Water User Payment Characteristics in the Eastern Region of Ghana

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GIS 102: Advanced GIS

Coordinate System: WGS 1984

Projection: UTM Zone 30N

Sources: ESRI World Imagery, National Geographic

Tufts UNIVERSITY

Introduction

Infrastructure such as boreholes (BHs) provides access to safe water, which is important to preventing a number of diseases in low-income rural areas. However, these systems inevitably need repair and many communities find themselves unable to facilitate necessary work, thus losing any health benefits gained by the BH's installation[1]. Studies have found non-functionality rates as high as 59% in rural sub-Saharan Africa[2,3].

The community management model, in which community members are responsible for the long-term care of the water system, has been widely utilized by agencies that implement systems[4]. However, water committees often lack training and resources, and challenges such as inconsistent tariff collection and misuse of funds can prevent money from being available when repairs are necessary[1,5]. Therefore, good financial management practices are a component of sustainable infrastructure functionality.

Certain spatial variables, such as the location of other water sources, may also contribute to BH functionality[6,7]. For instance, there will be more pressure to maintain a BH if there are no alternative unimproved water sources (UWSs) nearby. Users may also have increased willingness-to-pay for water from BHs located close to their houses, which can contribute to financial sustainability and long-term functionality[1,4,8].

This project seeks to investigate the following research questions:

1) How do the spatial distributions of all houses, participant houses, BHs, and UWSs compare to each other in 10 towns in the Eastern Region, Ghana?

2) What spatial and management variables predict surveyed users' payment for water and perception of cost fairness?

Methods

Study Design & Data Collection

This study took place in 10 towns in the Eastern Region, Ghana. Towns were chosen from 74 towns used in a wider study[9]. These towns had been previously stratified by groundwater quality characteristics, which have been shown to affect users' perceptions of borehole water. For this study, 10 towns from two water quality clusters were purposively selected: towns 1-5 had high total dissolved solids (TDS) and hardness and towns 6-10 had high iron concentrations.

Data collection took place in January 2014, May 2015, and May 2016. With the help of local guides, the location of town infrastructure was recorded as follows: houses in 2016, UWSs (including hand dug wells and surface water access points) in 2014 and 2016, and public BHs in all three years (Town Characteristics).

Surveys were also conducted in 2016. An administrator from each town was surveyed about the water system's financial management. Women who used a BH were surveyed regarding their payment characteristics using convenience sampling, and their responses were matched to their house coordinates.

Town Characteristics

Town	# All Houses	# Participant Houses	# BHs	# UWSs
1	169	46	2	7
2	167	10	2	7
3	163	32	2	4
4	160	29	4	6
5	380	64	5	15
6	298	54	7	12
7	220	42	6	10
8	344	60	8	17
9	128	31	4	3
10	440	45	11	11
Total	2469	413	51	92

Study Objective 1

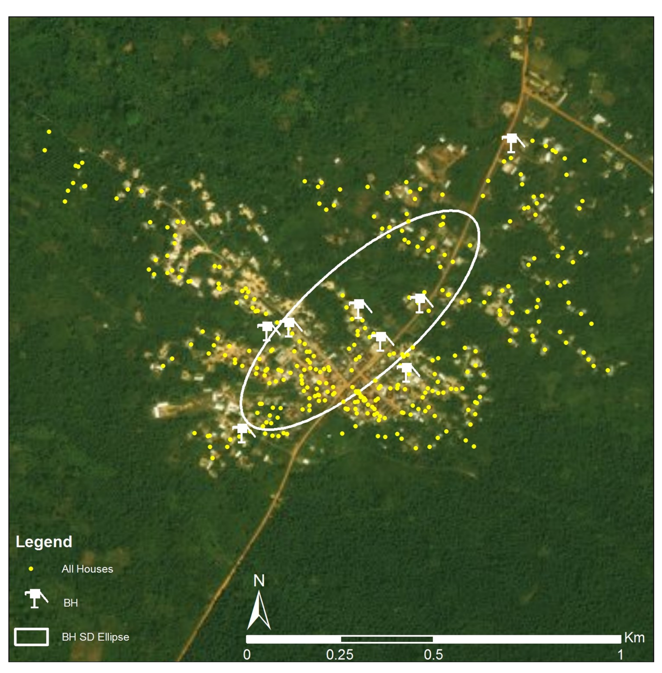
The mean center and one standard deviation (SD) ellipse were calculated by town for the following variables: all houses, BHs, and UWSs. The three towns with only two BHs (towns 1, 2, and 3) did not have SD ellipses. Next, the layer all houses was intersected with the BH and UWS ellipses and the layer participant houses was intersected with these ellipses in addition to the all houses ellipse layer. The results of all intersections were used to calculate the percentage of houses and/or responses within various SD ellipses.

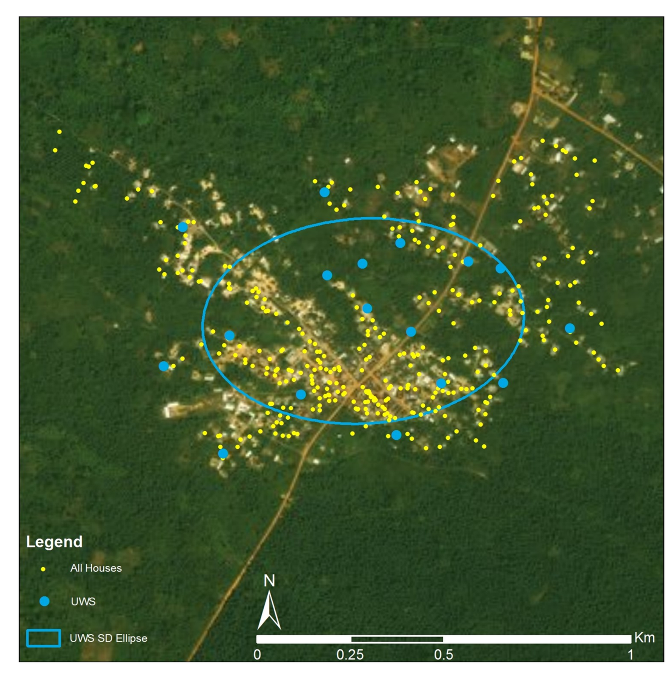
Study Objective 2

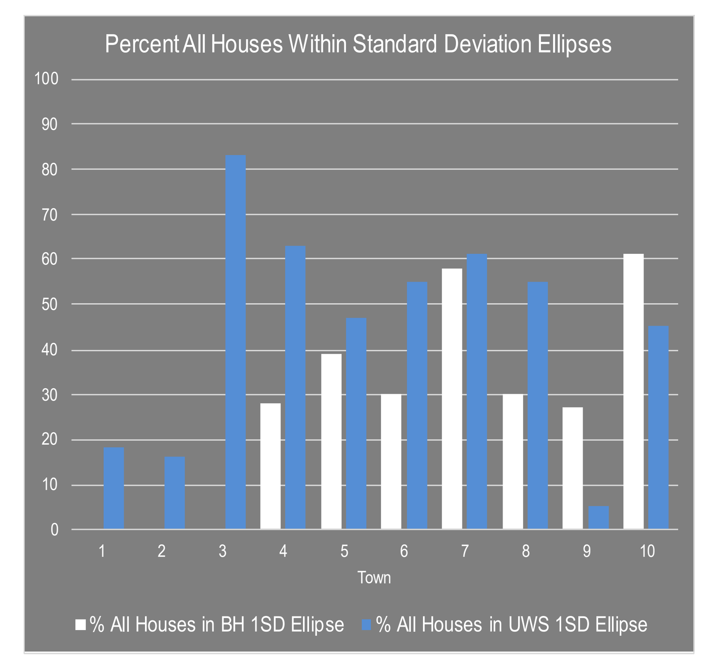
Two outcome variables were examined: whether women water users paid for BH water (pay), and whether they considered the price their paid fair (price fair). Three predictor variables were calculated with ArcMap. The point distance tool found the distance from participant houses to all BHs within 1000 m, and then a key was used to select entries with distance from house to the BH used by that participant. For the second variable, the near tool was used to find the straight-line distance from each participant's house to the nearest UWS. The difference variable was produced by subtracting the second distance variable from the first.

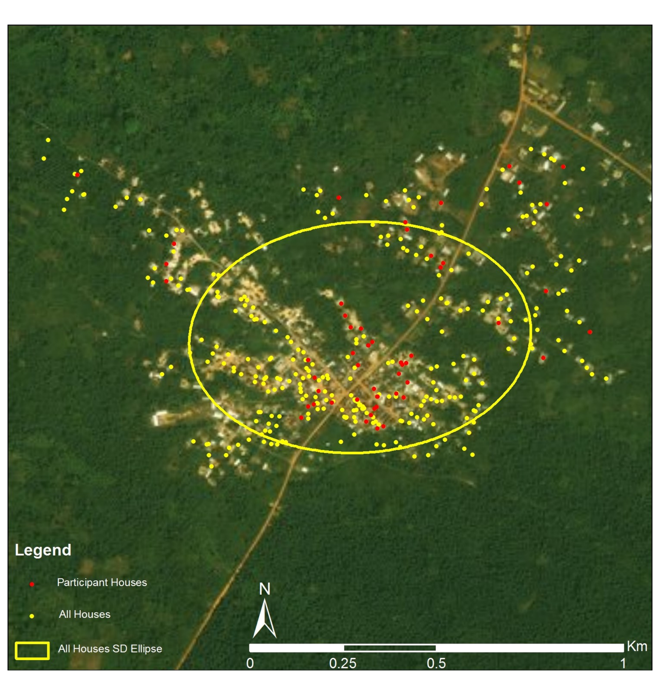
Univariate regressions were performed using 11 predictor variables for each outcome variable. To create the final multivariate models, some variables were removed due to collinearity issues. There were not enough observations in each category of the variable "pay structure", so it was condensed into a binary variable.

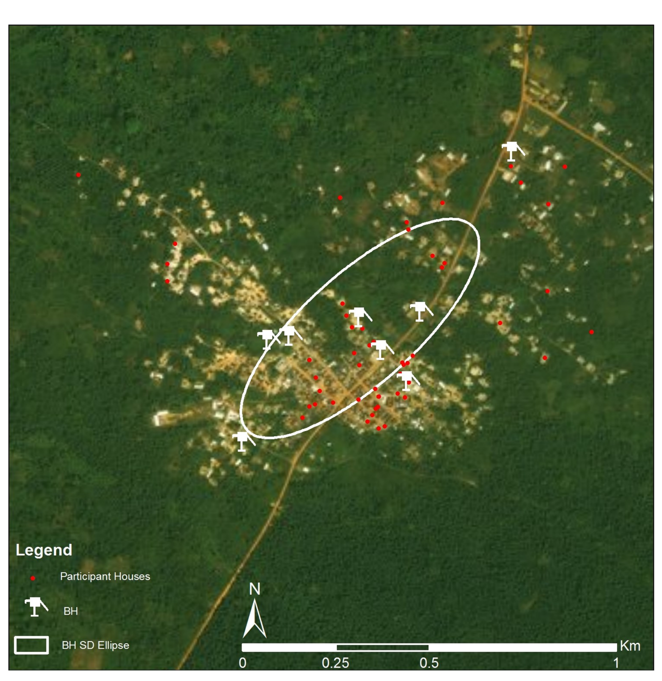
Standard Deviation Ellipses: Town 8

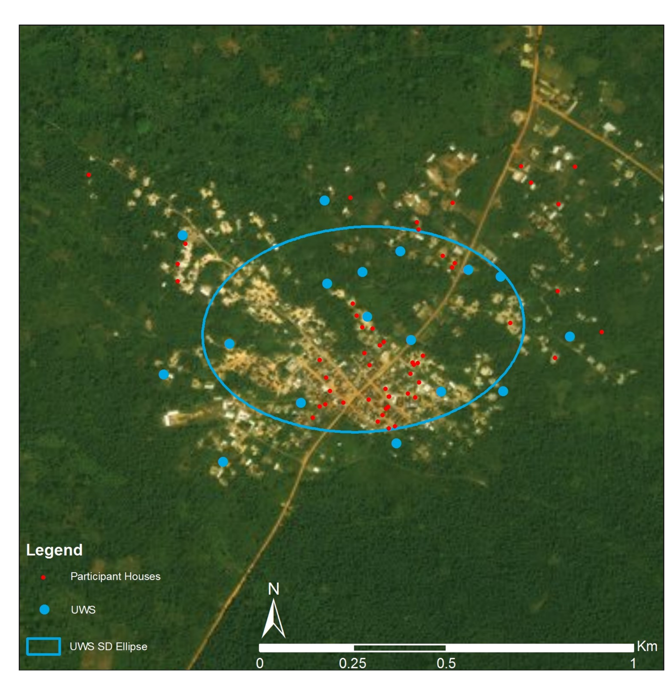


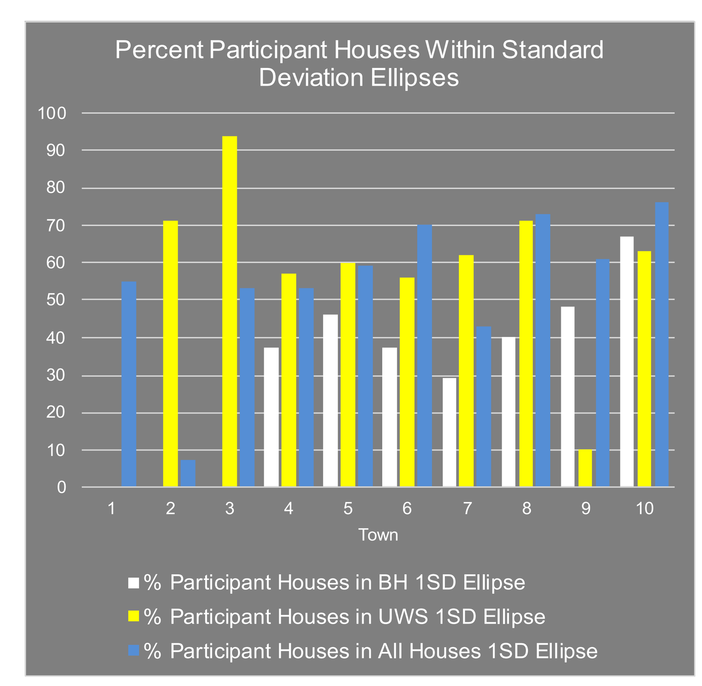












Results

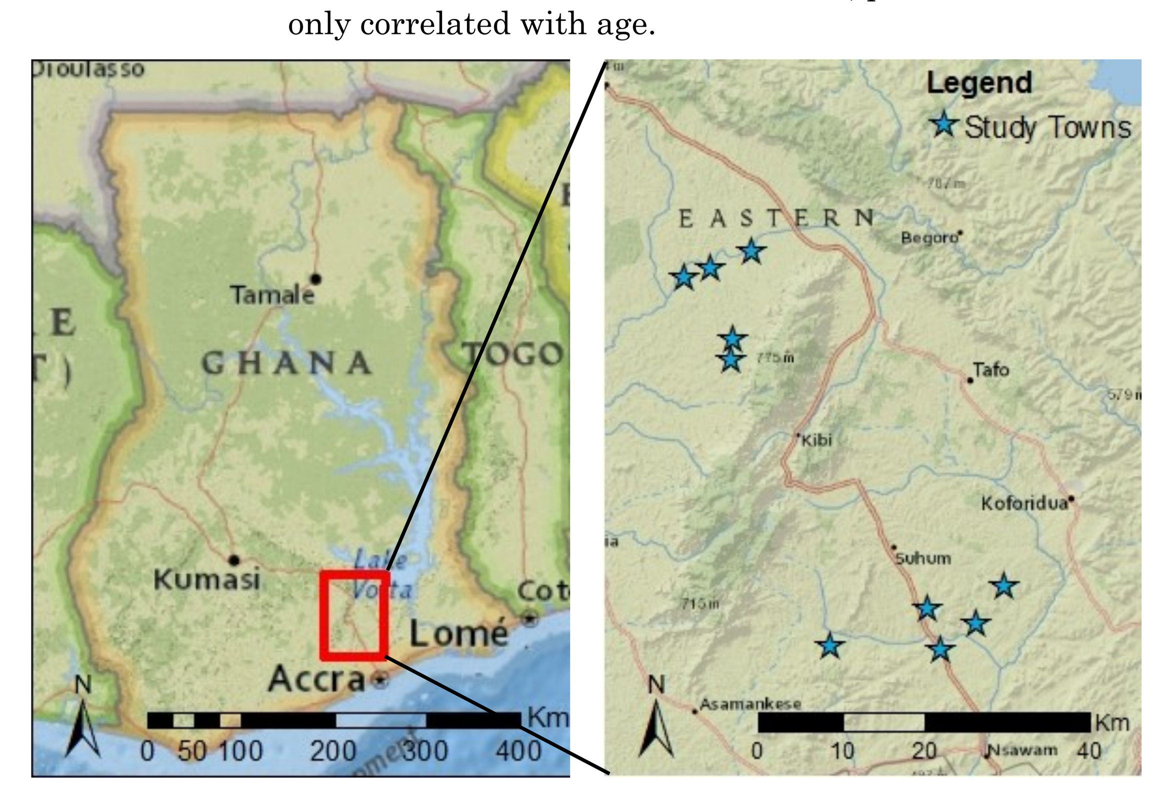
Study Objective 1

Among the 7 towns with more than 2 BHs, 27% – 61% of all houses and 29% – 67% of participant houses were within the BH ellipses (figures to left). There was more variability observed between towns when examining all houses (5% – 83%) and participant houses (0% – 94%) within the UWS ellipses. In 8 of the 10 towns over 50% of the participant houses were within the all houses ellipses; however, this percentage was only 7% in town 2.

Study Objective 2

For the outcome variable pay, the univariate logistic regressions found significant ($p < 0.05$) relationships for the following variables: pay structure, bank account, one person responsible for money, and water quality cluster (Logistic Regression Results). Both the categorical and binary versions of the pay structure variable had significant findings. For the outcome variable price fair, the univariate logistic regressions found significant relationships for the following variables: bank account and committee states everyone pays same amount.

Of the 9 variables in the first multivariate model, pay was only significantly correlated with age. Likewise, of the 9 variables in the second model, price fair was also only correlated with age.



Conclusions

There were almost twice as many UWSs as BHs and in the majority of towns a higher percentages of all houses and participant houses fell within UWS ellipses than BH ellipses. This indicates that UWSs were generally more accessible than BHs for both populations. More than half of participant houses were within the all houses ellipses for most towns, however the low percentage in town 2 suggests that convenience sampling is not a reliable method for obtaining a spatially representative sample.

Age was the only significant variable in both final models. The relationship with both pay and price fair was positive, indicating that older women were more likely to pay for water and are more likely to believe the price they pay is fair. Interestingly, bank account had a negative relationship in univariate models with both outcome variables. Since these models did not control for other variables, this provides only limited evidence that payment rates and perceived price fairness were lower in communities that used a bank account. None of the distance variables were significant in any model, therefore the expected relationship between perceived price fairness and distance to water sources was not observed.

Limitations

While SD ellipses capture general trends and the most average values, they do not give much information about observations on the periphery of towns. For example, they do not indicate whether participant houses outside the all houses ellipse are representative or clustered. Therefore, they are not the strongest measure of spatial distribution.

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Logistic Regression Results

Pay

Univariate Models

Predictor Variable	Coefficients	P-value	95% Confidence Interval	
Pay Structure, Categorical				
Funeral funds	-1.085	0.060	-2.218	0.047
Regular interval	-1.786	**0.011**	-3.157	-0.416
When broken	-0.279	0.806	-2.507	1.950
Pay Structure, Every Use	1.151	**0.039**	0.058	2.244
Water Quality Cluster	-1.178	**0.022**	-2.183	-0.172
Age	0.029	0.073	-0.003	0.060
Committee Exists	0.753	0.125	-0.209	1.714
Records	-1.307	0.082	-2.780	0.165
Bank Account	-1.209	**0.014**	-2.171	-0.248
Everyone Pays	-0.522	0.411	-1.767	0.722
One Person Responsible for Money	1.396	**0.004**	0.434	2.358
Distance to BH Used	-0.001	0.584	-0.003	0.002
Distance to Nearest UWS	0	0.863	-0.002	0.003
Difference Between Distance to BH and Distance to Nearest UWS	-0.001	0.537	-0.003	0.002

Multivariate Models

Predictor Variable	Coefficients	P-value	95% Confidence Interval	
Pay Structure, Every Use	1.465	0.423	-2.117	5.046
Water Quality Cluster	-6.534	0.990	-1010.862	997.793
Age	0.040	**0.021**	0.006	0.074
Committee Exists	-5.585	0.991	-1009.908	998.737
Records	-1.970	0.104	-4.345	0.404
Bank Account	-0.426	0.520	-1.724	0.872
Everyone Pays	-6.610	0.990	-1010.932	997.713
Distance to BH Used	-0.002	0.331	-0.005	0.002
Distance to Nearest UWS	-0.003	0.140	-0.007	0.001

Price Fair

Univariate Models

Predictor Variable	Coefficients	P-value	95% Confidence Interval	
Pay Structure, Categorical				
Funeral funds	0.095	0.739	-0.462	0.651
Regular interval	0.296	0.576	-0.742	1.334
When broken	-0.129	0.815	-1.204	0.946
Pay Structure, Every Use	-0.097	0.716	-0.621	0.426
Water Quality Cluster	0.142	0.590	-0.374	0.658
Age	0.010	0.236	-0.007	0.027
Committee Exists	-0.397	0.145	-0.93	0.137
Records	-0.676	0.058	-1.375	0.023
Bank Account	-0.603	**0.028**	-1.141	-0.065
Committee - User Cost Discrepancy	0.273	0.387	-0.346	0.891
Everyone Pays Same Amount	0.879	**0.003**	0.307	1.451
Distance to BH Used	0.001	0.182	-0.001	0.003
Distance to Nearest UWS	0.002	0.097	0	0.004
Difference Between Distance to BH and Distance to Nearest UWS	0	0.656	-0.002	0.001

Multivariate Models

Predictor Variable	Coefficients	P-value	95% Confidence Interval	
Pay Structure, Every Use	0.203	0.726	-0.931	1.337
Age	0.025	**0.036**	0.002	0.048
Committee Exists	-0.415	0.434	-1.457	0.626
Records	-0.760	0.194	-1.907	0.387
Bank Account	0.176	0.764	-0.973	1.325
Committee - User Cost Discrepancy	-0.349	0.361	-1.099	0.400
Everyone Pays Same Amount	1.303	0.071	-0.112	2.718
Distance to BH Used	0.002	0.155	-0.001	0.005
Distance to Nearest UWS	0.003	0.140	-0.001	0.007

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