# Adoption and sustained use of the arborloo in rural Ethiopia: a cross-sectional study

Dionna Fry, Dejene Mideksa, Argaw Ambelu, Yeshewahareg Feyisa, Bekele Abaire, Katherine Cunliffe and Matthew C. Freeman

## ABSTRACT

In rural Ethiopia, only 19% of the population has access to improved sanitation, which has no doubt contributed to high levels of diarrhea, trachoma, and helminth infection. Low-cost sanitation options are needed in Ethiopia, but few studies have assessed their effectiveness and sustainability. The composting arborloo is one such option. Catholic Relief Services (CRS) has promoted the arborloo since 2004. Eighty thousand Ethiopian households have constructed arborloos with their assistance. We assessed the arborloo's adoption and sustainability in 20 communities that received arborloo promotion. We surveyed 690 households and conducted 24 key informant and 33 in-depth interviews. Over two-thirds [462 (67.0%)] of surveyed households constructed an arborloo; 352 (76.2%) sustained use and 65 (14.1%) moved to a more permanent latrine. There is a clear role for the arborloo in rural Ethiopia to increase the rate of sanitation adoption, sustainability, and movement up the sanitation ladder. We found no evidence that sustainability differed by arborloo age or socio-economic status. Sustainability was most strongly associated with use of the arborloo pit for planting and a cement slab. Slab subsidy discontinuation after 2012 may negatively impact sustainability. However, CRS sanitation marketing could increase slab access, maintain sustainability rates, and decrease reliance on programing for sanitation solutions.

**Key words** | adoption, arborloo, ecological sanitation, Ethiopia, latrine, sustainability

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## INTRODUCTION

Only 21% of Ethiopians have access to improved sanitation and 45% practice open defecation; the conditions are more dire in rural areas (JMP 2013). This lack of sanitation has no doubt contributed to high levels of diarrhea, trachoma, and helminth infection (Pruss *et al.* 2002; Clasen *et al.* 2010; Stocks *et al.* 2014; Strunz *et al.* 2014). Owing to the sanitation situation in Ethiopia, low-cost options are needed, but few studies have assessed their effectiveness and sustainability.

One such low-cost option is the arborloo, an ecological sanitation (eco-san) approach that is designed to utilize composted material for tree planting, which was developed in Zimbabwe in 1998 (Morgan 1998). By eliminating the barriers of cost and time, the arborloo has the potential to increase the rate of rural sanitation adoption in Ethiopia, which could in turn decrease the burden of sanitation-related infectious disease (Simpson-Hebert 2007). As a low-cost technology, promotion of the arborloo is especially well suited to Ethiopia in today's context, since the government implemented a zero-subsidy sanitation policy in 2012.

The arborloo includes a household-dug pit (which should measure 0.8 m wide and 0.5–1 m deep), an optional ring beam to protect the pit, a concrete slab (which should be light and overlay the ground by at least 0.1 m on all sides), and a superstructure (Morgan 1998, 2004). The household generally provides the labor to dig the shallow pit and build the arborloo, thus this element of the arborloo does not have a monetary cost to adopters who are generally engaged in non-wage labor, although there is an opportunity

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cost since adopters must invest 2–5 hours in building the arborloo (Morgan 1998, 2005; Simpson-Hebert 2007). If the opportunity cost were to be monetized, the household labor costs for digging the arborloo pit range from $0.18 to $0.44 for 2–5 hours of labor (U.S. Department of State 2013). If the household chooses to include a ring beam, the supplies to make bricks and cement cost $3.5–5. The cement slab costs $5.00–6.60 to purchase, although some households choose to utilize free natural materials to construct a slab. Since the arborloo is moved often, the superstructure should be portable or easily replaceable. The superstructure is most often made of local materials (woven reeds or sticks), but if purchased, materials for a cement superstructure may cost an additional $10 (Smet 2007). While an arborloo could cost from $0 (natural materials' slab) to $22 if all materials are purchased, no households surveyed in this study purchased materials for a superstructure; therefore, the cost estimate for the arborloo used throughout this paper is $5–10 (Hebert 2010; Mara 2012). The arborloo is a low-cost eco-san option as compared to other eco-san options and improved latrines. Other eco-san options generally cost between $58 (fossa alterna) and $400 (urine diversion); ventilated improved pit latrines generally cost between $52 and $400, although these figures will vary by country (Smet 2007). In 2010, a traditional pit latrine with a cement slab cost $32–121 in Ethiopia. The larger, thicker slab costs $15–44 and labor to dig the 3 m deep pit ranges from $17 to $77 (Hansch 2003; Hebert 2010). A traditional pit latrine with a slab made out of natural materials (improved or unimproved) costs from $17 to $77 for the labor to dig the 3 m deep pit (Hansch 2003; Hebert 2010). These costs are still much higher than those for the typical arborloo latrine in Ethiopia (Hansch 2003; Hebert 2010).

After the arborloo is constructed, a layer of leaves, ash, and/or soil is placed in the pit, and the same components are added after each use to accelerate composting and reduce odor and flies (Morgan 1998, 2007a). Once the pit is two-thirds full, which generally occurs every 6 months, the pit is backfilled with a thick layer of soil and a fruit tree is planted on the nutrient rich pit (Morgan 2004, 2007a). The household digs another arborloo pit once the first one is filled, and the concrete slab and superstructure are moved to the new pit (Figure 1). This process is repeated as pits are filled (CRS 2010b).

The arborloo is considered ecological sanitation (Esrey *et al.* 2001; GTZ 2002), which utilizes the productive value of human excreta (Esrey 2000). Use of eco-san can address the issues of environmental degradation and flagging soil fertility since human excreta contains many of the nutrients taken from the soil in the form of harvested plants (Morgan 1998; Esrey *et al.* 2001; Dagerskog *et al.* 2014). Human excreta can be used as fertilizer by hygienically breaking down these nutrients and organic matter (Langergraber & Muellegger 2004; Winblad *et al.* 2004). While other eco-san options call for transportation of composted excreta to another location for use, the arborloo design utilizes composted excreta for tree planting *in situ* (Winblad *et al.*

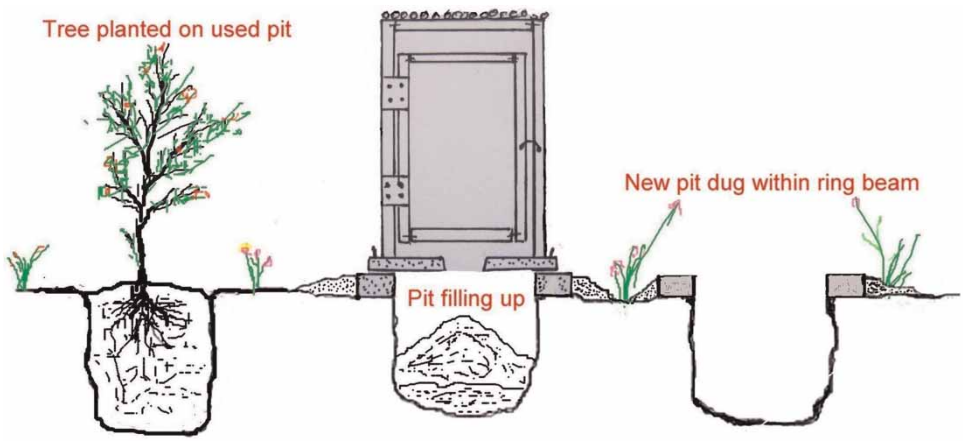


**Figure 1** | The life cycle of an arborloo (Morgan 2007b).

2004). The arborloo's design minimizes contact with composted excreta and the associated risks (Jimenez *et al.* 2006; Duncker *et al.* 2007; Lines-Kelly 2010). When added to soil, eco-san compost can improve soil quality and therefore crop yields; improvements in crop yields can positively impact food security or nutritional status by increasing nutrient variety or caloric availability (Esrey 2000; Esrey *et al.* 2001; GTZ 2002). This aspect of eco-san is particularly relevant in much of Sub-Saharan Africa, since soil degradation and declining soil fertility occurs in many countries (Henao & Baanante 1999 ; Dagerskog *et al.* 2014).

In rural areas of Ethiopia, 19% of people use improved sanitation, 28% used unimproved or shared sanitation, and 53% practice open defecation (JMP 2013). The Ethiopian Ministry of Health considers ecological sanitation an improved sanitation option, and it is used by approximately 3.5% of Ethiopian households (Rosemarin 2008; DHS 2012). Eco-san options generally fall into two overarching categories: (1) urine-diversion latrines separate urine for use and utilize desiccation (drying) to treat feces, and (2) composting latrines such as the arborloo, fossa alterna, and modified Blair latrine that utilize decomposition to treat combined urine and feces excreta (Winblad *et al.* 2004).

Since arborloos have shallower pits and the excreta composts relatively quickly (usually 3–4 months) they have a lower risk of groundwater contamination as compared to deeper, unlined latrine designs (Esrey *et al.* 2001; Winblad *et al.* 2004). The arborloo can also be utilized in water-scarce areas both because the design does not require water and because the crops planted on the arborloo pit may exhibit increased crop resiliency in drought conditions (Esrey *et al.* 2001). The shallower arborloo is also a good option in areas where soils are rocky or sandy, as is the case in much of Ethiopia (Morgan 2005; Simpson-Hebert 2007; Seremet 2008). In a 2004 evaluation of their sanitation programs, Catholic Relief Services (CRS) Ethiopia found that the rocky and sandy soils found in much of Ethiopia were unsuitable for the deeper conventional pit latrine or ventilated improved pit latrine designs that they were promoting. Their evaluation found that rocky conditions caused difficulty in digging the 3 m deep pits and sandy soils often caused the deeper pits to collapse once constructed (Seremet 2008). CRS Ethiopia also found that these two deeper pit latrine designs, which require thicker, more expensive slabs and hired labor to dig the pit, were too costly for the rural Ethiopian population at $60 per conventional improved latrine and $150 per ventilated improved latrine (Seremet 2008). In response to these issues, CRS Ethiopia began promoting the arborloo, an improved sanitation option, in 2004 in partnership with the Global Water Initiative, since it has a shallower 0.5 m deep pit, a thinner, cheaper cement slab, and therefore a relatively lower cost ($5–10). Since that time, CRS Ethiopia has assisted in the construction of over 80,000 arborloos throughout Ethiopia (CRS 2010a; Tolessa 2013).

From 2005 to 2012, the program coupled arborloo promotion with participatory hygiene and sanitation transformation (PHAST) (Simpson-Hebert 2011). The PHAST training was open to all community members and slabs were distributed free of charge from 2005 to 2012 if a household dug a pit after training completion, although slabs were not always available to every household that completed training due to limited supplies (Tolessa 2013). Seedlings – most often mango, papaya, avocado, and banana – were distributed to households with a filled pit for free or at a small cost and were also available in certain areas through the local ministry of agriculture or at the local market. CRS focused on working with established community governance structures, health extension workers, and development agents as part of their implementation strategy (Tolessa 2013).

In 2012, the Ethiopian government changed its WASH policy to mandate a zero subsidy model. As a result, a household seeking to construct an arborloo must now pay the full cost of the arborloo and seeds/seedlings. The cost of a slab produced by CRS partners is $5–6.60 and the supplies to construct a ring beam are an additional $3.5 (Morgan 1998, 2005; Simpson-Hebert 2007; Hebert 2010). This government policy change necessarily altered the program implementation strategy, and sanitation marketing was prioritized to increase access to slabs and seedlings for purchase through local marketplaces. At this time CRS also changed its sanitation approach to community led total sanitation and hygiene (CLTSH), in line with newly implemented zero subsidy government policy. CLTSH is an intervention strategy based on stimulating a collective sense of shame and disgust around mass open defecation and its negative impact that also includes a hygiene component (Kar 2005; Ethiopian Ministry of Health 2011).

### Research aims

We assessed the sustained use of arborloos within CRS program areas in rural Oromia region, Ethiopia. By identifying factors that may contribute to the sustained use of arborloos, we provide evidence for implementation of arborloo interventions in rural areas. We also examined arborloo adoption in program areas and factors associated with households beginning arborloo use.

## METHODS

### Ethics

The study was deemed exempt by the Institutional Review Board of Emory University, as it was a program evaluation. Verbal consent was obtained from respondents.

### Study design

We used a two-stage, stratified sampling approach, where the three partner organizations operating in distinct geographic areas were each considered as strata. We calculated our sample size based on a 75% chance of households ever having an arborloo, a design effect of 2, 80% power, and a significance level of 0.05. With an additional 10% for non-response, our sampling target was 625 households in 20 communities.

The gott (community) was our primary sampling unit. We included in the sampling frame all gotts in Oromia region where CRS intervened between 2004 and 2013 by providing at least 30 arborloo slabs. Gotts were selected using random sampling from each of the three strata. The number of arborloo slabs provided in each of the three CRS partner catchment areas was used to decide the proportional sample size for each of the three strata. Meki Catholic Secretariat (MCS) had provided 9,115 arborloo slabs, Wongi Catholic Church (WCC) had provided 1,490, and Hararghe Catholic Secretariat (HCS) had provided 6,425 since 2004. Nine gotts were sampled in the MCS strata, four were sampled for the WCC strata, and seven were sampled from the HCS strata.

Our secondary sampling unit, households, were selected by simple random sampling from a census list of all households in the gott obtained from the government, the CRS partner organization, or from community leaders. All households in the gott were eligible for inclusion in the study. The enumerators skipped over a selected household (replacing it with a different one from the census list) if an adult member of that household was not available or if the household declined to participate in the study.

### Structured interviews

Data were collected on paper surveys by trained enumerators in Oromiffa. The survey included questions on respondent and household characteristics, past and present latrine access and type, and latrine use. If applicable, questions on the household's experience with the arborloo and their arborloo pit usage were asked. The survey also included questions on how households heard about the arborloo and if CRS assisted the household with their latrine in any way. Questions and observations to establish a household wealth index were included on the survey. The latrine and handwashing station were observed as part of the survey if applicable.

### Qualitative data

Key informant interviews (KIIs) and in-depth interviews (IDIs) were conducted by trained researchers in Oromiffa or Amharic according to the participants' preference. CRS staff or partner staff translated the interview responses to English. Rigorous notes were taken and pertinent quotes were recorded in English at the time of the interviews.

Thirty-three IDIs with community members were conducted to examine household level experience with the arborloo and to elucidate the reasons behind the associations seen in the survey data. Interviews were conducted with households who currently had an arborloo (20), with households who had stopped using their arborloo (8), and with households who never had an arborloo (5). Topics covered in the IDIs included the respondents' opinions on and experiences with their arborloo. Respondents were asked about any sanitation-related assistance CRS provided, why they chose to adopt the arborloo or not, and why they stopped using the arborloo if applicable.

Twenty-four KIIs were conducted with community and kebele leaders, health extension workers, WASH committee members, and health development army members. Interviewees articulated the community-wide experience with the arborloo. Leaders were asked about where community members heard about the arborloo, why community members chose to construct the arborloo or not, what community members felt the arborloo's advantages and disadvantages were, and reasons why community members stopped arborloo use. Interviewees also discussed the community's sanitation training and experience with planting on the arborloo pits.

### Data analysis

Survey data were entered into Excel 2010 then cleaned and analyzed using SAS 9.3 (Cary, NC, USA). Multi-level categorical variables were combined into logical groups when the cell frequency was less than 3%. Family size was recoded as a categorical variable using the mean family size for rural Oromia region, which is five (Zewoldi 2007). The number of years since a household built their arborloo was also recoded as a categorical variable with three levels: 0–2 years ago, 3–5 years ago, and 5–10 years ago.

Socio-economic status (SES) was included as an independent variable. SES was assessed using principal component analysis (PCA); PCA necessitates the use of binary or continuous variables (Filmer & Pritchett 2001; McKenzie 2005), so all non-binary categorical variables used in the PCA were recoded as binary (Vyas & Kumaranayake 2006). The number of hectares a household owned was included as a continuous variable to help alleviate data truncation and clustering concerns. The number of various animals owned was recoded from a continuous count to binary variables because these data were skewed. When households had a missing value for one of the categorical SES variables, the household was assigned the median value for that variable; when a continuous variable was missing the mean value for that variable was assigned. Only 4.9% of households had a missing SES data point. SES is presented in quintiles with the lowest quintile (1) being the poorest of the poor and the highest quintile (5) being the least poor households.

To account for our sampling design, survey responses were weighted by the probability of selection at the cluster and strata levels. Survey procedures were utilized in SAS 9.3 to account for population variances in the survey design.

We conducted a bivariate analysis using logistic regression to assess determinants of surveyed households ever having an arborloo. We used households self-reported use of present and past latrine types to establish sustained arborloo use. We conducted a bivariate analysis using logistic regression to assess characteristics of the households, their arborloo usage, and the sample that were associated with sustained arborloo use. A multivariate logistic model of factors associated with sustained arborloo usage is presented.

Qualitative data, including field notes on responses and pertinent quotes that were collected on paper interview guides, were organized by respondent and question then entered into Excel 2010. The number of households and leaders expressing the same idea were enumerated and outliers were noted. When enumerated interview data were examined, trends in the interview responses could be perceived and themes emerged; they are presented with the number of respondents who expressed that opinion noted or in ranked order. This allows the reader to establish if the presented opinion was an outlier or if a large number of the interviewees expressed this opinion.

## RESULTS

### Demographic characteristics

We conducted a total of 690 surveys in 20 communities. The respondents' median age was 35 years (range 18–88 years) (Table 1). Approximately 44.6% of male and 26.7% of female heads of household reported that they had attended some school or could read. The median household size was six (range 1–17) with most households being evenly split between Ethiopian Orthodox (45.7%) and Islam (44.1%).

A vast majority of respondents stated they (558, 80.9%) had a latrine at the time of the survey, while 58 (8.4%) previously had a sanitation facility but did not any longer and 74 (10.7%) never had one; 462 (67.0%) of households reported they had an arborloo at some point. Among those households that had a toilet at the time of the interview,

**Table 1** | Demographics and toilet access of the study population; Oromia region, Ethiopia, 2013 ($n = 690$)

| Characteristic | *n* (range or %) |
|---|---|
| Respondent | |
| Median age | 35 (18–88) |
| Female | 352 (50.1%) |
| Female head of household | |
| Median age | 35 (18–75) |
| No education | 492 (71.3%) |
| Non-formal education (literate) | 57 (8.3%) |
| Some school (grade 1–12) | 127 (18.4%) |
| Male head of household | |
| Median age | 40 (18–88) |
| No education | 307 (44.5%) |
| Non-formal education (literate) | 96 (13.9%) |
| Some school (grade 1–12) | 212 (30.7%) |
| Median household size (persons per household) | 6 (1–17) |
| Head of household's reported religion | |
| Ethiopian Orthodox (Christian) | 315 (45.7%) |
| Islam | 304 (44.1%) |
| Other (Catholic, Protestant, Animism) | 71 (10.3%) |
| Improved sanitation currently | 558 (80.9%) |
| Arborloo | 352 (51.0%) |
| Traditional/improved latrine at their household | 206 (29.9%) |
| Household reported stopping use of their latrine and returning to open defecation | 58 (8.4%) |
| Household reported never having any type of latrine at their household | 74 (10.7%) |
| Households reported ever having an arborloo at any point in time | 462 (67.0%) |

63.1% currently had an arborloo and 36.9% had a traditional or improved pit latrine (Table 1).

## Factors associated with arborloo adoption

We found evidence of a meaningful difference in arborloo adoption by the partner organization (Table 2). The odds of households having an arborloo were 1.73 times as high for households in HCS as compared to the odds for households in MCS (prevalence odds ratio (POR) 1.73, 95% confidence interval (CI) 1.19–2.52). There was no statistically significant difference between the odds of households having an arborloo for WCC and HCS or WCC and MCS.

There was an association between a household ever having an arborloo and practice of Islam as compared to Ethiopian Orthodox Christianity (POR 2.21, 95% CI 1.12–4.36), but no evidence for Catholicism, Protestantism, and Animism (POR 1.34, 95% CI 0.77–2.33) as compared to those who practiced Ethiopian Orthodox Christianity. Ever having an arborloo was associated with larger households (POR 1.12, 95% CI 1.01–1.23) and older female heads of household (POR 1.02, 95% CI 1.00–1.04). The evidence did not suggest a meaningful difference between arborloo ownership and male head of household's age or head of household's educational status (Table 2). Some differences were found between arborloo adoption and SES, but there was no clear trend.

## Determinants of arborloo adoption as discussed in the interviews

KII respondents were asked why households chose to adopt the arborloo. The following reasons are listed in order of times mentioned by leaders and/or household members in the interviews. They chose to adopt the arborloo because the compost has agricultural value, the shallow design is safer, and it is easier and faster to construct. One community leader stated of the agricultural value, 'The seedlings that are planting on the arborloo grow faster than others' (Male, WCC, 30). Another stated, 'There is a difference between the health of those trees planted on the pit and those that are planted elsewhere' (Male, HCS, 36). A third said, 'Because of the compost of human feces, and the depth of the loosened soil, the trees grow well and harvest quickly' (Male, HCS, 35). Households also made this decision because of the arborloo's lower cost as compared to the traditional latrine, as stated,

> 'It [the arborloo] is also cheap. Our community is a drought area and is poor as a result. Because of this we can't afford to construct the traditional latrine but we can afford the arborloo. With the arborloo there is no additional cost beyond the slab because the household can dig the hole themselves. With the other deep latrine we must hire a laborer' (Male, WCC).

Respondents also chose to adopt the arborloo because they felt it provided them more privacy and because the design attracted fewer flies than other traditional latrine designs.

**Table 2** | Unadjusted associations between independent characteristics and households having an arborloo at any point in time; Oromia region, Ethiopia, 2013 ($n = 690$)

| Characteristic | Household had arborloo ($n = 462$) *n* (range or %) | Household never had arborloo ($n = 217$) *n* (range or %) | POR | 95% CI | *p* |
|---|---|---|---|---|---|
| Partner organization (unweighted POR) | | | | | |
| MCS | 84 (12.4%) | 116 (53.5%) | Ref. | – | – |
| HCS | 172 (37.2%) | 56 (25.8%) | 1.73 | 1.19–2.52 | 0.005 |
| WCC | 206 (44.6%) | 45 (20.7%) | 1.05 | 0.68–1.61 | 0.82 |
| Median household size | 6.2 (1–16) | 5.7 (1–17) | 1.12 | 1.01–1.23 | 0.03 |
| Female head of household | | | | | |
| Median age | 36 (18–66) | 33 (18–75) | 1.02 | 1.00–1.04 | 0.02 |
| No education | 335 (72.5%) | 153 (70.5%) | Ref. | – | – |
| Non-formal education (literate) | 39 (8.4%) | 18 (8.3%) | 1.15 | 0.49–2.71 | 0.74 |
| Some school (1–12) | 77 (16.7%) | 44 (20.3%) | 1.34 | 0.89–2.02 | 0.16 |
| Male head of household | | | | | |
| Median age | 43 (18–80) | 41 (20–86) | 1.01 | 1.00–1.03 | 0.16 |
| No education | 201 (43.5%) | 103 (47.5%) | Ref. | – | – |
| Non-formal education (literate) | 62 (13.4%) | 33 (15.2%) | 0.95 | 0.42–2.14 | 0.90 |
| Some school (1–12) | 142 (30.7%) | 65 (30.0%) | 0.85 | 0.59–1.22 | 0.37 |
| Head of household's reported religion | | | | | |
| Ethiopian Orthodox (Christian) | 180 (39.0%) | 129 (59.5%) | Ref. | – | – |
| Islam | 240 (51.9%) | 62 (28.6%) | 2.21 | 1.12–4.36 | 0.02 |
| Other (Catholic, Protestant, Animism) | 42 (9.1%) | 26 (12.0%) | 1.34 | 0.77–2.33 | 0.30 |
| SES | | | | | |
| Poorest households (1st quintile) | 91 (19.8%) | 41 (19.0%) | Ref. | – | – |
| 2nd quintile | 89 (19.3%) | 48 (22.2%) | 1.09 | 0.67–1.75 | 0.73 |
| 3rd quintile | 98 (21.3%) | 37 (17.1%) | 1.87 | 1.09–3.19 | 0.02 |
| 4th quintile | 95 (20.7%) | 42 (19.4%) | 1.16 | 0.57–2.38 | 0.68 |
| Least poor households (5th quintile) | 87 (18.9%) | 48 (22.2%) | 1.09 | 0.58–2.04 | 0.80 |

KII respondents were also asked why some households chose not to adopt the arborloo. Respondents said that households did not adopt the arborloo because they never received a slab (10 respondents), they did not understand the importance of sanitation and hygiene (four respondents), or they already had a different latrine design (two respondents). Leaders also reported that households did not adopt the arborloo because they did not feel like digging the pit or were unable to do so, because it took up too much space, or because the shallow pit was prone to flooding (one respondent each). Some leaders noted that arborloo adoption had increased after community members saw the success early adopters were having with the seedling planting. Community members reported that they chose not to adopt the arborloo because they did not like the design, which necessitates frequent movement of the latrine and reinvestment in the latrine's superstructure with that movement. Other respondents chose not to adopt the arborloo because their household moved locations often, their compound was small, the shallow pit could easily flood, or they felt they were too old to dig the pit.

## Characteristics of arborloo intervention households

Of the households interviewed, 502 (72.8%) had received a slab from CRS. Most respondents used that slab for an arborloo (62.8%), but 51 (7.4%) used the slab for a traditional latrine and 16 (2.3%) did not use a slab for a

latrine at all. Of the 188 (27.2%) respondents who never received a slab, 24 (3.5%) used other materials to construct an arborloo (Figure 2). Households who did not receive a slab but instead used stone or wood to construct their arborloo top were less likely to sustain arborloo use (POR 0.21 95% CI 0.06–0.81) (data not shown).

The majority of respondents (67.0%) stated that they had an arborloo in the last 10 years. Among the 462 households that ever had an arborloo, 352 (76.2%) were currently using an arborloo (Figure 2). Those households had sustained their arborloo usage from 1 to 10 years, depending on when they first adopted the arborloo intervention. Of all respondents in the communities surveyed, 352 (51.0%) households currently had an arborloo, 65 (9.4%) had switched from the arborloo to a traditional latrine, and 45 (6.5%) had switched from the arborloo back to open defecation (Figure 2).

Of the 462 respondents who reported their household ever having an arborloo, 424 (91.8%) reported filling one or more arborloo pits; 232 (50.2%) used the arborloo pit compost for agricultural purposes while 192 (41.6%) did not use the pit compost (Table 3). While 45 out of 462 (9.7%) households returned to open defecation after having an arborloo, 65 (14.1%) moved up the sanitation ladder and had constructed a more permanent latrine structure. The main change these households made was digging a deeper pit, although many households also added a more permanent superstructure. These changes add the additional costs of labor ($17–77) to dig the 3 m deep pit as well as the costs of the superstructure materials ($10) if they were purchased (Hansch 2003; Smet 2007; Hebert 2010). If the household also chose to purchase a larger slab in their move up the sanitation ladder, that would add an additional $15–44 (Hansch 2003; Hebert 2010).

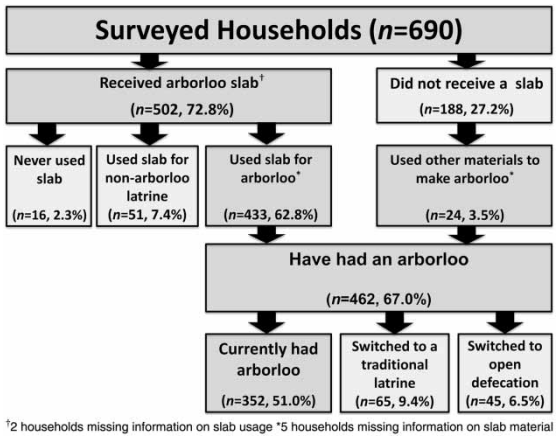


**Figure 2** | Household slab allocation, slab usage and continued use of arborloo.

**Table 3** | Characteristics of households' arborloo usage for households who reported ever having an arborloo; Oromia region, Ethiopia, 2013 ($n = 462$)

| Characteristics | *n* (%) |
|---|---|
| Households' arborloo status | |
| Currently had an arborloo at their household | 352 (76.2%) |
| Currently had a traditional latrine, but previously had an arborloo | 65 (14.1%) |
| Stopping use of their arborloo and returned to open defecation | 45 (9.7%) |
| Reported age of original arborloo the households built | |
| Built <3 years ago | 78 (16.9%) |
| Built from 3 to 5 years ago | 265 (57.4%) |
| Built more than 5 years ago | 105 (22.7%) |
| Household reported filling one or more arborloo pits | 424 (91.8%) |
| Household did not use the arborloo compost for agricultural purposes | 192 (41.6%) |
| Household used the arborloo compost for agricultural purposes | 232 (50.2%) |
| Got seedling for arborloo pit from a CRS Partner | 118 (25.5%) |
| Planted seedling(s) survived | 131 (28.4%) |

Of the 105 households that reported building their arborloos more than 5 years ago, 67.6% had sustained arborloo use (data not shown).

## Factors associated with sustained arborloo usage

We found limited evidence of an association between self-reported sustained arborloo usage and the household's demographics. The odds of sustained arborloo usage were twice as high (POR 2.01, 95% CI 1.27–3.08) for households who practiced Catholicism, Protestantism, or Animism as compared to those who were Ethiopian Orthodox (Table 4). The odds of sustained arborloo usage were 80% higher for households who practiced Islam as compared to those who were Ethiopian Orthodox, although this association was not statistically significant (POR 1.80, 95% CI 0.91–3.58) (Table 4). Doing nothing with the arborloo pit was significantly associated with households who practiced Islam (POR 3.52, 95% CI 1.62–7.66) (data not shown).

**Table 4** | Unadjusted associations between household characteristics and household's self-reported sustained arborloo use; Oromia region, Ethiopia, 2013 ($n = 462$ unless otherwise noted)

| Characteristics | POR | 95% CI | p |
|---|---|---|---|
| Partner Organization (unweighted POR) | | | |
| MCS | Ref. | – | – |
| HCS | 1.38 | 0.85–2.22 | 0.19 |
| WCC | 1.25 | 0.69–2.26 | 0.47 |
| SES | | | |
| Poorest households (1st quintile) | Ref. | – | – |
| 2nd quintile | 1.00 | 0.59–1.68 | 1.00 |
| 3rd quintile | 1.85 | 0.78–4.81 | 0.16 |
| 4th quintile | 1.21 | 0.52–2.81 | 0.65 |
| Least poor households (5th quintile) | 0.63 | 0.35–1.14 | 0.13 |
| Household size (using Oromia median) | | | |
| Household size >5 people | Ref. | – | – |
| Household size ≤5 people | 1.04 | 0.70–1.55 | 0.85 |
| Head of household's religion | | | |
| Ethiopian Orthodox | Ref. | – | – |
| Islam | 1.80 | 0.91–3.58 | 0.09 |
| Other (Catholic, Protestant, Animism) | 2.01 | 1.37–3.08 | 0.0005 |
| Male head of household's level of educational attainment | | | |
| No education | Ref. | – | – |
| Some formal education (grade 1–12) | 0.51 | 0.24–1.08 | 0.08 |
| Some informal education (literate) | 2.30 | 0.44–12.12 | 0.32 |
| Female head of household's level of educational attainment | | | |
| No education | Ref. | – | – |
| Some formal education (grade 1–12) | 0.98 | 0.45–2.17 | 0.96 |
| Some informal education (literate) | 1.57 | 0.50–4.91 | 0.44 |
| Male head of household's age | 1.00 | 0.96–1.03 | 0.88 |
| Female head of household's age | 0.99 | 0.96–1.03 | 0.76 |
| Type of material household used for arborloo platform | | | |
| Used non-cement slab | Ref. | – | – |
| Used cement slab from CRS | 4.59 | 1.24–16.97 | 0.02 |
| Usage of composted arborloo pit material for agricultural purposes | | | |
| Never used arborloo pit compost | Ref. | – | – |
| Used arborloo pit compost for agricultural purposes | 2.00 | 0.86–4.63 | 0.11 |
| Number of years ago households built their first arborloo | | | |
| Built arborloo >5 years ago | Ref. | – | – |
| Built arborloo 3–5 years ago | 1.53 | 0.54–4.30 | 0.42 |
| Built arborloo <3 years ago | 1.37 | 0.49–3.83 | 0.55 |
| Where households who planted on their arborloo pit(s) reported getting the seedling(s) ($n = 228$) | | | |
| Did not receive seedling from CRS partner | Ref. | – | – |
| Received seedling from a CRS partner | 1.40 | 0.49–3.98 | 0.53 |
| Survival of seedlings for households that planted seedling (s) on their arborloo pit ($n = 227$) | | | |
| Seedling(s) died | Ref. | – | – |
| Seedling(s) survived | 0.43 | 0.13–1.40 | 0.16 |

There was an association between sustained arborloo use and using a cement slab for the arborloo platform (POR 4.59, 95% CI 1.24–16.97) and usage of the filled arborloo pit for planting purposes (POR 2.00, 95% CI 0.86–4.63), although this association was not significant in this bivariate analysis. The evidence did not suggest a meaningful difference between groups who sustained arborloo usage or not based on where households got the seedlings they planted, survival of seedlings, family size, female or male educational attainment, female or male head of household's age, or SES. There was no evidence to suggest that sustained arborloo use differed between HCS and MCS (POR 1.38, 95% CI 0.85–2.22) or between WCC and MCS (POR 1.25, 95% CI 0.65–2.26). There was no evidence to suggest that sustained arborloo use differed by arborloo age (Table 4).

## Determinants of sustained arborloo usage discussed in the interviews

The 18 community members who currently had an arborloo and all 24 leaders reported that they found the arborloo to be advantageous to themselves or their communities. Respondents

felt the most important arborloo benefit was the ability to plant on the filled arborloo pit. Leaders also said that the arborloo was safer than the traditional latrine, especially for children, since it was shallow and there was no fear of the cement slab collapsing. Respondents mentioned that it was easier and cheaper to construct as compared with the traditional latrine. One respondent said, 'I paid 300 birr for the traditional latrine to be built, but I can construct the arborloo myself in an hour' (Male, WCC). The extra costs associated with the traditional latrine that the respondents are likely referring to include labor to dig the deeper pit ($17–77), which is a necessary component of both improved and unimproved traditional latrines, and the costs of the larger slab ($15–44) and the superstructure ($10) if the household chose to purchase these items (Hansch 2003; Hebert 2010). Respondents also mentioned that the arborloo had fewer flies and smells than other latrines. This was likely the case because deeper pits with a lot of moisture are breeding grounds for flies and smells; the ash that is added to the arborloo after use decreases moisture in the pit, which decreases flies and smells around the arborloo (Morgan 2005; Hailu 2010). These explanations of what households like about the arborloo speak to the likely reasons for the high rate of sustained arborloo usage that was seen in the survey data.

We also enquired about the reasons households stopped using the arborloo. Community leaders and household members reported that there was sometimes no reason other than their pit filling up for stopping arborloo usage and returning to open defecation. One respondent said,

> 'The cycle of sanitation might break in transferring the pits so often. The community does not want to move the pits so often so they might just go back to open defecation instead of digging another pit at that time. To avoid people breaking the sanitation cycle when the pits are filled, we switched from the arborloo to the traditional latrine' (Female, 40, WCC).

Respondents noted not receiving a seedling or having a seedling die determined their switch to a traditional latrine because they did not see the arborloo's benefit without the agricultural benefit, although this association was not seen in the bivariate analysis. Households sometimes stopped using the arborloo simply because the slab broke. Respondents also felt that the pit filled too quickly, frequent movement of the slab increased breakage, and the pits took up too much space.

## Multivariate analysis of sustained arborloo use including all determinant variables

The covariates most strongly associated with self-reported sustained arborloo use were the use of arborloo pits for planting (adjusted (a) POR 2.98, 95% CI 1.37–6.75); use of a cement slab from CRS for arborloo platform (aPOR 7.19, 95% CI 1.05–49.19); practicing Catholicism, Protestantism, or Animism (aPOR 1.99, 95% CI 0.92–4.28) when controlling for arborloo age (Table 5). While being in SES quintile 3 was significantly associated with sustained arborloo use, we saw no trend to indicate that SES played an important role in sustained arborloo use. The male head of household having some formal education was associated with lower sustained access to arborloos (aPOR 0.33, 95% CI 0.16–0.67).

## Discussion

We found strong evidence that arborloo usage was sustained in intervention communities, even after many years. In this study, factors such as pit usage, availability of an affordable or subsidized cement slab, seedling availability and survival, cost, and arborloo planning were found to impact sustainability of the arborloo. This evaluation found no clear relationship between household wealth and ability to sustain arborloo facilities. We found compelling evidence for high rates of arborloo adoption, although there were significant differences in the groups that adopted the arborloo.

We found no clear relationship between SES and arborloo adoption. It is possible that this lack of an association was due to the fact that the slabs were provided free of charge between 2005 and 2012, since having a lower SES may limit access to some of the more costly sanitation materials (Mairena 2008). However, the low cost of the arborloo, even without subsidies, may improve adoption of this sanitation option across socio-economic lines. Others have found a strong relationship between SES and access to sanitation materials (Mairena 2008; Tumwebaze *et al.* 2011). In Uganda where the most prevalent eco-san options are more costly urine diverting latrines, evaluators found that indicators of SES including education, occupation, and age were significantly associated with adoption of an eco-san intervention (Tumwebaze *et al.* 2011). However,

**Table 5** | Adjusted associations between household characteristics and household's self-reported sustained arborloo use; Oromia region, Ethiopia, 2013 ($n = 361$)

| Household characteristics | POR | 95% CI | p |
|---|---|---|---|
| Usage of composted arborloo pit material for agricultural purposes | | | |
| Never used arborloo pit compost | Ref. | – | – |
| Used arborloo pit compost for agricultural purposes | 2.98 | 1.32–6.75 | 0.009 |
| SES | | | |
| Poorest households (1st quintile) | Ref. | – | – |
| 2nd quintile | 1.27 | 0.64–2.502 | 0.50 |
| 3rd quintile | 3.73 | 1.07–12.99 | 0.04 |
| 4th quintile | 2.24 | 0.69–7.28 | 0.18 |
| Least poor households (5th quintile) | 1.26 | 0.41–3.85 | 0.69 |
| Head of household's religion | | | |
| Ethiopian Orthodox | Ref. | – | – |
| Islam | 1.43 | 0.66–3.06 | 0.36 |
| Other (Catholic, Protestant, Animism) | 1.99 | 0.92–4.28 | 0.08 |
| Household size (using Oromia median) | | | |
| Household size >5 people | Ref. | – | – |
| Household size ≤5 people | 1.89 | 0.86–4.14 | 0.11 |
| Type of material household used for arborloo platform | | | |
| Used non-cement slab | Ref. | – | – |
| Used cement slab from CRS | 7.19 | 1.05–49.19 | 0.04 |
| Male head of household's level of educational attainment | | | |
| No education | Ref. | – | – |
| Some formal education (grade 1–12) | 0.33 | 0.16–0.67 | 0.002 |
| Some informal education (literate) | 2.15 | 0.32–14.37 | 0.43 |
| Male head of household's level of educational attainment | | | |
| No education | Ref. | – | – |
| Some formal education (grade 1–12) | 2.10 | 0.56–7.86 | 0.27 |
| Some informal education (literate) | 3.45 | 0.70–17.04 | 0.13 |
| Male head of household age | 0.97 | 0.90–1.04 | 0.37 |
| Female head of household age | 1.02 | 0.93–1.13 | 0.64 |

eco-san users in Uganda reported that they could reduce the price of the eco-san latrine if they utilized locally available materials for some components of the latrine. When the latrines were cheaper, lower income households viewed eco-san options as affordable and beneficial (Tumwebaze *et al*. 2011). Our finding indicates that the arborloo, which utilizes locally available materials for some aspects of the latrine and costs between $5 and $10 to build, is a more accessible eco-san option for poorer households.

Households reported stopping arborloo usage simply because they failed to dig a new pit when the old one was filled. Increasing the focus, during training and in follow-up visits, on planning for future pit construction and placement could help households think through the process they will go through while moving the arborloo to a new pit once the old pit is filled. People are more likely to sustain behavior change if they have an action plan in place (Bandura 1989; Rollnick *et al*. 2001), and planning for future pit construction placement during training could therefore potentially decrease the rate of return to open defecation.

Improving pit usage for groups that are not utilizing the pit after the arborloo is moved might improve arborloo sustainability for those populations, since use of arborloo pits for agricultural purposes was associated with arborloo sustainability in this study. Pit usage varied by religion in this study, with households who practiced Islam planting on their arborloo pits significantly less than households who practiced Ethiopian Orthodoxy. It is possible that this finding is attributable to a fecophobic culture in Islamic households (Nawab *et al*. 2006). This finding should be examined further to see why Islamic households are not using the arborloo for planting and adjusting the messages or program accordingly.

Use of cement slabs was associated with sustained arborloo use; therefore, ensuring continued access to affordable slabs is essential to arborloo sustainability. However, the Ethiopian government's 2012 zero-subsidy mandate precludes CRS from providing slabs for free or at a reduced rate. While it is possible subsidy policy change could negatively impact the arborloo's sustainability in the study area, it could also be an opportunity for the arborloo program. Via CRS-led sanitation marketing efforts, the policy change could encourage development of local markets for affordable cement slabs, which could potentially provide more routine access to slabs with an added benefit of job generation (Dagerskog *et al*. 2014). This is especially relevant because respondents in this study reported that people stop using the arborloo when their arborloo slab broke since new slabs were unavailable. If a new household wants an arborloo or if a household's arborloo slab breaks, community members in the study areas often have no way of getting a

new slab; they must choose between using a traditional material latrine top or utilizing open defecation. Sanitation marketing to promote increased local availability of affordable slabs may allow for not only the continued success of the adoption and sustained usage rates seen in this study, but also long-term programmatic sustainability via decreased costs and decreased reliance on CRS' programing for sanitation solutions.

The ability to use composted excreta as fertilizer is an important advantage to beneficiaries (Dankelman *et al.* 2009; Tolessa 2013). Some interviewees reported that they had switched to a traditional latrine when they did not observe this benefit. This association was not apparent in the survey data, but a 2010 rapid assessment of CRS' arborloo programs in east Africa found that access to seedlings influenced whether or not arborloos were adopted (Hebert 2010). In a focus group of arborloo users conducted by CRS Ethiopia in 2011, respondents attributed households failing to dig pits after the old one filled to people being unable to purchase seedlings to plant on the old pit immediately (Tolessa 2013). Presenting the agricultural benefits of the arborloo to target populations may improve adoption of the arborloo intervention. This been found to be effective in Burkina Faso, Niger, and Ivory Coast (Sugden 2003; Dankelman *et al.* 2009; Dagerskog *et al.* 2014).

In this study, interviewees reported that they chose to adopt the arborloo because the design was cheaper than other latrine options. The arborloo has lower initial investment and capital maintenance costs than pit latrines or VIP latrines, since the slab is cheaper and no hired labor is required to dig the pit (Morgan 2005; Smet 2007). The arborloo's lower relative cost ($5–10) as compared to other improved sanitation options could be one reason for the arborloo's high rate of adoption in intervention communities. The arborloo's lower cost could decrease the barrier to acquiring household sanitation; it therefore has the potential to increase the rate of rural sanitation adoption in Ethiopia where it is promoted (Simpson-Hebert 2007).

## LIMITATIONS

There are a number of limitations that could impact the internal and external validity of our findings. We used the responses to the households' present and past latrine types to establish sustained arborloo use, which may be subject to bias. Ideally, the proportion of households in an individual community that initially received a slab could have been used as an indicator for sustained arborloo use; however, this indicator could not be utilized in this case because the slabs were not distributed at the community level.

Since this is a cross-sectional study, no causal relationship can be established. There were a number of missing data points in this study which limited our analysis capacity at times. Seedling survival and where households obtained seedlings could not be used in the multivariate analysis of arborloo sustainability because these data were only recorded if a household reported pit usage. Our multivariate model provided limited analysis since this cross-sectional study is meant to be hypothesis generating.

## CONCLUSIONS

Here we present an exploratory study on arborloo adoption and sustained use in a certain place and time. It can help inform research questions for future work, contribute to the body of peer-reviewed literature on the adoption and sustainability of ecological sanitation interventions, and provide evidence for implementation of arborloo interventions in rural areas. This study should not be considered a definitive study that is applicable to all settings.

While this research found that a number of factors were associated with arborloo adoption and sustained use, further research is needed to better understand *why* and *how* these factors are associated with adoption and sustained usage. Better understanding why and how these factors impact arborloo adoption and sustained use could help program implementers inform how they can address these factors in current and future programs in order to improve adoption and sustainability for the groups that were seen to have lower rates of adoption or sustained use.

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