***0.005***	***0.79 [0.65, 0.96]***	***0.017***
	Number of improved water sources (#)	-	-	-	-	-	-	***1.11 [1.06, 1.16]***	***<0.001***	0.96 [0.84, 1.09]	0.518
	Rural access to water supply systems (%)	-	-	1.29 [0.88, 1.89]	0.197	-	-	-	-	-	-
	Water scarcity	0.85 [0.54, 1.34]	0.478	1.09 [0.76, 1.56]	0.637	***0.77 [0.64, 0.94]***	***0.010***	***1.35 [1.26, 1.44]***	***<0.001***	***1.33 [1.15, 1.55]***	***<0.001***
Waterborne disease burden	Cholera risk (cases/100,000pp)	-	-	0.80 [0.59, 1.09]	0.154	1.03 [0.83, 1.29]	0.769	***1.20 [1.09, 1.31]***	***<0.001***	1.05 [0.91, 1.23]	0.486
	Diarrhea prevalence (%)	-	-	-	-	***1.27 [1.12, 1.44]***	***<0.001***	-	-	-	-

[a] Binary outcome metric, ODF achieved were coded "1," ODF not achieved was coded "0."
[b] Binary outcome metric, ODF sustained were coded "1," ODF not sustained was coded "0." Only communities which achieved ODF were included in models (n_{max}=3,148).

ANNEX B. UNDERSTANDING FAVORABILITY – DETERMINING SPLIT POINTS

With a better understanding of the predictors of CLTS performance, implementers could better identify suitable locations, prioritize resources, and consider other complementary implementation approaches, such as market-based sanitation. To facilitate the delineation of favorable areas, we offer a methodology to derive "split points" and describe how they can be used individually, or else across multiple variables to predict a specific level ODF achievement.

Split points can guide implementation. Our analysis identified four contextual variables strongly associated with ODF achievement in Cambodia and Ghana, five in Liberia, and seven in Zambia. To translate these findings into practical information for implementers, we identified split points for each of these variables using a CART approach (Table 4) (R Core Team 2019). The split point indicates the value of a contextual variable corresponding to the largest possible gain in ODF achievement, maximizing the difference in communities above and below the threshold value (Therneau et al., 2019). Box B-1 depicts an illustrative example of split point determination. Split points allow implementers to identify favorable and unfavorable areas for ODF achievement to aid in their programming efforts. For example, to improve cost-effectiveness, implementers can the use split points provided in Table 4 to target CLTS activities and resources to areas with the highest probability of success (Radin et al., 2019) and/or adapt their approach in areas likely to be less favorable.

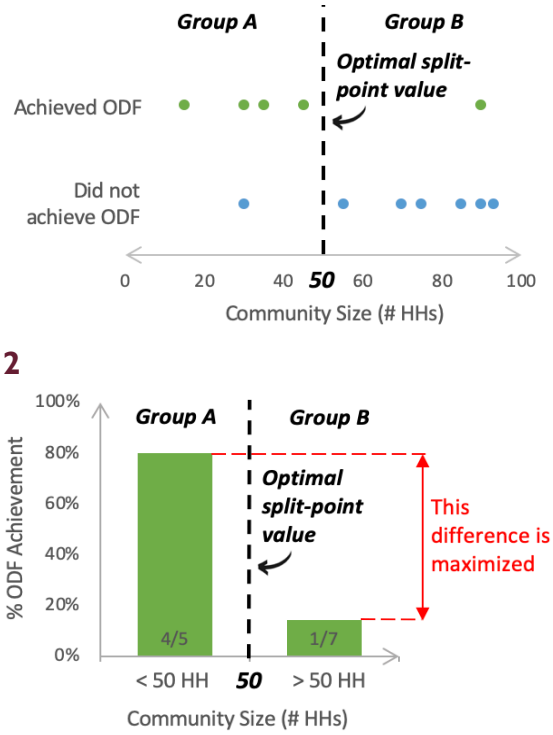
Box B-1. UNDERSTANDING SPLIT POINTS. CASE STUDY: COMMUNITY SIZE

A split point value separates the dataset in two groups:

1. Communities with a size below the split point (Group A) and
2. Communities with a size above the split point (Group B).

- The Classification and Regression Tree (CART) algorithm identifies the split point that *maximizes the difference in ODF achievement between the two groups* (Figure 2).

Assume that the community size split point is 50 households. This means that ODF achievement amongst communities with less than 50 households is higher than communities with more than 50 households, *and there is no other community size for which this difference is greater*.
Therefore, a program manager can categorize communities with less than 50 households as "favorable" for ODF achievement, and communities with more than 50 households as "unfavorable," knowing that in no other categorization the probabilities of ODF achievement are more distinct between the two groups.



Conditions can be leveraged to predict achievement of a desired probability of CLTS success. The same CART algorithm discussed above can be used to identify groups of contextual conditions leading to a desired probability of ODF achievement, and thus, map CLTS "favorability." For this, we ran the CART algorithm with all contextual variables significantly associated with ODF achievement ($p<0.05$) and identified the pathways on the tree where ODF achievement exceeded the desired probability. In our study, we defined 50 percent probability of ODF achievement to be favorable in Cambodia and Zambia and 70 percent in Ghana and Liberia. The desired probability is partially determined by the overall ODF achievement of the dataset. For example, after viewing the CART, we found that no combinations of conditions could predict 70 percent ODF achievement in Cambodia and Zambia in at minimum 10 percent of communities, so we defined the target probability at 50 percent in these countries. Re-running the CART algorithm with only publicly available, mapped variables results in a set or sets of conditions that can then be mapped in GIS software. All resulting maps for the study countries are presented in Figure 3, and detailed condition sets are presented in Table B-1.

Table B-1. Contextual conditions corresponding to a minimum 50% (Cambodia and Zambia) or 70% probability of ODF achievement (Ghana and Liberia).

USING ALL CONTEXTUAL VARIABLES AVAILABLE		USING ONLY CONTEXTUAL VARIABLES FROM PUBLICLY AVAILABLE DATASETS (mapped in Figure 3)	
CONDITIONS FOR A MINIMUM 50% PROBABILITY OF ODF ACHIEVEMENT	ODF (%)	CONDITIONS FOR A MINIMUM 50% PROBABILITY OF ODF ACHIEVEMENT	ODF (%)
Cambodia			
>= 63% baseline latrine coverage **OR**	60	>= 85% male literacy	57
< 63% baseline latrine coverage AND >= 83% male literacy **OR**			
< 63% baseline latrine coverage AND < 83% male literacy AND < 136 households			
Zambia			
34-92 minutes from cities AND >= 12km from waterbodies AND < 46 households AND >= 77% access to improved water	57	>=34 minutes from cities AND >= 27km from waterbodies AND 0.83-3.9 cholera cases/100,000	52
CONDITIONS FOR A MINIMUM 70% PROBABILITY OF ODF ACHIEVEMENT	ODF (%)	CONDITIONS FOR A MINIMUM 70% PROBABILITY OF ODF ACHIEVEMENT	ODF (%)
Ghana			
17- 40 households AND < 57% female literacy AND < 13 pp/km^2 localized population density	72	<57% female literacy AND < 28 pp/km^2 localized population density AND >= 67% male literacy **OR**	72
		<35% OR >=67% male literacy AND <57% female literacy AND 1.4-4.7 pp/km^2 localized population density	
Liberia			
< 1.7 water scarcity AND <11 households **OR**	72	1.1-1.4 water scarcity	76
1.1-1.7 water scarcity AND <11 households AND > 54% forest coverage			

U.S. Agency for International Development
1300 Pennsylvania Avenue, NW
Washington, DC 20523
Tel: (202) 712-0000
Fax: (202) 216-3524
www.usaid.gov