The influence of household spatial relationship on household water treatment use: A geographic analysis of Gift of Water's filter program evaluation in Haiti

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Projection: WGS 1984 UTM Zone 18N

Data Sources: Spatial Data Repository, The Demographic & Health Surveys Program, ICF International; Geofabrik; US National Park Service; ESRI Online

INTRODUCTION

- Lack of access to safe drinking water, inadequate sanitation, & poor hygiene practices are the leading attributable cause of nearly 760,000 deaths, annually, in children under 5 due to diarrhea around the world (**WHO 2013**).
- Numerous randomized control trials (RCT) have shown that household water treatment & safe storage (HWTS) technologies improve the microbiological quality of stored water resulting in a reduction in diarrheal disease burden (**Fewtrell & Colford 2005; Clasen et al 2007; Waddington et al 2009; Peletz et al 2012**).
- In contrast to the success found in RCTs, evidence from real world, at-scale HWTS programs is mixed. A primary challenge remains sustained uptake & adoption of HWTS technologies by users over time (**Boisson et al 2013**).
- Social support is characterized by whether a user perceives that their community supports a practice, and thus are more likely to also adopt that practice. Social support, facilitated through social networks, has been identified as one key behavioral factor driving sustained uptake and adoption of HWTS technologies in real-world programs (**Figueroa & Kincaid 2010**).
- To our knowledge, geospatial methods have not been used to investigate a behavioral determinant of adoption within HWTS programs.

Research Question & Hypothesis

- To understand the role that neighboring households (HH) might have on influencing the behavior of individual HHs, we examined the relationship between verified use of a HWTS system by an "index" HH & the spatial distribution of other surveyed HHs who also used the HWTS intervention; this measure of spatial distribution served as a proxy for "social support."
- We hypothesized that greater HH density (more HHs with verified used of the HWTS system within close distances) would have a supportive effect & would encourage use of the intervention by index HHs through sustained influence within existing social networks.

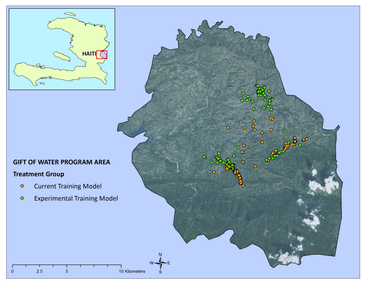

Figure 1. Gift of Water program area in Haiti & surveyed households by treatment group

Gift of Water

Gift of Water (GoW), is a US-based non-governmental organization dedicated "to providing filtered & clean drinking water to the third world communities that it serves." GoW began working in Haiti in 1995 to promote a two-bucket purifier that uses chlorine tablets together with polypropelyene filters & activated carbon to deliver high-quality drinking water. GoW is currently working in over 100 rural communities across Haiti, including Belladère commune.

DATA & METHODS

A geospatial analysis was conducted on primary data from a cluster randomized evaluation assessing the effect of a new training model for encouraging use of GoW's HWTS system in Haiti. Evaluation took place in two rural communities: Belladère & Croix Fer. Participating HH were randomized into the current training model (control), or an experimental training model (**Figure 1**). Baseline data collection took place in May 2013; four follow-up surveys were administered at 1-month, 3-month, 6-month, & 12-month time points after distribution of the HWTS system.

Data Collection

- Surveys captured demographic & health information about the HH & HWTS behaviors; follow-up surveys also asked questions about assembly, use, & maintenance of the distributed HWTS intervention.
- Enumerators also collected samples of drinking water from the top & bottom bucket of the water filter to test for free chlorine residual (FCR), a measure of whether the water had been treated with chlorine within the previous 24 hours.
- Spatial coordinates for HHs were captured using Garmin eTrex Legend hand-held GPS units. Paper surveys were administered & later entered into an Excel database.

Geospatial Analysis

- Spatial distribution of HHs served as a proxy for measuring "social support." This was calculated by stratifying the proximity of other surveyed HH with verified use from the index HH into a varying range of distances.
- Buffer zones (circles) were "drawn" around each index household over the following radii lengths: 50m, 100m, 150m, 250m, 500m, & 1000m. (**Figure 2**)
- Spatial queries for proximity, the number of other surveyed HH with verified use that lay within the various buffer zones around each index HH, were obtained to produce the crude estimate of "household density."
- HH density was separated into 4 categories: 1HH within buffer zone; 2HHs within buffer zone; 3HHs within buffer zone; and, 4 or more HHs within buffer zone.

Statistical Analysis

- After extracting the number of houses with verified use of the HWTS technology across varying radii lengths & across the different categories for HH density, Fisher's Exact Test was used to determine whether HH density was a statistically significant predictor ($p<0.05$ & $p<0.10$) of HWTS use in the index HH.
- Two measures for the outcome of interest:

CONFIRMED USE = FCR in bottom bucket ≥ 0.2 mg/L

CORRECT USE = FCR in bottom bucket ≥ 0.2 mg/L AND FCR in top bucket ≥ 1.5 mg/L

- Statistical analyses were conducted in R (3.3.2) across all 4 follow-up time points to determine if the relationship between HH density & the outcomes of interest were consistent over time.

This secondary data analysis qualifies for exemption by Tufts University Institutional Review Board since the GPS coordinates for each HH are not linked to any other personally identifiable information from the study participants. The study was funded by Gift of Water.

RESULTS

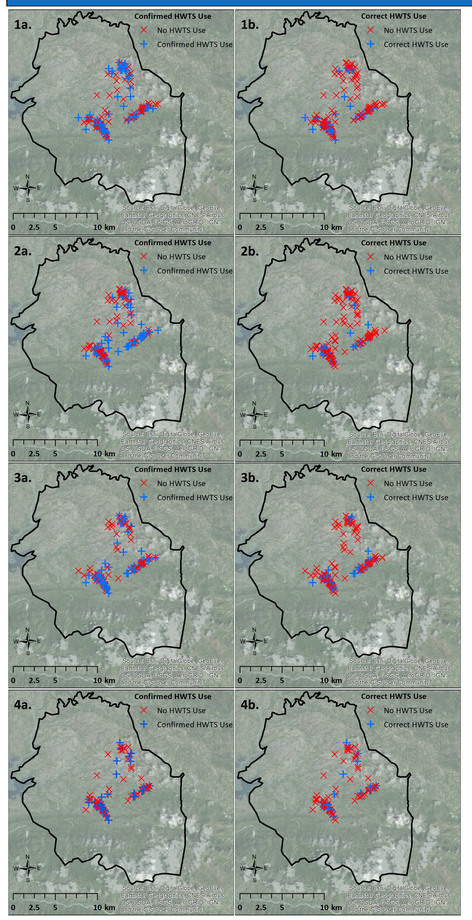

Figure 3. Spatial distribution of index HHs with confirmed (a) & correct (b) use of HWTS technology across four follow-up surveys (1,2,3,4)

Buffer radius (m)	Other HH within buffer: avg(min-max, median, stddev)	1 HH		2 HH		3 HH		4 HH	
50	0.6(0-6,0,1.3)	21	85	10	96	7	99	8	98
		5	89	2	92	2	92	2	92
100	1.6(0-9,0,2.4)	23	83	13	93	3	103	29	77
		12	82	4	90	3	91	9	85
150	2.7(0-12,1,3.6)	20	86	13	93	7	99	37	69
		13	81	7	87	5	89	15	79
250	5.3(0-18,3,6.1)	12	94	13	93	7	99	53	53
		7	87	7	87	11	83	30	64
500	12.2(0-40,6,11.8)	5	101	10	96	1	105	81	25
		8	86	7	87	1	93	56	38
100	24.2(0-52,16,20.2)	0	106	5	101	3	103	91	15
		0	94	6	88	6	88	74	20

Buffer radius (m)	Other HH within buffer: avg(min-max, median, stddev)	1 HH		2 HH		3 HH		4 HH	
50	0.4(0-3,0,0.7)	17	65	15	67	1	81	0	82
		8	93	4	97	1	100	0	101
100	0.8(0-4,0.1.1)	15	67	14	68	11	71	2	80
		9	92	11	90	5	96	2	99
150	1.5(0-8,0,2.0)	10	72	9	73	12	70	17	65
		5	96	8	93	4	97	20	81
250	3.1(0-15,2,3.9)	7	75	7	75	12	70	31	51
		9	92	5	96	8	93	30	71
500	7.2(0-21,5,7.3)	9	73	1	81	6	76	52	30
		13	88	3	98	5	96	56	45
100	14.2(0-29,12,10.8)	1	81	1	81	2	80	70	12
		4	97	7	94	2	99	79	22

Buffer radius (m)	Other HH within buffer: avg(min-max, median, stddev)	1 HH		2 HH		3 HH		4 HH	
50	0.4(0-5,0,0.9)	19	65	10	74	4	80	2	82
		3	88	2	89	0	91	2	89
100	1.0(0-7,0,1.5)	23	61	15	69	3	81	14	70
		5	86	12	79	3	88	3	88
150	1.7(0-8,1,2.1)	16	68	10	74	10	74	24	60
		13	78	6	85	3	88	14	77
250	3.5(0-13,2,3.7)	10	74	9	75	5	79	42	42
		8	83	17	74	3	88	28	63
500	8.9(0-25,6,8.2)	2	82	5	79	7	77	58	26
		2	89	4	87	7	84	59	32
100	17.3(0-38,11,12.9)	1	83	5	79	0	84	75	9
		2	89	4	87	2	89	73	8

Buffer radius (m)	Other HH within buffer: avg(min-max, median, stddev)	1 HH		2 HH		3 HH		4 HH	
50	0.3(0-3,0,0.7)	10	35	1	44	4	41	0	45
		4	64	2	66	0	68	0	68
100	0.5(0-5,0,1.1)	10	35	3	42	6	39	1	44
		2	66	1	67	4	64	1	67
150	0.9(0-5,0,1.6)	8	37	2	43	2	43	11	34
		7	61	0	68	2	66	5	63
250	1.7(0-8,1,2.0)	10	35	6	39	3	42	12	33
		1	67	5	63	4	64	16	52
500	4.3(0-13,2,4.2)	7	38	7	38	3	42	20	25
		17	51	5	63	2	66	31	37
100	9.2(0-19,6,7.3)	1	44	8	37	5	40	29	16
		3	65	9	59	5	63	43	25

Buffer radius (m)	Other HH within buffer: avg(min-max, median, stddev)	1 HH		2 HH		3 HH		4 HH	
50	0.2(0-3,0,0.5)	9	38	5	42	1	46	0	47
		8	138	2	144	0	146	0	146
100	0.6(0-5,0,1.1)	7	40	7	40	2	45	8	39
		11	135	9	137	6	140	1	145
150	1.2(0-6,0,1.9)	7	40	3	44	2	45	18	29
		11	135	2	144	10	136	17	129
250	2.6(0-12,0,3.7)	6	41	2	45	1	46	24	23
		16	130	5	141	5	141	35	111
500	6.3(0-23,2,7.7)	3	44	4	43	3	44	28	19
		17	129	14	132	6	140	51	95
100	11.6(0-27,4,11.4)	1	46	1	46	6	41	32	15
		6	140	18	128	23	123	69	77

Buffer radius (m)	Other HH within buffer: avg(min-max, median, stddev)	1 HH		2 HH		3 HH		4 HH	
50	0(0-1,0,0.2)	4	20	0	24	0	24	0	24
		1	158	0	159	0	159	0	159
100	0.1(0-2,0,0.3)	6	18	0	24	0	24	0	24
		5	154	2	157	0	159	0	159
150	0.3(0-3,0,0.6)	4	20	2	22	2	22	0	24
		12	147	11	148	0	159	0	159
250	0.7(0-4,0,1.2)	7	17	2	22	3	21	1	23
		14	145	10	149	18	141	5	154
500	1.7(0-7,1,2.1)	4	20	5	19	1	23	6	18
		27	132	11	148	6	153	39	120
100	4.1(0-9,3,3.9)	3	21	1	23	6	18	10	14
		27	132	6	153	17	142	63	96

Buffer radius (m)	Other HH within buffer: avg(min-max, median, stddev)	1 HH		2 HH		3 HH		4 HH	
50	0.1(0-2,0,0.4)	4	32	3	33	0	36	0	36
		4	134	1	137	0	138	0	138
100	0.2(0-2,0,0.5)	10	26	4	32	0	36	0	36
		13	125	4	134	0	138	0	138
150	0.4(0-3,0,0.7)	14	22	6	30	0	36	0	36
		30	108	7	131	1	137	0	138
250	1.1(0-5,1,1.3)	13	23	10	26	4	32	1	35
		20	118	21	117	14	124	7	131
500	3.2(0-9,3,2.9)	1	35	9	27	11	25	11	25
		8	130	9	129	28	110	48	90
100	6.6(0-15,6,4.7)	0	36	1	35	5	31	28	108
		3	135	7	131	16	122	86	52

Buffer radius (m)	Other HH within buffer: avg(min-max, median, stddev)	1 HH		2 HH		3 HH		4 HH	
50	0.1(0-1,0,0.3)	10	16	0	26	0	26	0	26
		5	80	0	85	0	85	0	85
100	0.3(0-2,0,0.6)	8	18	4	22	0	26	0	26
		4	81	5	80	0	85	0	85
150	0.5(0-2,0,0.8)	6	20	9	17	0	26	0	26
		6	79	10	75	0	85	0	85
250	0.8(0-4,0,1.1)	6	20	9	17	0	26	0	26
		5	80	18	67	0	85	4	81
500	2.0(0-7,1,2.2)	2	24	2	24	7	19	6	20
		8	77	4	81	11	74	24	61
100	5.3(0-11,5,4.4)	4	22	0	26	1	25	18	8
		12	73	1	84	2	83	48	37

Table 1. 2X2 tables of HH presence within buffer by FCR presence, stratified by buffer radius across four follow-up time points.
Columns: Confirmed use (**Left**), Correct use (**Right**) | **Rows:** Follow-Up 1, Follow-Up 2, Follow-Up 3, Follow-Up 4 (from top to bottom)

P-Value Key		
$p < 0.05$	$p < 0.10$	Unable to calculate a p-value

Fisher's Exact Test 2x2 Key	
# of index HH with column # of surveyed HH in buffer and FCR ≥ 0.2 mg/L	# of index HH without column # of surveyed HH in buffer and FCR ≥ 0.2 mg/L
# of index HH with column # of surveyed HH in buffer and FCR < 0.2 mg/L	# of index HH without column # of surveyed HH in buffer and FCR < 0.2 mg/L

There were a total of 398 HHs who received the GoW HWTS intervention. Out of these HHs, 244 HHs had both a GPS location & FCR test results at Follow-Up 1; 230 HHs had both a GPS location & FCR test results at Follow-Up 2; 230 HHs had both a GPS location & FCR test results at Follow-Up 3; and, 221 HHs had both a GPS location & FCR test results at Follow-Up 4. Due to similar HWTS use rates across the control & experimental groups, data was pooled for both treatment groups to examine the outcomes of interest.

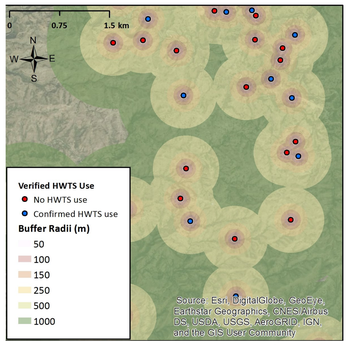

Figure 2. Sample geographic area with buffer zones around each index HH

Results for confirmed vs. correct use across the follow-ups show a reduction in both confirmed use & correct use over time among study HHs (**Figure 4**).

The spatial distribution among users (**Figure 3**) shows that non-users, both measured by confirmed & correct use, were more geographically isolated than HH with verified HWTS use. Results from significance testing, ($p < 0.05$ & $p < 0.10$) confirmed this relationship (**Table 1**).

Across the increasing buffer radii, when there were 4 or more HHs within the buffer zone, index HHs were more likely to use the HWTS system indicating a possible "threshold effect" for adoption.

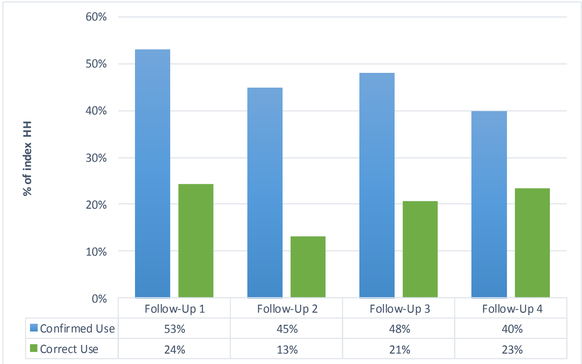

Figure 4. % of index houses with verified HWTS use across four follow-up surveys

DISCUSSION & CONCLUSIONS

Overall, the exploratory geospatial analysis provides evidence of an association between the spatial distribution of households & use of the HWTS technology by the index HH. This trend suggests that HHs closer to the index HH predicts HWTS use; additionally a possible "threshold effect" with 4 or more HH also predicts HWTS use.

Limitations

The following issues preclude our ability to develop more robust methods of analysis, such as regression models, and move beyond an association to explore correlations or causation between our variables:

- This was a retrospective secondary analysis so we were restricted to the original data collected during the training evaluation.
- Between a 1/3 to a 1/2 of the HHs in this evaluation were missing GPS coordinates or FCR results, significantly diminishing the sample size for analysis.
- In both communities, not all HHs received the HWTS technology. For non-surveyed HHs, we have no data on their HWTS behaviors, nor their GPS locations within the communities. It is possible that HWTS behaviors of these HH might influence & confound any relationship we see within the data.
- Spatial distribution serves as a proxy for social support, but we have no data on the actual social network relationships between HHs within the two communities to adequately quantify peer influence as social support.

Conclusions

There is a paucity of knowledge of the behavioral determinants of HWTS adoption in real-world program implementations. Our results suggest that community-based models of distribution might be more effective at sustaining HWTS adoption over time. Furthermore, geospatial methods are a promising new approach to studying behavioral determinants of long-term HWTS use.

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