

UNDERSTANDING RURAL SANITATION SUSTAINABILITY THROUGH SYSTEM DYNAMICS

USAID UGANDA SANITATION FOR HEALTH ACTIVITY (USHA)

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SUMMARY

While there are many indications that the enabling environment for safely managed WASH in Uganda is improving, high-risk practices (open defecation, lack of hand hygiene, use of surface water) persist in rural regions [1]. Among other factors, literacy, poverty, and cultural beliefs are believed to affect rural households' sanitation behaviors [2]. The purpose of this research was to learn more about rural sanitation dynamics with governance actors (through participatory modeling) and to explore mechanisms (through computer simulations) for sustainably achieving desired sanitation outcomes. We engaged with district-level sanitation actors in three USHA districts to build a System Dynamics model describing the drivers of sanitation coverage over time. Based on the participants' inputs and the model structure, we generated hypotheses about what type of interventions might be required to reach and sustain universal sanitation at the district level. We found that, once households have adopted improved sanitation, their perception of its value should be directly and continually reinforced. We recommend that sanitation actors consider how systemic, structural changes can be incorporated into programs or policies so that desirable intervention outcomes are maintained through self-reinforcing processes.

WHY THIS MATTERS

Interventions aimed at improving rural sanitation coverage are often deemed successful when more people own latrines at the end of the intervention than at the outset. However, long-term monitoring and ex-post evaluations have revealed a widespread phenomenon whereby households which had ascended the sanitation ladder revert to open defecation [3,4]. This means that rural families continue to suffer compromised community health and many other detriments to well-being [5,6].

According to systems thinking theories, interventions that alter the structure, rules, or governing paradigms of a system are more likely to have a lasting effect than those that do not [7]. In this research, we first aimed to understand and formalize, by way of a System Dynamics stock-flow model, the structure of rural sanitation governance in Uganda. This model was then used to explore, through simulation, how its structure might be changed to promote sustainable sanitation outcomes that outlast intervention timeframes.

Some System Dynamics terminology

Systems thinking approaches such as **System Dynamics** have been touted as necessary for managing the complexity of WASH systems [8,9,10].

BEHAVIOR – change over time. Time series graphs of important variables or indicators are often used to visualize a system’s behavior, either in its problem or desired state.

STRUCTURE – the way that elements in a system are interrelated to produce its behavior. Structure is described in terms of interconnected reinforcing and balancing feedback loops acted on by external (exogenous) constraints and forces.

FEEDBACK – reinforcing or balancing actions that relate endogenous variables to each other. The dominance of different feedback loops can shift over time depending on changes in exogenous factors and the presence of tipping points.

EQUILIBRIUM – state at which feedback loop dominance is stable. This is usually characterized by behavior that is stagnant or in controlled oscillations.

FINDINGS



#1. Perceived Value Influential

Households’ perceived value of sanitation appears to influence sanitation outcomes more than factors such as household finance, sanitation service availability, or enforcement of sanitation bylaws.



#2. Equilibrium is Low

Gains made by limited term interventions that focus on improving one or two factors are lost after external support is removed. This means that the system naturally seeks a low equilibrium.



#3. Structural Change Needed

When a direct, positive connection is made between the attainment of improved latrines and households’ perceived value of sanitation, latrine demand increases and the system’s equilibrium shifts upward.

METHODOLOGY

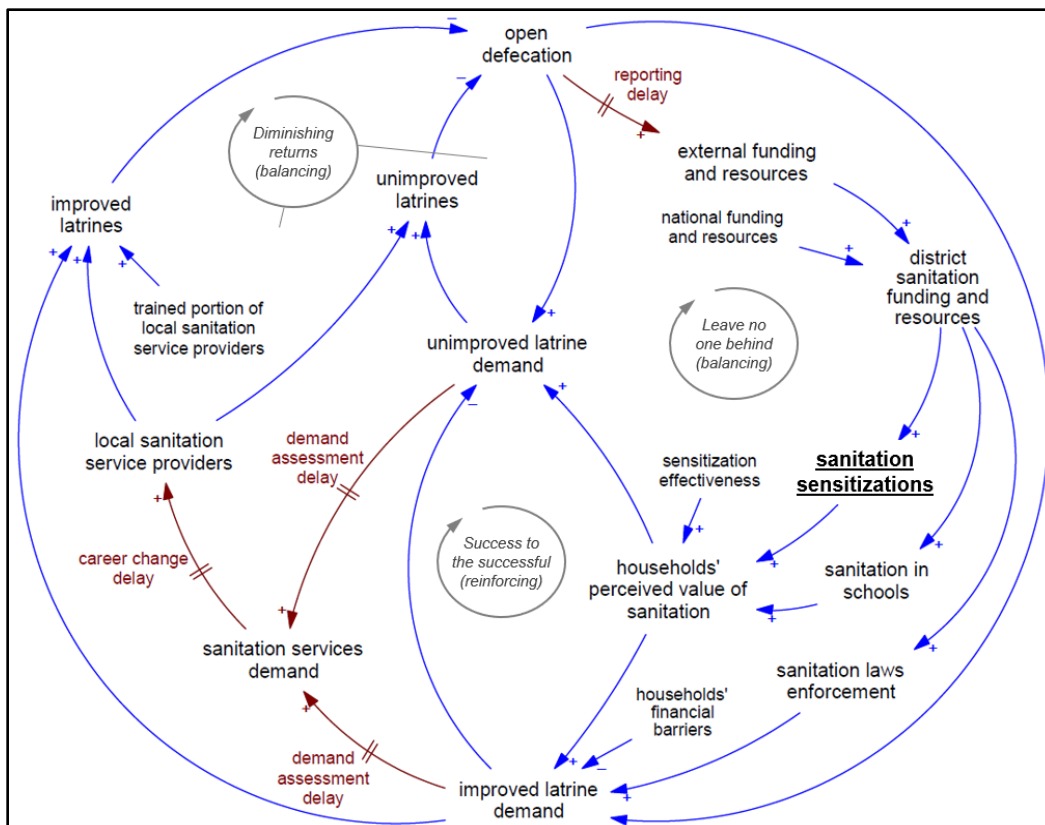
Group Model Building is a participatory approach used to elicit information from a collective and formulate that knowledge into a model describing the systemic causes of a particular observation. This requires specialized skills in qualitative research methods, facilitation, and System Dynamics modeling. However, the process is highly adaptable and can be designed to suit the context and the experience level of the model building team. For example, Group Model Building might consist of a single 90-minute workshop resulting in a qualitative causal loop diagram or might be part of a sustained community-based, co-creative process [11].

The Uganda Sanitation for Health Activity (USHA) was a USAID-funded WASH program implemented in 20 districts across three regions in Uganda from 2018 to 2023. We conducted this study in three USHA target districts (one from each regional cluster) where participants were invited to two half-day Group Model Building workshops and a preliminary interview. The 37 participants were district government officers from the departments of Water, Environmental Health, Education, and Community Development, as well as local Civil Society Organization representatives, elected officials, and community leaders. In the interviews and workshops, we elicited a collective conceptual model (also known as a *dynamic hypothesis*) about what drives rural sanitation outcomes in Uganda.

Next, we built a quantitative stock-flow model derived from the participants' dynamic hypothesis. This type of model contains "stocks," which represent quantities that can accumulate over time (e.g., the number of households with a latrine), "flows," which are the rates at which stocks increase or decrease, other explanatory variables controlling the flows, and parameters (often constant values). Stock-flow models are helpful for exploring complex systems that contain feedback and non-linearity. Using publicly available data and data collected by USHA, we parameterized and calibrated the model and built confidence that the model's structure was a valid explanation for observed sanitation trends in the study districts. Finally, we used participants' suggested improvement strategies along with sensitivity analyses to generate and simulate "what if?" scenarios in the model.

UGANDA'S RURAL SANITATION DYNAMICS

DYNAMIC HYPOTHESIS

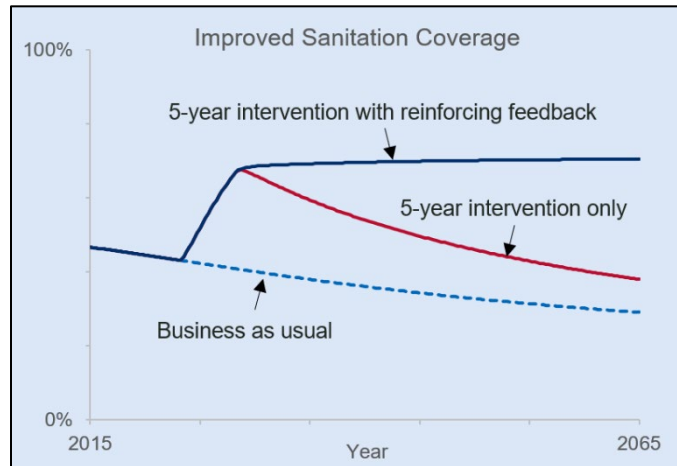


Dynamic hypotheses are not a comprehensive description of a system; rather, they are one of several possible explanations for a specific observed behavior. In the figure below (known as a causal loop

diagram), arrows indicate causal relationships. A change in the variable at the tail of an arrow causes a change in the variable at the arrow's head in the same (+) or opposite (-) direction, all else being equal. Slash marks across an arrow indicate significant delays for an effect to take place. Factors that are not affected by any others in the model (national funding and resources, sensitization effectiveness, households' financial barriers, and trained portion of local sanitation service providers) are considered *exogenous*, whereas factors within closed loops are *endogenous*.

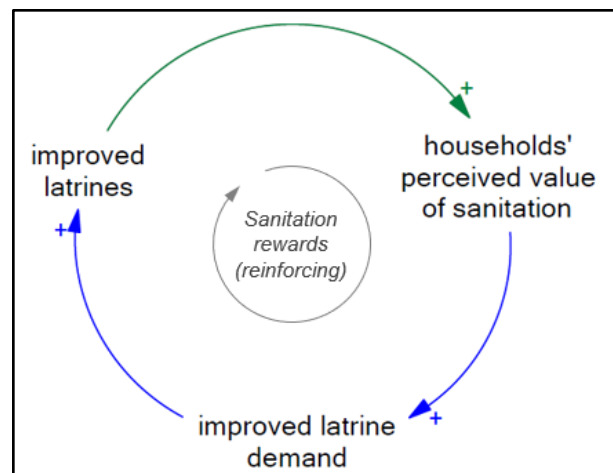
SIMULATION RESULTS

In status quo (business as usual) simulations, improved sanitation coverage remained relatively low or decreased in all the study districts. We tested several scenarios in which a potentially influential factor was idealized, such as households' financial barriers, sanitation laws enforcement, sensitization effectiveness, and trained portion of local sanitation service providers, among others. The strategy with the greatest effect on improved sanitation coverage targeted latrine demand through sanitation sensitizations (**underlined and in bold** in the causal loop diagram above).



In Uganda, sanitation sensitizations are typically administered at the household or community level by the Environmental Health Division of the Ministry of Health. In these sessions, sanitation promoters raise awareness about sanitation generally, but also about the benefits of improved sanitation.

When we enabled the idealized sanitation sensitizations for a five-year period within a simulation, the gains in improved sanitation were gradually lost due to feedback processes that steered the system towards a relatively low “goal” or equilibrium. This balancing action is depicted in the dynamic hypothesis as the “leave no one behind” and “diminishing returns” feedback loops. In short, the sensitization strategy had affected the system while it was enabled but shifted the system’s equilibrium only minimally or not at all. We hypothesized that adding a direct connection from improved latrines to household’s perceived value of sanitation would lead to sustained outcomes. This connection would alter the structure of the system by creating a new reinforcing feedback loop, and thereby shift the equilibrium upwards. This “sanitation rewards” loop is shown in the diagram below, with the green arrow representing a new causal relationship.



As expected, when we simulated the strategies with the altered model structure, the intervention gains were maintained. Importantly, we found that this new causal connection should impact households'

perceptions directly and continuously to counteract any negative experiences with sanitation (e.g., inconvenience and cost of maintenance). Unfortunately, the public health benefits of improved sanitation (one possible mechanism for closing the loop) may take many years to realize, depend on community-wide adoption and practice, and are not necessarily apparent to household decision makers. Further context-specific research is needed to identify an appropriate mechanism for closing the “sanitation rewards” feedback loop.

RECOMMENDATIONS

In rural Uganda, we suggest that closing the loop between improved latrines and households’ perceived value of sanitation would enable sustained sanitation improvements. In simpler terms, owning, using, and maintaining an improved latrine should become a perceptibly rewarding experience. This may be occurring naturally in some places, where latrine ownership has become a status symbol reinforced by admiration within one’s social groups. Might this process be sped up or enhanced by sanitation actors? Social marketing research could provide guidance for designing a context-specific feedback mechanism which appeals to societal norms and perceptions of value.

We also provide the following three recommendations for WASH actors more broadly:

- 1 Conceptualize systems in terms of dynamic closed loops.** Beyond understanding *what* factors are at play, this helps to hypothesize *how* those factors interact to produce a behavior. Participatory methods and quantitative modeling can help build confidence in these hypotheses.
- 2 Identify leverages and tipping points.** Sensitivity analyses help to identify components of the system that are the most influential on behavior. Intervention threshold analyses help discover whether lasting effects can be achieved after external support is removed.
- 3 Design and implement feedback mechanism to sustain results.** Systems seek an equilibrium according to their structure and exogenous constraints. Changing the structure of a system by strategically introducing feedback can shift that equilibrium toward a desired state.

WAY FORWARD

This study provides insight into the question posed in the title of USAID’s ex-post evaluation report, “What does it take to sustain water, sanitation, and hygiene outcomes?” [1]. Initially, sanitation improvements have often been achieved through evidence-based intervention strategies. Our findings suggest that backsliding occurs, and sanitation service levels remain low, because households’ perceived value of sanitation is low and/or lost over time. Similarly, Novotný et al. found that emotional satisfaction with one’s sanitation practices is independent of improved sanitation attainment, and that this is “likely to impair upward shifts in the sanitation ladder” [12].

While applications of systems thinking in WASH are on the rise, many lack explicit analyses of the interactions between components [13]. Our study demonstrates how to conceptualize and explore the way that systems produce behavior through component interactions – specifically closed-loop

relationships and processes known as feedback. Importantly, approaches such as ours can account for the interconnectivity, non-linearity, and self-organizing behavior inherent in complex systems. We believe that systems thinking, as a perspective on complexity, can become integrated into most aspects of WASH research, programming, and implementation. Widespread adoption of systems thinking will require education and practice to supplement reductionist ways of thinking, which are currently more prevalent.

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