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Willingness-to-pay and demand for sanitation products in rural northern Ghana: Impacts of seasonality and methodology

John Trimmer[1,2], **Joyce Kisiangani**[3], **Bessy Ewoenam Odame-Boafo**[3], **Stanley Bortse Sam**[3], **Chloé Poulin**[1], **Dominic Osei**[4], **Valerie Bauza**[5*]

1 The Aquaya Institute, Nairobi, Kenya, **2** Department of Civil and Environmental Engineering, Syracuse University, Syracuse, New York, United States of America, **3** The Aquaya Institute, Accra, Ghana, **4** Global Communities, Accra, Ghana, **5** The Aquaya Institute, San Anselmo, California, United States of America

* valerie@aquaya.org

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Abstract

Open defecation practices persist in some resource-limited contexts, such as rural northern Ghana, where poverty and environmental conditions can make appropriate sanitation infrastructure unaffordable. This study assessed household willingness-to-pay (WTP) for sanitation products in 146 communities across four regions of northern Ghana. Sanitation products included the Digni-Loo slab, a locally marketed plastic latrine slab, and four full toilet facilities (Digni-Loo Toilet, Sato Toilet, BioFill Toilet, Water Closet), each including a slab, superstructure, and durable substructure suitable for local soils. During harvest and non-harvest seasons, we measured revealed WTP for the Digni-Loo slab using Becker-DeGroot-Marschak auctions, where households bid money to purchase the product (N = 587 unique households). We measured stated WTP for all sanitation products using contingent valuation, where households report what they would pay without making a real purchase (N = 638 households). We found WTP levels far below all sanitation products' actual costs, suggesting a need for subsidies. Revealed WTP for the Digni-Loo slab during harvest season averaged 191 GHS (17 USD; 14% of cost) and was slightly lower during non-harvest season (171 GHS; 16 USD). Revealed WTP also tended to be higher in rural small towns than in more remote communities. Households' stated WTP typically overestimated their revealed WTP for the Digni-Loo slab, with revealed WTP averaging 53–77% of stated WTP. Stated WTP was especially high during non-harvest season, averaging 419 GHS (38 USD) or 30% of cost. During harvest season, stated WTP averaged 295 GHS (27 USD) and was more consistent with revealed WTP, suggesting agricultural households were better able to predict purchasing behavior when more funds were available. Stated WTP for other toilet facilities ranged between 11–31% of their cost. Overall, findings from this work can inform

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regional efforts toward sanitation promotion, while also providing broader insight into sanitation demand seasonality and relationships between stated and revealed WTP.

1. Introduction

Over the past decades, the global community has made considerable progress in reducing the number of people practicing open defecation, with approximately 95% of the global population using some type of sanitation facility as of 2022 [1]. However, important areas of limited improvement remain, such as in rural parts of sub-Saharan Africa. In Ghana, for example, 30% of the rural population practiced open defecation in 2022 – a level that has remained nearly unchanged, improving by less than 1.5 percentage points, since 2000 [1]. Despite widespread efforts to encourage toilet installation and use, critical factors related to program design, product availability, and poverty continue to deter progress, particularly in difficult-to-reach rural areas with limited resources.

As many hardware-driven programs of latrine construction without adequate community participation and engagement have led to low levels of latrine use and maintenance [2,3], more recent approaches have focused on strategies to promote household- and community-level behavior change (e.g., Community Led Total Sanitation, CLTS) and the development of sanitation markets [2–6]. However, sanitation facilities that are contextually appropriate and durable may be unaffordable for low-income households, especially those in resource-limited settings such as urban informal settlements or remote rural communities [7–11]. For example, a study in three predominantly rural counties of Kenya found that the SAFI Latrine (a low-cost ventilated pit latrine with concrete rings lining the pit) was unaffordable for households falling in lower socioeconomic wealth quintiles [10]. Recently, there has been growing interest in how to efficiently and effectively offer pro-poor subsidies to promote the installation and use of appropriate sanitation facilities among low-income households [7–11].

Northern Ghana represents an important context where a combination of high poverty levels and challenging soil conditions makes constructing and sustaining appropriate sanitation facilities particularly difficult. Much of the open defecation occurring in rural Ghana takes place in the country's northern regions, with the 2021 Census reporting that 51–69% of households in each of these regions practice open defecation, compared with only 18% across the entire country [12]. Meanwhile, Ghana's most recent Living Standards Survey (GLSS 7, 2016–2017) estimated that mean annual household income in these regions ranged from 13,000–23,000 GHS (2,900–5,100 USD), compared with a countrywide average of 44,000 GHS (9,800 USD; 4–5 GHS = 1 USD in 2017; due to recent inflation, the exchange rate in 2023 was approximately 11 GHS = 1 USD, which we use for this study) [13]. Additionally, given that approximately two-thirds of all employed residents in rural Ghana work in agriculture [13], these households' primary income streams are likely seasonal. Agrarian households in Ghana and elsewhere may obtain most of their income during relatively brief periods of crop harvest, placing limits on the times when large

purchases can be made [14–16]. Low and temporally constrained income levels are especially problematic in northern Ghana, because even when households have installed latrines, unstable soil conditions often cause low-cost facilities built using low-quality materials to collapse during the rainy season or otherwise fall into disrepair [17,18].

Accordingly, sustainable sanitation in northern Ghana requires the use of more expensive technologies that include durable pit lining. Subsidies may improve affordability for such technologies, especially for low-income households. Previous research in this context has examined the impacts of a recent pro-poor sanitation subsidy program [17]. The program identified vulnerable households through community consultation meetings, and these households received vouchers that they could redeem with local vendors to cover the full cost of a durable latrine slab and substructure (households could select from one of three available substructure options, while the household was responsible for completing the superstructure themselves). This study found that the subsidies considerably improved sanitation conditions among those households identified to receive the voucher, but there was limited spillover to other members of the community (i.e., seeing vulnerable households building more durable facilities did not lead others to purchase and install their own latrines as well) [17]. Even those households not identified as vulnerable during community consultation may still have been unable to afford more durable sanitation facilities, suggesting a potential need for subsidy programs capable of providing at least partial support to a broader group of households. To be effective, such a program would need to set appropriate subsidy levels that are consistent with household demand and willingness-to-pay (WTP) for durable sanitation products in northern Ghana.

However, collecting reliable information on household WTP can be challenging, especially when actual purchasing data are not yet available and local communities have limited awareness of a product. Methods that measure revealed WTP, where households have the opportunity to purchase the product as part of the study, are generally considered to be better predictors of a population's true demand and purchasing behavior than stated WTP methods, in which respondents state their preferences and/or maximum price points without actually making a purchase [10,19]. Although, stated WTP methods tend to be easier to implement, since they do not involve the expenses and logistics associated with making the product available to participants during the study [19].

The objectives of this study were (i) to determine prices at which rural households in northern Ghana would be willing and able to pay for contextually appropriate sanitation products, (ii) to identify factors that may affect a household's WTP level, and (iii) to compare and offer recommendations regarding different approaches for measuring WTP. We focused primarily on WTP for a plastic toilet slab known as the Digni-Loo slab, a product developed relatively recently by local organizations and designed to function as part of a durable sanitation facility that is easy to install. We collected data through multi-visit household surveys containing both hypothetical contingent valuation scenarios (stated WTP) [19,20] and Becker-DeGroot-Marschak (BDM) auctions (revealed WTP, where the household bids a certain amount of money to actually purchase the product) [21]. Beyond the Digni-Loo slab, we also explored stated WTP for four full toilet facilities (containing a durable substructure, slab, and superstructure), one of which incorporated the Digni-Loo slab. We collected revealed and stated WTP data on the Digni-Loo slab during harvest and non-harvest times to consider possible seasonal effects on household demand, and we examined potential associations between WTP and other geographic, demographic, and socioeconomic factors using multivariate regression analyses.

2. Methods

2.1. Study context

This study was conducted as part of the Enhancing Water, Sanitation, and Hygiene (EnWASH) Program, which aimed to increase adoption of sustainable and equitable water, sanitation, and hygiene services, and to enhance governance and financing related to these services, across 30 districts located within six regions of northern Ghana [22]. The EnWASH Program focused particularly on communities with high levels of poverty and low access to water and sanitation.

The main WTP study for the Digni-Loo slab focused on a total of 26 communities across 11 districts in four regions (Northern, Savannah, Upper East, and Upper West), where the program planned to implement CLTS activities to address poor sanitation conditions [3,18,23]. Beyond the Digni-Loo slab, we also collected related information on WTP for four full toilet facilities as part of the EnWASH Program's baseline survey, which was implemented in 120 communities across 8 districts in the same four regions of northern Ghana.

2.2. Summary of sanitation technologies considered in this study

This study focused primarily on WTP for the Digni-Loo slab, which is a plastic rectangular toilet slab that includes a drop hole, grooved foot panels for increased traction, and an additional hole designed to accommodate a ventilation pipe. The bottom of the slab can be fitted with plastic rings that act as pit lining and help to prevent collapse. As a relatively recent technology developed in Ghana, the Digni-Loo is currently being promoted by various organizations and has been used in at least one sanitation subsidy trial in northern Ghana [17]. At the time of the survey, the cost of the Digni-Loo slab was estimated to be approximately 1,375 GHS (125 USD), but local organizations were selling it at a reduced market price of 800 GHS (73 USD) to increase affordability. We used the full cost when comparing with WTP, as this reflects the full value of the subsidy that would be required.

We also collected stated WTP for four complete toilet facilities, each composed of a slab, substructure, and superstructure (under the EnWASH baseline survey, Table 1; Figure A in S1 Text). These facilities included a pit latrine with a plastic slab lined with plastic rings (the Digni-Loo Toilet, which was the least expensive of the four), a pit latrine with a plastic bowl, molded concrete slab, and concrete block lining (the SatoPan Toilet), a ceramic flush toilet directing wastewater to an anaerobic digester (the BioFill Toilet), and a ceramic flush toilet directing wastewater to a septic tank (the Water Closet, which was the most expensive; Table 1).

2.3. Willingness-to-pay survey design

Our study measured revealed WTP (for the Digni-Loo slab only) using BDM auctions and stated WTP (for all sanitation technologies) using the contingent valuation method known as double-bounded dichotomous choice. This section provides details on the implementation of these methods through household surveys.

In the BDM auction, we asked a household to make a monetary bid in an attempt to win the Digni-Loo slab [21]. After receiving the household's bid amount, the survey enumerator then opened a sealed envelope holding a random unknown price point. The household won if their bid was equal to or higher than the random price point. If they won, the household would pay the envelope price (not their original bid) and receive the Digni-Loo slab in return. If they lost, the household would not pay anything and not receive the slab. Random price points in the envelopes ranged from 100 to 800 GHS (9–73 USD, 12–100% of the reduced market price or 7–58% of the full cost), in increments of 100 GHS. If a household

Table 1. Four complete toilet facilities for which we collected stated WTP as part of the EnWASH baseline survey.

Toilet facility	Slab	Substructure	Superstructure	Estimated cost at time of survey
Digni-Loo Toilet	Plastic Digni-Loo slab with drop hole, grooved foot panels, and vent pipe	Circular pit lined with plastic rings	Clay walls, zinc roof, wooden door	2,100 GHS (190 USD)
SatoPan Toilet	Dome-molded concrete slab with a plastic SatoPan bowl and raised foot panels	Circular pit lined with concrete blocks	Clay walls, zinc roof, wooden door	2,800 GHS (250 USD)
BioFill Toilet	Concrete slab with tile finish and ceramic cistern-flush toilet bowl	Rectangular BioFill anaerobic digester made with masonry blocks	Clay walls, zinc roof, wooden door	4,300 GHS (390 USD)
Water Closet	Concrete slab with tile finish and ceramic cistern-flush toilet bowl	Rectangular concrete septic tank with optional connection to sewer line (if available)	Clay walls, zinc roof, wooden door	13,200 GHS (1,200 USD)

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declined to participate in the auction because they did not have sufficient funds to bid, we assigned them a bid of 0 GHS and selected a random price point during data analysis, so that their inability to pay could be considered in our results. A small fraction (<3%) of households in each round won the auction but then declined to purchase the slab. We included these households; removing them would have only a minimal impact on the results (e.g., < 5% change in mean WTP).

In the double-bounded dichotomous choice method for stated WTP [19,20], we first asked a respondent two close-ended (yes/no) questions, asking if they would be willing to pay a certain price for the Digni-Loo slab. Prices came from a pre-determined list of six possible values (100, 200, 300, 500, 600, and 800 GHS). In the first question, the price point was selected randomly from the middle four values. If the respondent answered the first question affirmatively, the second question would increase the amount to the next highest price point in the list. If the respondent responded negatively to the first question, the second price point would be the next lowest. Following these two close-ended questions, we asked the respondent a final open-ended question, in which they reported the maximum amount they were willing to pay. As a whole, this procedure helps respondents think through the implications of different price points and provides upper and/or lower bounds on the final reported amount. Previous literature has found this double-bounded approach to have greater statistical efficiency than a single-bounded approach (with only a single yes/no question) [24].

In each season, we collected stated and revealed WTP for the Digni-Loo slab over the course of two visits to each participating household. The first visit introduced households to the Digni-Loo slab and collected stated WTP, along with sociodemographic characteristics and existing sanitation infrastructure. Additionally, this survey also asked respondents whether they would be willing to pay a higher total amount for the Digni-Loo slab if they could use a 6-month payment plan or a 12-month payment plan. The visit concluded with an offer for the household to take part in a future auction to win a slab, and the enumerator conducted an example auction demonstrating the BDM methodology, where the household could win a bar of soap for a small amount of money (≤8 GHS or ≤ 0.73 USD) if they wanted to participate. During the second visit, after confirming we had returned to the same household, we reintroduced the Digni-Loo slab and then conducted the auction.

The EnWASH baseline survey also employed the double-bounded dichotomous choice method when measuring stated WTP for the installation of four full toilet facilities. Due to the large range of costs across the four options, we included price points representing approximately 5%, 10%, 20%, 40%, 60%, 80%, and 100% of each facility's total cost. These prices were inclusive of all materials and labor for the substructure, slab, and superstructure for each type of toilet facility.

2.4. Data collection

Originally, we had planned to only conduct a single round of two-visit surveys. In this round, we targeted a sample size of 520 households, which would result in a 5.8% margin of error under conservative assumptions at a 95% confidence level. We surveyed a total of 528 randomly selected households in 22 communities during visit 1, and 491 of these households were available and participated again during visit 2. The first visit occurred in April-May 2023, and the second visit occurred in May-June 2023, with approximately 4 weeks between visits to a given household (Fig 1). However, after recognizing that the timing of this round of surveys fell during a non-harvest time, when the area's predominantly agricultural households had less money available, we decided to add a second round of data collection. This second round took place in December 2023, during harvest time, with approximately 2 weeks between the first and second visit (Fig 1). We surveyed 10 communities, six of which had also been included in the first round. We surveyed 15–19 households per community, including a portion of households in revisited communities who participated in round 1 (and lost the auction). In total, we surveyed 110 new households during the first visit of round 2, 96 of whom also participated in the second visit (Fig 1). We did not resurvey revisited households for their stated WTP, but did reintroduce them to the Digni-Loo slab and example auction with soap during this first visit. With the addition of 53 revisited households, a total of 149 households were included in the auction during the second visit (Fig 1). A team of five local enumerators fluent in relevant local

languages received training and administered the surveys via the CommCare software platform, in a language that was comfortable for each respondent.

The baseline survey measuring stated WTP for four toilet facilities occurred prior to both rounds in December 2022-February 2023 (Fig 1). Accordingly, the early portion of these baseline surveys occurred during harvest time as well. We collected stated WTP data from 478 households during baseline data collection, a subset of total baseline participants. This sample size provided a margin of error of approximately 5% under conservative assumptions at a 95% confidence level.

Across data collection for this study, participant recruitment began on 21/12/2022 and ended on 24/12/2023.

2.4. Household selection and eligibility

During the first visit of round 1 of the WTP survey, we randomly selected households according to the following procedure: The CommCare survey assigned each enumerator a randomly-generated direction and number of households at the beginning of a new survey. The enumerator then walked in the assigned direction until they passed the assigned number of households, and the next household was asked to participate. Respondents were eligible if they were at least 18 years of age and participated in making financial decisions for the household. Written consent was collected from eligible respondents. During the BDM auction, if a participating household owned an existing toilet in partnership with other household(s), those others were deemed ineligible. We used these same procedures and criteria during round 2, apart from those round 1 households we revisited. For revisited households, the enumerators used a randomly ordered list of households who had participated in round 1 and did not win the auction to find and resurvey a random subset of these households.

2.5. Data analysis

We generated revealed WTP demand curves for the Digni-Loo slab based on participants' bid amount during the BDM auction, while stated WTP demand curves for the Digni-Loo slab and other toilet facilities were based on the maximum

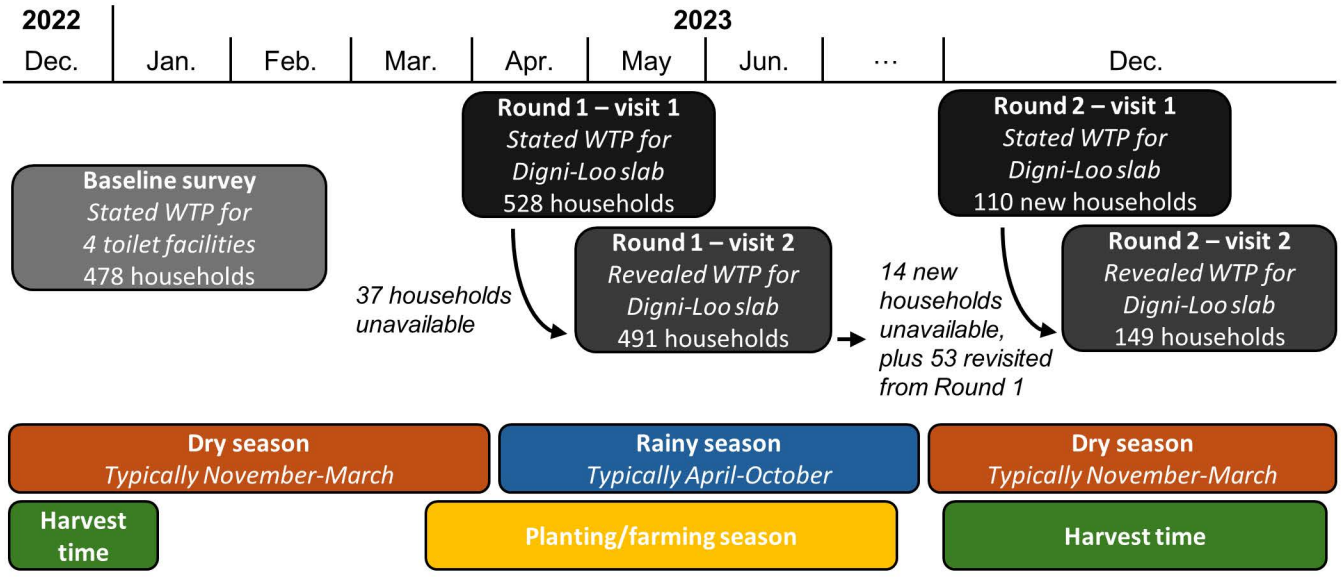

Fig 1. Timeline of data collection activities. For each set of surveys, we have included the number of households surveyed. During Round 2, we distinguish between new households and those revisited from Round 1. The figure also displays typical timings of dry and rainy seasons, the planting and farming period, and harvest time. Note the break between June and December 2023.

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amount respondents stated when asked the final open-ended question during the double-bounded dichotomous choice methodology. In addition to characterizing the WTP distributions across various price points, we also calculated mean values and percentiles (e.g., 25th, 50th, and 75th percentiles). We compared WTP distributions using non-parametric Wilcoxon rank-sum tests. For other categorical variables (e.g., respondent gender and education level), we compared percentage values using difference in proportion tests. Generally, following recent guidance from the American Statistical Association [25], we avoided making definitive statements of statistical significance based on a threshold p-value (e.g., $p < 0.05$), though we still report p-values from statistical tests and use them to help interpret our results.

We also performed several multivariate regression analyses to examine associations between WTP and respondent characteristics. We used linear regression models to consider associations with WTP values and logistic models for associations with whether a respondent won the BDM auction. The following independent categorical variables were included in each model:

- Community type (rural small town vs. remote rural community; all surveyed communities fall under the Ghanaian government's definition of "rural", with remote communities being less densely populated and further from main roads)
- Region (Northern, Savannah, Upper East, or Upper West)
- Whether the respondent had completed at least primary education
- Whether the household head had completed at least primary education
- Respondent gender
- The household's wealth quintile within the survey sample (quintiles were calculated according to the wealth index methodology used by the Demographic and Health Survey Program [26])
- Whether the household reported a total monthly income of at least 500 GHS (45 USD)
- Whether the household had an existing toilet facility that was in use

The logistic model also included the BDM auction's random price point from the envelope. Additional variables that were considered but not incorporated into any final models included:

- Household head gender: This variable was less associated with WTP than respondent gender ($p = 0.18$ during non-harvest season and $p = 0.23$ during harvest season) and was removed to avoid collinearity
- Whether the respondent was the household head: This variable was not correlated with WTP in either season ($p = 0.24$-0.87) while also being collinear with respondent gender
- Whether the respondent's household owned or rented their dwelling: this variable was not correlated with WTP in either season ($p = 0.41$-0.76) and was highly unbalanced, with <4% of respondents renting in each season.

Additionally, we performed a second linear regression that also included stated WTP from round 1, to test for associations between stated and revealed WTP while controlling for the other variables listed above. All regression models included adjusted standard errors to account for community clustering. We explored relationships between stated and revealed WTP further by calculating each respondent's ratio of revealed to stated WTP. We used R Version 4.3.1 for all data analysis procedures.

2.5. Ethical approval

We obtained written informed consent from all participants. The Institutional Review Board for the Council of Scientific and Industrial Research in Ghana reviewed and approved our research protocol (RPN 022/CSIR-IRB/2022).

3. Results

3.1. *Summary of survey respondents*

3.1.1. Main willingness-to-pay study. Most demographic characteristics of the WTP survey populations in rounds 1 (non-harvest season) and 2 (harvest season) were similar (Table 2). Key differences between the participants in rounds 1 and 2 included geographic location, as we were unable to survey in the Northern and Savannah regions during round 2 due to project constraints, and respondent gender, with more women participating during round 2. Additionally, education levels among new and repeat respondents in round 2 were different. We will describe minor impacts these differences had on our WTP results in a later section on study limitations.

3.1.2. Baseline survey. Among the 478 included baseline respondents, levels of reported toilet use were low, with 83% practicing open defecation (Table A in S1 Text). Only 11% of surveyed households reported being satisfied with their current sanitation conditions. The toilet facilities that were present tended to be pit latrines with wood and earth slabs, and many of these facilities did not have a superstructure (walls and a roof). While 62% of respondents were already familiar with water closet facilities, few (0–5%) were familiar with the other three types of toilet facilities explored in this study. The water closet was also the facility that 45% of households would prefer to have. After baseline participants were informed about the characteristics of the Digni-Loo Toilet, 8% reported it as their preferred facility type (Table A in S1 Text). Another 15% reported a plastic slab such as a Digni-Loo slab or similar as their preferred facility type. These results indicate considerable need and demand for improved sanitation products in this context. Demand for the water closet

Table 2. Summary of revealed WTP study participant characteristics. To compare the characteristics of survey populations, we applied proportion tests in R, with p-values reported in the table.

Parameter	Round 1 (non-harvest) *n = 491*	Round 2 (harvest) *n = 149*	p-value: Round 1 vs. 2	Round 2 (harvest)		
				New households *n = 96*	Repeat households *n = 53*	p-value: new vs. repeat
Household size >7 members	47%	37%	0.041	32%	46%	0.108
Rural small town residents	61%	61%	1.000	64%	56%	0.384
Region: Upper West	36%	50%	0.001	53%	46%	0.374
Region: Upper East	18%	49%	<0.001	46%	54%	0.374
Region: Northern	32%	0%	<0.001	0%	0%	–
Region: Savannah	14%	0%	<0.001	0%	0%	–
Respondent has completed at least primary education	32%	32%	1.000	40%	19%	0.016
Household head has completed at least primary education	14%	16%	0.936	19%	10%	0.046
Female respondents	42%	56%	0.003	54%	58%	0.737
Female household heads	9%	10%	0.638	11%	9%	0.863
Household head works in agriculture	80%	87%	0.060	83%	93%	0.102
Household is able to feed itself year-round	91%	90%	0.755	93%	85%	0.173
Household has bank account	90%	89%	0.716	91%	85%	0.352
Reported household income >500 GHS	42%	33%	0.062	33%	33%	1.000
Household has and uses a toilet	27%	30%	0.485	28%	34%	0.505
Respondent has used Digni-Loo previously	3%	2%	0.677	4%	0%	0.288

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is particularly high, but lower demand for other products likely relates to limited existing awareness of these facilities. Notably, toilet use among WTP study participants was higher than among respondents from the baseline survey (Table A in S1 Text), likely because the WTP study included a higher proportion of rural small town residents, whereas baseline surveys occurred predominantly in more remote rural communities.

3.2. Revealed willingness-to-pay (WTP) for the Digni-Loo slab across two seasons

Revealed WTP for the Digni-Loo slab was generally low, with WTP typically being lower during non-harvest season than harvest season (Wilcoxon rank-sum test $p = 0.01$). During non-harvest season (round 1), the mean WTP was 171 GHS (16 USD), while the mean was 191 GHS (17 USD) during harvest season (round 2). These mean revealed WTP values represent 12–14% of the Digni-Loo slab's full cost of 1,375 GHS (125 USD), suggesting a need for high levels of subsidies to achieve high coverage rates of this technology in the area. Based on respondents' reported ranges of household income, we estimated that monthly household income averaged between 500 and 800 GHS (46–73 USD) among our study participants. Accordingly, the purchase of a Digni-Loo slab would represent a major expense for a typical household in the surveyed areas, which could be alleviated by an appropriately designed subsidy.

For a subsidy to encourage a large fraction of the population (e.g., 75%) to purchase the Digni-Loo, the subsidized price would likely need to be even lower than the mean values reported above (Fig 2). The price point at which 75% of participants won the auction and purchased the Digni-Loo was 100 GHS (9 USD) in harvest season. In non-harvest season, more than 25% did not have enough money to make a bid, meaning that the price at which at least 75% would purchase the Digni-Loo was essentially 0 GHS. This comparison highlights the fact that, while seasonal differences between mean WTP values were relatively small, differences became more prominent at lower price points. As another example, the median WTP was 100 GHS (9 USD) in non-harvest season and 200 GHS (18 USD) in harvest season. These trends suggest that WTP at lower price points increases somewhat during harvest season, when lower-income households involved in agricultural activities have more funds available due to crop sales (see Section 3.3 for additional evidence of this explanation).

To confirm that these seasonal differences were not caused by random differences in the auction, we compared auction outcomes across the two rounds of data collection. In round 1 (non-harvest season), 33% of participants won the auction, while 24% won during harvest season. Part of the reason for the lower percentage of winners during harvest season may be that over one-third of our round 2 households had already participated and lost the auction during round 1, and those who lost the auction tended to have lower WTP ($p < 0.001$; Table 3). Resampling these households enabled us to examine whether revealed WTP shifted between seasons among the same households, although the sample size was relatively small ($n = 53$). We found the average revealed WTP of these revisited households to be slightly larger during harvest season (117 GHS or 11 USD, compared to 105 GHS or 10 USD in non-harvest season), though these WTP distributions may not be meaningfully different, especially given the small sample size ($p = 0.15$). The difference between the median WTP values among this group was larger (100 GHS or 9 USD in harvest season vs. 0 GHS in non-harvest season), suggesting again that the WTP of lower-income agrarian households may increase somewhat during harvest season, particularly at lower price points.

Returning to our full study populations, as would be expected, revealed WTP was higher among those who won the auction in both seasons ($p < 0.001$; Table 3), but the winners' WTP across the two seasons was not meaningfully different ($p = 0.66$; Table 3). Auction winners did typically benefit from lower random price points than those seen by auction losers ($p < 0.001$), but again, the winners in both seasons saw price points that were similar ($p = 0.60$). These trends provided evidence that the seasonal differences we saw in revealed WTP were not due to quantitative inconsistencies in the auction between seasons. However, this comparison did reveal possible differences between stated WTP for the Digni-Loo slab (collected during the first visit in each round), which we will explore in Section 3.4.

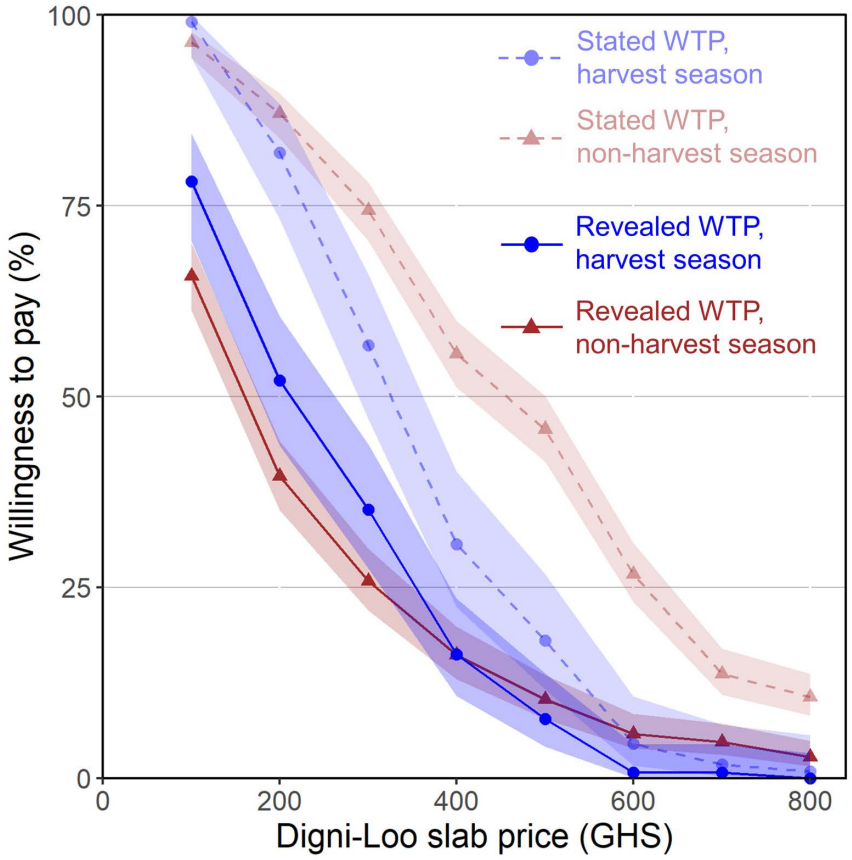

Fig 2. Willingness-to-pay (WTP) for Digni-Loo slabs in harvest (n = 142) and non-harvest (n = 465) seasons in northern Ghana. Revealed WTP values were derived from Becker-DeGroot Marschak (BDM) auctions, while stated WTP values came from double-bound dichotomous choice surveys. Shaded regions surrounding each curve provide 95% confidence intervals.

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3.3. Additional factors affecting revealed WTP

Looking beyond seasonality, we identified several other factors associated with respondents' revealed WTP by employing multivariate linear regression models with data from each season (Fig 3). During non-harvest season, rural small town residents' revealed WTP was higher than that of remote rural community residents by 90 GHS (95% confidence interval: 32–148 GHS; $p = 0.002$). The Northern Region also had higher WTP than the Upper West during non-harvest season ($p < 0.001$). This finding is consistent with Ghana's most recent Living Standards Survey (2016–2017), which found income levels in the Upper West Region to be lower than those in the Northern Region [13]. While these community and regional trends were directionally consistent during harvest season, the associated p-values were larger ($p = 0.07$-0.17), perhaps in part due to the smaller sample size.

During non-harvest season, female respondents exhibited revealed WTP that was 54 GHS lower (16–91 GHS; $p = 0.005$) than the WTP of male respondents, while households reporting monthly incomes above 500 GHS had WTP that was 40 GHS higher (8–72 GHS; $p = 0.015$) than other households. Again, in harvest season, differences in these two parameters were directionally consistent with the non-harvest season results, although the associated p-values were larger ($p = 0.09$ for gender and $p = 0.24$ for income). However, we did find one other relationship during harvest

Table 3. Summary of those who won and those who lost the BDM auction for the Digni-Loo slab. This table includes respondents who did not participate in the auction because they did not have the necessary money. For these respondents, we simulated the auction by assigning them a bid of 0 GHS and randomly selecting a price point. We compared datasets using Wilcoxon rank-sum tests, with p-values reported in the table.

Statistic	Non-harvest season (round 1)			Harvest season (round 2)			p-value: winners in round 1 vs. 2
	Auction winners	Auction losers	p-values: round 1 winners vs. losers	Auction winners	Auction losers	p-values: round 2 winners vs. losers	
Number	153	312	–	34	108	–	–
Percent	33%	67%	–	24%	76%	–	–
Average revealed WTP	346	85	<0.001	332	146	<0.001	0.664
Average price point	203	490	<0.001	209	538	<0.001	0.595
Average stated WTP	455	414	0.017	359	292	0.014	0.006
Average revealed/ stated WTP ratio	1.05	0.27	<0.001	1.09	0.67	<0.001	0.031

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season that may be important: those in the top wealth quintile of surveyed households tended to have greater WTP ($p = 0.022$).

Finally, results from regression models reinforced earlier findings that agricultural households tended to be less wealthy and increased their WTP somewhat during harvest season, raising the lower portion of the WTP demand curve. Bivariate regression models confirmed that households working in agriculture are less likely to be in the top wealth quintile ($p = 0.005$) and less likely to report monthly incomes over 500 GHS ($p = 0.004$). They are also more likely to be located in remote rural communities rather than rural small towns ($p < 0.001$). These trends offer evidence that agricultural

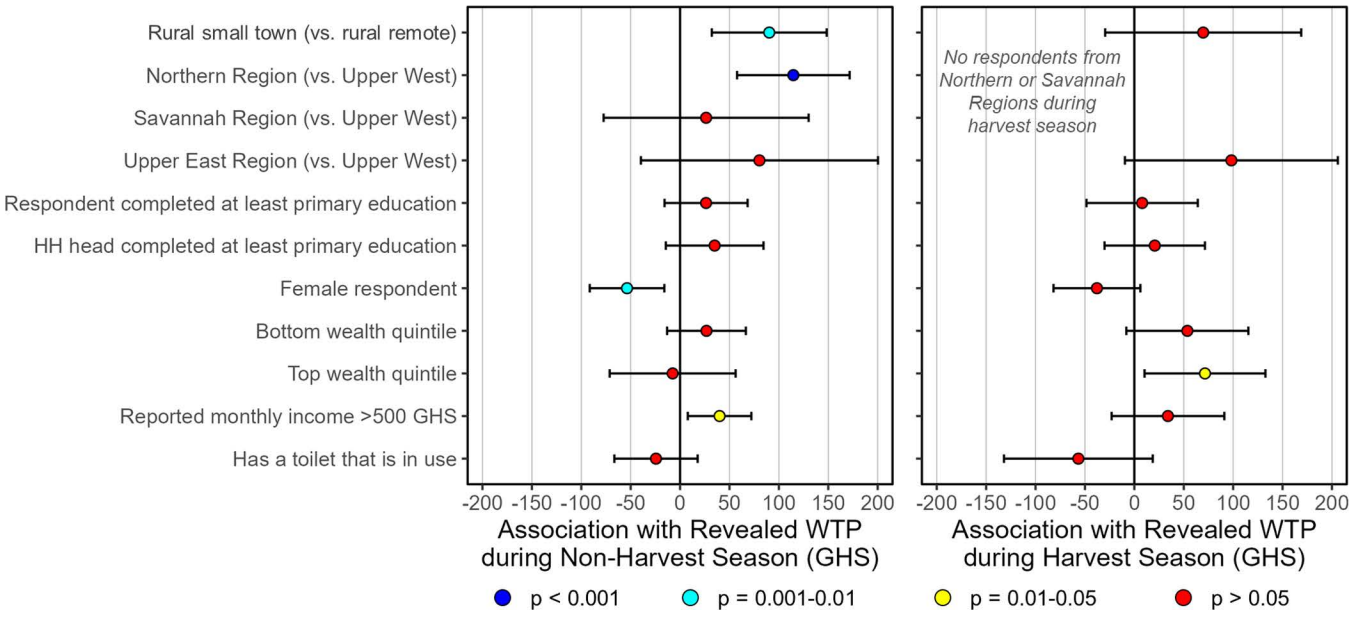

Fig 3. Associations with revealed WTP during non-harvest ($n = 441$) and harvest ($n = 137$) seasons. All factors shown were included as covariates in one linear regression model with adjusted standard errors for community clustering, where revealed WTP was the dependent variable. Points show estimated coefficient values, with error bars providing 95% confidence intervals and point color indicating p-values.

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households typically fall in the lower portion of the WTP distribution. Given how numerous these households are in our survey population (Table 2), even a small change in their WTP would likely have a measurable effect on the entire distribution.

Additionally, using logistic regression models, we considered how these same factors were associated with whether or not a participant won the auction (Figure B in S1 Text). Given that auction winners typically had the advantage of comparing their bid amounts with lower random price points (Table 3), these models also controlled for the random price point seen by each participant. During non-harvest season, we found that many of the same factors, including community type, region, and respondent gender, exhibited similar trends to the linear model of revealed WTP (Figure B in S1 Text). In other words, factors associated with an increase in revealed WTP also increased the odds of a participant winning the auction. Again, these trends were less meaningful during harvest season. One possible explanation for this outcome may be that, when agricultural households have more funds available during harvest time, their bid amount was more reflective of individual household preferences and interest in the Digni-Loo, rather than demographic, geographic, or other characteristics.

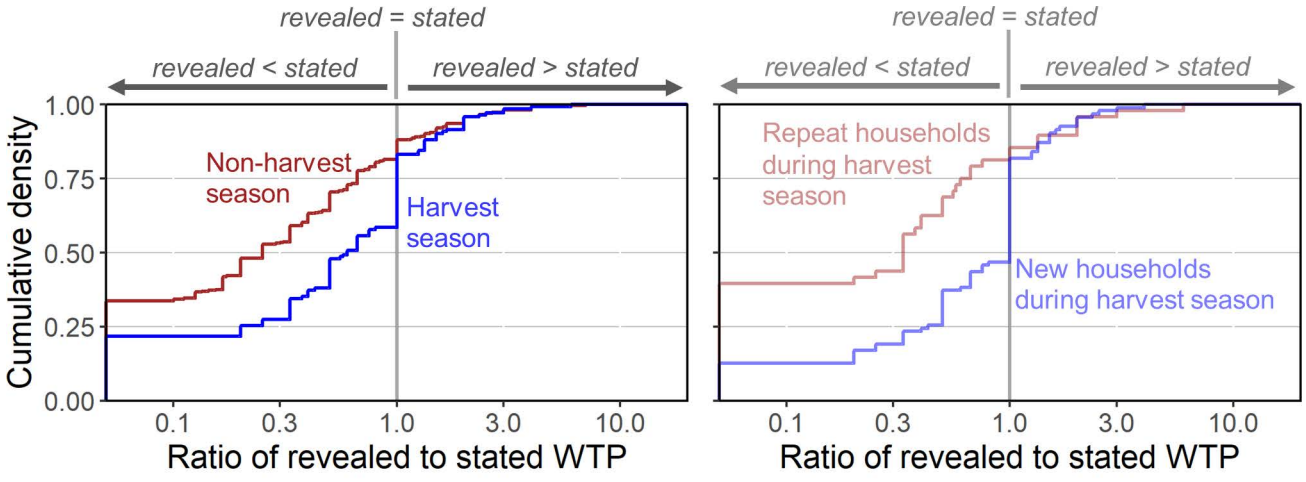
3.4. Relationships between stated and revealed WTP

Participants' stated WTP values during the first visit were often inflated above the amounts they were actually willing to bid during the BDM auction in the second visit, particularly during non-harvest season (Fig 2). Adding stated WTP to our previous linear regression model for revealed WTP (still including all other covariates) showed that stated and revealed WTP were not associated during non-harvest season ($p = 0.28$; Figure C in S1 Text). While stated WTP still often exceeded revealed WTP in harvest season, they tended to be closer together, and stated WTP was positively correlated with revealed WTP in our regression model ($p = 0.003$).

To further explore relationships between revealed and stated WTP, we calculated the ratio of revealed to stated WTP for each respondent. Ideally, perfectly reliable stated WTP results would always produce a ratio of 1, with stated and revealed WTP being equal. In our study population, the distributions of ratio values varied considerably, with a large proportion showing revealed WTP to be lower than stated values (Fig 4). On average, a participant's revealed WTP was only 53% of their stated WTP in non-harvest season. Stated values overestimated revealed WTP among 81% of participants, while stated and revealed WTP were equal for only 7% of participants. Alignment during harvest season was considerably better, with a participant's revealed WTP averaging 77% of their stated WTP ($p < 0.001$). Stated values were higher than revealed WTP among a smaller, but still large, proportion of respondents (58%; $p < 0.001$), while stated and revealed WTP were equal among one quarter of respondents ($p < 0.001$). These differences continued to hold true, and in some cases became more pronounced, when comparing new and repeat respondents during harvest season (Fig 4). The distribution of ratios among repeat respondents, who reported their stated WTP during non-harvest season (in round 1 of data collection) and then participated in the auction again during harvest season, looked very similar to the distribution of all respondents during non-harvest season. However, new respondents, who reported their stated WTP in harvest season approximately two weeks before participating in the auction, exhibited greater alignment. Among this group, 35% reported a stated value equal to their revealed WTP, while less than half (47%) stated a value larger than their revealed WTP ($p < 0.001$).

3.5. Stated demand for the Digni-Loo compared with other full toilet facilities

To help put the WTP findings for the Digni-Loo slab in context, this section describes stated WTP results for the installation and materials of four complete toilet facilities (i.e., Digni-Loo Toilet, SatoPan Toilet, BioFill Toilet, and Water Closet; Table 1) in the same study area a few months earlier. Generally, average stated WTP differed across the four toilet facilities, with higher values for facilities that were more expensive. For example, mean stated WTP for the Digni-Loo Toilet – the least expensive of the four facilities – was 642 GHS (58 USD), representing 31% of this facility's total cost of 2,100 GHS (190 USD). This result appears fairly consistent with stated WTP for the Digni-Loo slab on its own, which averaged 419 GHS (38 USD; 52% of the slab's reduced market price or 30% of the total cost) in non-harvest season and 295 GHS (27 USD; 37% of the reduced market price or 21% total cost) in harvest season. In contrast with average stated WTP for



	Harvest *n = 142*	Non-harvest *n = 462*
Mean ratio	0.77	0.53
Median ratio	0.60	0.25
revealed = stated	25%	7%
revealed < stated	58%	81%
revealed > stated	17%	12%

	New *n = 94*	Repeat *n = 48*
Mean ratio	0.85	0.60
Median ratio	1.00	0.33
revealed = stated	35%	4%
revealed < stated	47%	81%
revealed > stated	18%	15%

Fig 4. Cumulative distributions of individual households' ratios of revealed to stated WTP. The left plot shows all respondents from each season, while the right plot compares new and repeat households included during harvest season. The vertical line at a ratio of 1 represents the ideal result (revealed WTP = stated WTP). The x-axis on each plot is shown using a logarithmic scale. All ratios <0.1 had a value of 0 (no revealed WTP), which could not be shown on the logarithmic axis.

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the full Digni-Loo Toilet, mean stated WTP for the most expensive facility (the Water Closet) was 1,450 GHS (132 USD; $p < 0.001$), or 11% of its total cost of 13,200 GHS (1,200 USD). It is possible that higher levels of familiarity with the Water Closet in the study area (Table A in S1 Text) contributed to the larger mean WTP for this facility. However, despite large differences in total cost, stated WTP at lower price points was similar across all four facilities, with 75% of respondents stating they would be willing to pay 300–500 GHS (27–45 USD) for each facility (Fig 5). This trend suggests that demand for the Digni-Loo would be similar to demand for other types of sanitation facilities at low price points.

Additionally, it is worth noting that at least some of the difference in mean stated WTP values across the four facilities may be caused by anchoring. Anchoring is a phenomenon in which the random price point selected to begin the double-bounded dichotomous choice sequence of questions influences the respondent's perception of a reasonable price for the product, thereby affecting their responses to future questions about their WTP [9,27,28]. Essentially, a respondent might be more likely to state a higher WTP when the initial price point is larger. Across all four toilet facilities, we found a positive correlation between the initial price point and a respondent's final stated WTP ($p < 0.001$ in bivariate linear regression models), which can also be seen by visualizing the distributions of stated WTP among surveys including each initial price point (Figure D in S1 Text). For example, an increase of 100 GHS (9 USD) in the initial price point was associated with an increase of 26 GHS (2 USD) in a respondent's stated WTP for the Digni-Loo Toilet ($p < 0.001$). Since the four toilet facilities had very different costs, we used different price points in an attempt to capture details across a reasonable range of prices for each facility. Accordingly, the smaller mean stated WTP for the Digni-Loo Toilet may be at least partially related to the fact that it was the least expensive facility.

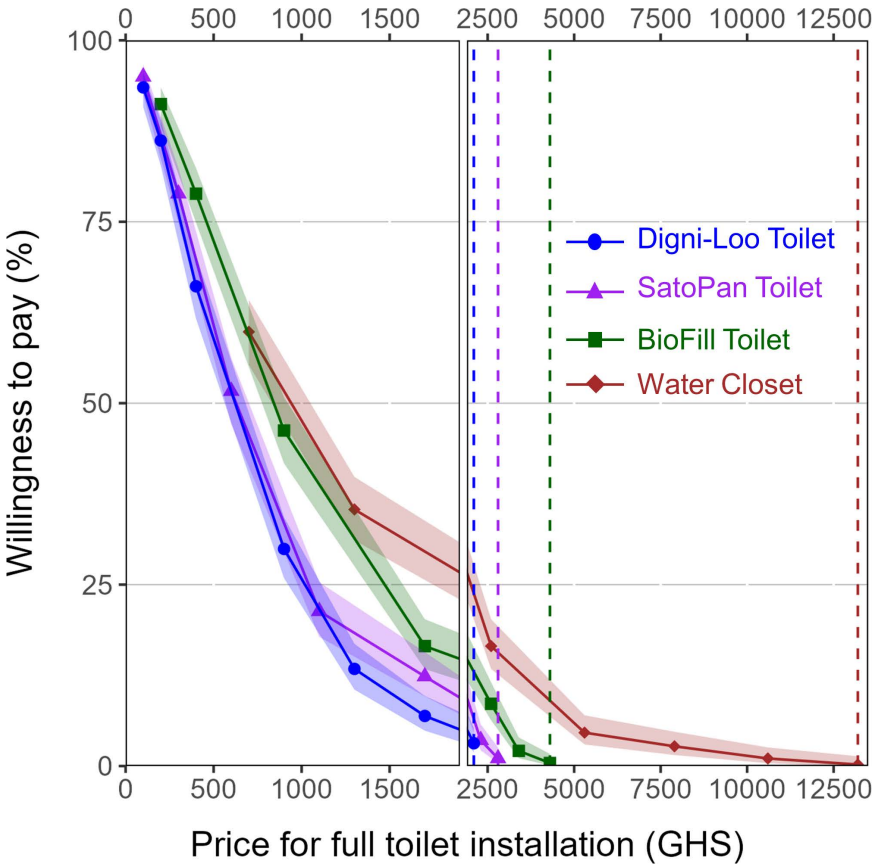

Fig 5. Stated willingness-to-pay (WTP) for four complete toilet facilities (inclusive of materials and labor for substructure, slab, and superstructure) in northern Ghana. Stated WTP values came from double-bounded dichotomous choice surveys administered prior to the auction as part of EnWASH program baseline data collection (n = 478). Shaded regions surrounding each curve provide 95% confidence intervals. Dashed vertical lines indicate the estimated cost of each facility (reported in Table 1). The x-axis includes a break at 1,900 GHS, to allow for greater detail at lower price points.

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3.6. Additional considerations related to stated WTP for the Digni-Loo slab

Anchoring: Similar to stated WTP for the full toilet facilities discussed above, anchoring likely also affected stated WTP for the Digni-Loo slab in our survey. Interestingly, however, our bivariate linear regression models only found meaningful anchoring effects during non-harvest season, where an increase of 100 GHS (9 USD) in the initial price point for the slab was associated with an increase of 51 GHS (5 USD) in the respondent's stated WTP ($p < 0.001$; Figure E in S1 Text). The fact that this relationship was not apparent during harvest season ($p = 0.77$) may provide further evidence for the argument that stated WTP is more reliable when collected close to the time when a household might actually purchase the product.

Payment plans: Our surveys revealed that respondents may be willing to increase the total amount they are willing to pay for a Digni-Loo slab if they have the option of paying that amount over time, via a monthly payment plan. During non-harvest season, respondents stated the total amount they would be willing to pay would increase by an average of 21% with a 6-month payment plan and 31% with a 12-month plan. Respondents during harvest season reported an average increase of 14% for a 6-month plan and 33% for a 12-month plan. In addition to promoting the technology at an

appropriate time of the year (during harvest season), sanitation providers may also increase demand by offering flexibility in payment plans for the Digni-Loo slab.

4. Discussion

Collectively, our WTP results suggest that subsidies are likely necessary to enable a substantial portion of the population in rural northern Ghana to gain access to safe, sustainable, and contextually appropriate sanitation infrastructure. We found large discrepancies between what study participants were willing to pay for various sanitation products and their total costs. For example, average revealed WTP for the Digni-Loo slab during harvest season was only 14% of the slab's total cost. Stated WTP values, which likely overestimated true purchasing behavior, also fell far below total costs, with stated WTP for the full Digni-Loo Toilet representing only 31% of the toilet's 2,100-GHS (190-USD) cost. A previous study using the same stated WTP methodology in urban areas of Ghana, Kenya, and Bangladesh similarly found that average WTP for various types of toilet facilities ranged from 16% to 40% of each facility's cost [29]. Specifically in Kumasi, Ghana, stated WTP for facilities similar to the BioFill Toilet and Water Closet averaged 19–40% of cost [29], which was higher than our average results (11–22% for these two facilities). The lower WTP we found in comparison with other studies was likely due, at least in part, to higher poverty levels [13] in rural northern Ghana. Additionally, low levels of awareness surrounding the toilet facilities considered here (e.g., less than 10% of baseline respondents reported being familiar with the Digni-Loo, SatoPan, and BioFill Toilets) may have suppressed WTP results in this context. Future awareness campaigns or other demand generation efforts may help to increase local WTP for these sanitation products.

At least initially, any intervention promoting these types of sanitation products in northern Ghana will likely need a subsidy as one of its elements. The following sections provide recommendations, derived from our findings and existing literature, concerning potentially appropriate subsidy levels, when to focus promotion efforts, and possible strategies to increase WTP levels among the population, with a primary focus on the Digni-Loo slab.

4.1. Recommendations regarding Digni-Loo subsidy amount and timing

Our revealed WTP findings suggest that the best time to promote the Digni-Loo slab and any associated subsidies would be during harvest season, when agricultural households typically face better economic circumstances and are more likely to make a purchase. Our second round of data collection occurred in December, when crops are harvested following the typical end of northern Ghana's one annual rainy season in October-November [14]. At this time, we found higher revealed WTP for the Digni-Loo slab at lower price points (e.g., 100 GHS or 9 USD) than we did in our first round of data collection. That first round occurred in April-May, which represents the end of the dry season and beginning of the rainy season [30], a time of year sometimes referred to as the "hunger season" in northern Ghana, when food availability and accessibility may be low [14]. At this point, households are likely to be much more focused on meeting basic food security needs than on building new sanitation infrastructure, while unstable soils and heavy rains make latrine construction difficult throughout much of the rainy season.

With regard to appropriate subsidy amounts, we recommend setting the subsidy to a level that is expected to encourage a majority of households to improve their sanitation facilities to yield higher potential impact. Setting the subsidy so that the Digni-Loo slab price corresponds to 75% revealed WTP among our survey population might be a reasonable approach, in that it could capture a majority of households while allowing for some margin of error and program inefficiencies. Our revealed WTP results from harvest season suggest a subsidized price that would encourage 75% of households to purchase the Digni-Loo slab may fall around 100 GHS (9 USD).

A blanket approach to sanitation subsidies may be justifiable in the high-poverty context of northern Ghana, but alternative approaches may also be appropriate. For example, local governments or organizations could employ targeting programs based on community consultation meetings (where community members identify poor households themselves, using certain criteria) and/or proxy means testing (PMT) surveys to identify those eligible for subsidies [17,31]. Additionally, offering flexibility

in the form of monthly payment plan options might increase a household's ability to pay somewhat higher subsidized prices, while setting multiple subsidy levels to cover a large proportion of the population might better reflect the fact that many households in these communities face varying conditions of poverty [17]. Local governments or organizations could, for example, offer this subsidy in the form of a voucher that households could present to a pre-approved vendor when making a purchase [17]. Of course, it is important to recognize that the full cost of a subsidy program would also include substantial expenses related to program implementation (e.g., voucher distribution, vendor verification and payment). A previous study in northern Ghana found these program implementation costs to be comparable to the cost of the subsidies themselves [17].

4.2. Possible strategies to increase demand for the Digni-Loo slab

While our results primarily offer insight into existing demand and WTP for the Digni-Loo slab, they may also suggest potential approaches that could, in conjunction with a subsidy program, increase existing WTP levels. First, broad efforts to promote and generate demand for the Digni-Loo slab and toilet in northern Ghana may boost WTP, since at least some households in the region likely still have limited experience with this relatively new technology. Compared with the Digni-Loo Toilet, our baseline survey participants did indicate higher stated WTP for better known sanitation facilities such as the Water Closet, so it is possible that households will be more interested in and willing to pay more for the Digni-Loo once they become more aware of it. However, while differences in stated WTP may relate to disparities in respondent awareness of the facilities, they may also come from anchoring and actual differences in household preferences and toilet value. Additionally, as we saw for the Digni-Loo slab and as others have noted in previous literature [19], discrepancies between stated and revealed WTP suggest caution when interpreting how stated WTP relates to true demand.

Another strategy for boosting WTP may involve increasing access to financing options, such as by offering monthly payment plans, to make it easier for households to afford these sanitation products. While our results supported this approach, we were not able to test revealed WTP for monthly payment plans, so it is important to be cautious when interpreting these stated WTP values. Additionally, an appropriate payment plan approach for this area would likely need to account for fluctuations in agricultural households' monthly income, perhaps providing flexibility where households could pay more when they have more funds available and less when they are more constrained. Another approach to increase access to financing might involve promoting and strengthening Village Savings and Loan Associations (VSLAs), which could provide a locally trusted mechanism for community members to collectively raise funds and provide loans that could increase sanitation access [10,32].

4.3. Drawbacks and potential uses of stated willingness-to-pay

Given the potentially high cost of a subsidy program for the Digni-Loo slab, it may be tempting to use our stated WTP results instead of revealed WTP to inform potential subsidy levels. Stated WTP values tended to be higher than participants' revealed WTP, which would suggest a higher subsidized price point and, therefore, a smaller required subsidy. However, previous studies have raised questions about the ability of contingent valuation methods, and stated preference approaches more broadly, to reliably indicate a population's actual market behavior with respect to sanitation and other products [19]. Our results suggested a similar misalignment, especially in non-harvest season, and we generally considered the revealed WTP findings to be more reflective of reality, given that revealed WTP corresponded to study participants' actual purchases of the Digni-Loo slab.

To explore this in further detail, we considered the potential outcomes of setting the price point based on stated WTP results, while assuming that revealed WTP would provide the most accurate representation of real purchasing behavior. Employing stated WTP findings to set the subsidized price point (at 200 GHS during harvest season or 220 GHS during non-harvest season, corresponding to 75% stated WTP) could cause the subsidy to considerably underperform relative to its objective (higher coverage of sanitation facilities such as the Digni-Loo). Compared to our revealed WTP results from harvest season (100 GHS for 75% WTP), fewer people would actually purchase the Digni-Loo slab at the stated WTP price points, leading to lower coverage than the program goal (Fig 6). In our hypothetical example scenario, using harvest

season stated WTP would result in an actual coverage level of 52%, while using non-harvest season stated WTP would only reach 35% coverage (Fig 6).

However, stated WTP data is often easier and less costly to collect, and collecting revealed WTP data may not always be possible. In this case, stated WTP surveys could provide an estimate of a likely upper limit on the survey population's true WTP to inform possible subsidy levels, but we would recommend thinking carefully about the most appropriate and reliable methodology to employ. For example, discrete choice experiments offer an alternative stated WTP method that may be superior to double-bounded dichotomous choice in certain cases, especially when asking participants to compare their preferences for different technologies or sets of conditions [19].

Beyond the selection of an appropriate methodological approach, our results also suggest that stated WTP surveys are more likely to accurately reflect real market behavior if they occur at a time close to when participants have more funds available, are better able to predict their actual demand, and are most likely to make purchases. Given the high prevalence of agricultural households in northern Ghana, this would fall during or just after harvest time, while households may be more optimistic about their future economic prospects and overestimate their actual purchasing behavior during non-harvest time. Other agrarian contexts would likely follow similar patterns related to when households have money available for purchases and the most effective timing of stated WTP surveys. For example, one study found that farm households in a village in Maharashtra, India received 82% of their annual income during a three-month harvest period at the beginning of the year [15]. Similarly, a study of households in greater Rangpur, Bangladesh found that income during a lean (non-harvest) season was 50–60% less than during other seasons characterized by rice harvests [16].

4.4. Limitations

There are several factors that may limit the accuracy or generalizability of the findings presented here. First, it is important to acknowledge that the communities included in our survey were selected primarily for their relevance to the EnWASH Program, which focused on rural areas with high poverty and low levels of water and sanitation coverage. Accordingly, our results may not be fully representative of northern Ghana as a whole. Still, our understanding is that other communities in these regions face similar challenges, though perhaps to a somewhat lesser extent. Additionally, due to economic volatility in the country, it is unclear how far into the future our WTP findings will be relevant, and respondents' valuations of price points may have changed between rounds. Although the market price of toilet options such as the Digni-Loo and SatoPan did not change during the study, it is possible that high levels of overall inflation (e.g., 38% in 2023 [33]) may have decreased the real value of participants' bids between rounds (April-May to December 2023), potentially underestimating WTP in later data. Future research should adjust for inflation to ensure comparability. Within each round, it is also possible that the time between the first visit (when the auction was introduced) and the second (when the auction occurred) did not provide sufficient time for some households to gather as much money as they would have liked to purchase the Digni-Loo slab. Households planning for a purchase further in advance might have been able to bid greater amounts. Furthermore, we were only able to collect revealed WTP data for a single sanitation technology, and it is possible that our stated WTP results do not capture important distinctions in demand for other types of toilet facilities. This point may be especially relevant, given the different price points used for each toilet type and the potential influence of anchoring discussed previously.

Perhaps a particularly critical limitation is that we did not initially design this study to consider seasonality. The question of how seasons affect WTP was one that arose during the course of our work, and we decided to add a second round of data collection after the first round was already complete. Accordingly, we were not able to pre-select survey populations for rounds 1 and 2 with the level of randomness and statistical rigor one would desire to ensure that results from two different samples are comparable. Moreover, in round 2, we intentionally revisited some respondents who had lost the auction in round 1, which may have reduced overall WTP among our round 2 sample and underestimated the strength of the seasonal trend we found. Additionally, due to program constraints, the timing between the first and second visits was shorter in harvest season than in non-harvest season.

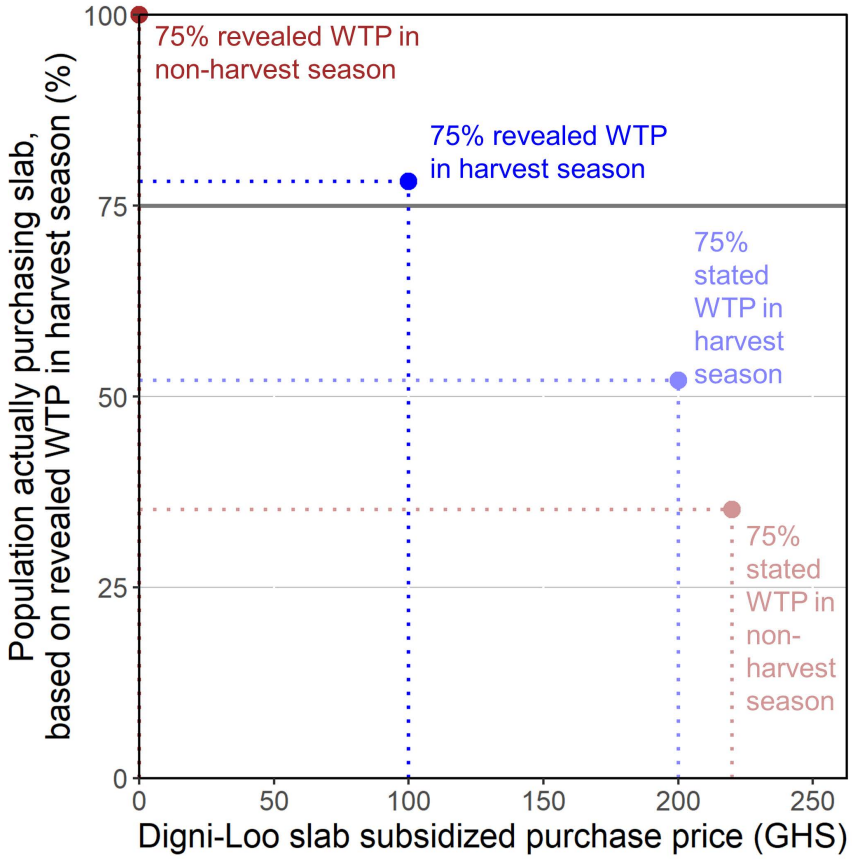

Fig 6. Expected implications of using different sets of results to determine Digni-Loo slab subsidies. Each point shows the proportion of the survey population we would expect to purchase the slab at different subsidized prices, assuming revealed WTP from harvest season is most reflective of reality due to its alignment with actual purchasing behavior in BDM auctions. We set the prices to reflect 75% WTP from each of our four sets of results (stated and revealed WTP during harvest and non-harvest seasons), meaning that the goal was to set the subsidy level so that at least 75% of the population will purchase the slab.

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Overall, our earlier summary of respondent characteristics (Table 2) showed some key differences between our round 1 and 2 survey populations. The most striking difference is that we were unable to include any respondents from the Northern and Savannah Regions during round 2. To test our results' sensitivity to this issue, we repeated our round 1 analysis after removing respondents from the Northern and Savannah Regions. The mean revealed WTP dropped slightly, to 154 GHS (14 USD, versus 171 GHS or 16 USD with all data included), but this does not appear to be a substantial change ($p = 0.21$), suggesting that including the data from all four regions did not meaningfully affect our conclusions. Round 1 also included a somewhat lower proportion of female respondents (42% vs. 56% in round 2; $p = 0.003$). However, our regression analysis showed women tended to have lower revealed WTP in the first round (non-harvest season), so it is possible that better gender alignment between rounds 1 and 2 might have led to an even greater seasonal difference in revealed WTP, further strengthening that finding. Finally, in round 2, the education level of repeat participants (who participated in the auction during both non-harvest and harvest seasons) was lower than it was among new respondents. However, our regression analysis showed that education level did not correlate with revealed WTP. Overall, despite some important differences between the survey populations included in our two rounds of data collection, we do not feel that these differences substantially influenced our conclusions.

4.5. Developing effective sanitation subsidy programs

Gaining a better understanding of willingness-to-pay and demand for sanitation products in underserved, low-resource contexts such as northern Ghana is an important step toward developing programs that increase access to safe and sustainable sanitation. The preceding sections provide insight into factors affecting household WTP, potentially appropriate subsidy amounts and characteristics, and methodological considerations for measuring WTP. However, other considerations also exist. First, while our findings suggest that subsidies are likely to be an appropriate strategy in northern Ghana, other approaches may be more appropriate or effective in other contexts. For example, studies in Bangladesh and Lao PDR evaluated the effectiveness of alternate strategies including supply-side market access interventions that linked households with suppliers, information provision to increase community motivation, and village incentives for eliminating open defecation [34,35]. In Bangladesh, supply-side interventions and information provision initiatives were relatively ineffective [34], but that may not be the case elsewhere. Meanwhile, in Lao PDR, combining CLTS with a village-level incentive (a monetary award paid to the village's administration committee) did increase toilet ownership rates, although primarily among households classified as non-poor [35].

Beyond increases in toilet access, implementers might also consider the cost-effectiveness of sanitation marketing and promotion programs, with respect to factors including the health and time savings that come from improving sanitation access at household and community levels, the operation and maintenance costs associated with an installed toilet, the activities needed to establish and strengthen the supply chains needed to ensure sanitation products are available in remote areas, and the implementation costs of the program itself [17,36]. As mentioned previously, the implementation costs associated with subsidy programs can be considerable [17], and the balance between the benefits of safer sanitation and the costs to implementing organizations and households remains an open and uncertain question. Future research focused on designing and evaluating various sanitation promotion and marketing efforts will likely provide valuable insights into contextually appropriate strategies and best practices, in northern Ghana and in other challenging, underserved contexts.

Supporting information

S1 Text. Supplementary figures and tables.
(PDF)

S1 Data. Data and codebooks for baseline and willingness-to-pay surveys.
(XLSX)

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Author contributions

Conceptualization: John Trimmer, Joyce Kisiangani, Dominic Osei, Valerie Bauza.

Data curation: Joyce Kisiangani, Chloé Poulin, Valerie Bauza.

Formal analysis: John Trimmer, Stanley Bortse Sam, Chloé Poulin.

Funding acquisition: Dominic Osei.

Methodology: John Trimmer, Joyce Kisiangani, Bessy Ewoenam Odame-Boafo, Dominic Osei, Valerie Bauza.

Project administration: Joyce Kisiangani, Bessy Ewoenam Odame-Boafo, Valerie Bauza.

Supervision: John Trimmer, Valerie Bauza.

Visualization: John Trimmer.

Writing – original draft: John Trimmer.

Writing – review & editing: Joyce Kisiangani, Bessy Ewoenam Odame-Boafo, Stanley Bortse Sam, Chloé Poulin, Dominic Osei, Valerie Bauza.

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