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Climate Variability, Community-Led Sanitation and Child Health: An Analysis of CLTS Effectiveness in Malawi, 2021–2026

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Abstract

This study evaluates the effectiveness of community-led total sanitation (CLTS) in reducing childhood diarrhoea in Malawi under conditions of climate variability. It addresses the critical problem of whether CLTS, a key national policy, can sustain health gains when confronted with climate-related disruptions like flooding and drought, which compromise sanitation infrastructure and hygiene practices. Employing a longitudinal, mixed-methods design, the research analysed health surveillance data (2021–2026) from four districts, alongside qualitative data from community focus group discussions and key informant interviews with health surveillance assistants. Quantitative analysis employed regression models to measure changes in diarrhoeal incidence, while qualitative data were examined using thematic analysis. The results demonstrate that CLTS implementation initially correlated with a significant reduction in diarrhoeal disease under stable conditions. However, these health gains were substantially eroded in communities experiencing severe climate shocks, particularly floods that contaminated water sources and damaged latrines. The findings indicate that the prevailing CLTS model, focused on initial community mobilisation, lacks integrated adaptive mechanisms for climate resilience. This reveals a critical gap in current public health strategy. The paper concludes that for Malawi and similar contexts, integrating climate adaptation planning—including promoting climate-resilient sanitation technologies and strengthening community-led disaster preparedness—into sanitation programming is imperative to safeguard child health.

Keywords: *Community-led total sanitation, Climate resilience, Diarrhoeal disease, Sub-Saharan Africa, Implementation science, WASH, Child health*

INTRODUCTION

Community-led total sanitation (CLTS) is a critical strategy for improving public health, particularly in reducing childhood diarrhoea, a leading cause of morbidity in Malawi (Mumin et al., 2023; Panulo et al., 2024). However, the effectiveness of CLTS interventions is increasingly mediated by climate variability, which can exacerbate water scarcity, compromise sanitation infrastructure, and alter disease transmission pathways (Chirwa et al., 2024; Bronstert et al., 2025). Within Malawi, studies have begun to document this intersection, noting how climatic shocks undermine sustained sanitation behaviours and health gains (Munguambe, 2023; Nthezemu Kamanga, 2024).

Evidence from sub-Saharan Africa underscores the potential of CLTS, yet also reveals context-specific challenges (Banda, 2024). Research in Ghana and Kenya indicates that long-term sustainability and community acceptance are influenced by factors such as local leadership, ongoing follow-up, and cultural norms (Adam & Badu, 2024; Omufwoko et al., 2024). Conversely, studies focusing solely on CLTS pillars, such as those in Indonesia, demonstrate a correlation with reduced diarrhoea incidence but may not fully account for external environmental stressors (Syam & Bungawali, 2024; Suryanti, 2025). This highlights a significant gap: while the general mechanics of CLTS are understood, there is limited rigorous investigation into how climate variability specifically modulates its health outcomes in a Malawian context.

Furthermore, the existing literature on Malawi often treats climate and sanitation as parallel concerns (Bronstert et al., 2025). Studies examine hydro-climate dynamics (Chirwa et al., 2024; Bronstert et al., 2025) or sanitation practices (Munguambe, 2023) in isolation, with few integrating these themes to directly assess child health impacts. This study therefore addresses this gap by investigating the synergistic effect of CLTS and climate variability on childhood diarrhoea in Malawi. It posits that understanding this interaction is essential for designing resilient public health interventions that can withstand climatic pressures.

LITERATURE REVIEW

The global evidence base for Community-Led Total Sanitation (CLTS) as a strategy for reducing childhood diarrhoea is well-established, yet its effectiveness within the specific context of Malawi, particularly under conditions of increasing climate variability, remains inadequately understood and inconsistently documented (Cardarelli & Pomper, 2024). While CLTS principles have been successfully applied in various settings, outcomes are highly dependent on local socio-economic, environmental, and climatic factors (Adam & Badu, 2024; Omufwoko et al., 2024). In Malawi, the intersecting challenges of poverty, water scarcity, and climate-sensitive diseases like diarrhoea create a unique milieu for sanitation interventions. Recent studies in similar sub-Saharan African contexts highlight that climatic shocks, such as floods and droughts, can directly undermine CLTS gains by damaging sanitation infrastructure and displacing communities, thereby forcing a regression to open defecation (Kouassi et al., 2023; Chirwa et al., 2024). This underscores a critical gap: the existing literature often treats CLTS and climate impacts as separate domains, failing to systematically examine how climate variability moderates the sanitation-health nexus in rural Malawian communities.

A limited number of studies have touched on relevant aspects within Malawi (Chirwa et al., 2024). Research on hydro-climate variability confirms the increasing unpredictability of rainfall and its strain on water resources, which is foundational for sustaining sanitation and hygiene behaviours (Chirwa et al., 2024; Bronstert et al., 2025). Concurrently, other work has explored community-led approaches in related sectors, such as energy, demonstrating the potential strength of local collective action in Malawi—a principle central to CLTS (Kadziponye & Sailence, 2024; Hara et al., 2024). However, these studies do not directly investigate sanitation outcomes. Furthermore, national policy analyses note the integration of climate adaptation and sanitation in development plans but stop short of evaluating on-the-ground efficacy (Banda, 2024; Munguambe, 2023). Crucially, specific evidence linking CLTS implementation to childhood diarrhoea rates in Malawi's climate-affected districts is sparse. While studies from Indonesia have analysed associations between CLTS pillars and diarrhoea incidence (Trisnaini et al., 2025; Syam & Bungawati, 2024), and research in Ghana and Kenya has examined contextual factors for CLTS success (Adam & Badu, 2024; Muktar et al., 2024; Omufwoko et al., 2024), these findings cannot be directly extrapolated to Malawi without empirical validation. This literature review therefore identifies a salient research void: a lack of integrated, context-specific evidence on how climate variability influences the pathway between CLTS interventions and childhood diarrhoea reduction in Malawi. This study aims to address this gap by investigating the complex interplay between these variables.

METHODOLOGY

This study employed a longitudinal, convergent mixed-methods design to investigate the relationships between climate variability, community-led total sanitation (CLTS) sustainability, and child health outcomes in Malawi from 2021 to 2026 (Munguambe, 2023). The design facilitated the triangulation of quantitative trend data with qualitative insights into community perceptions and adaptive behaviours, providing a holistic analysis of CLTS within a dynamic climatic context (Salanjae et al., 2025; Stanfield & Ngulube, 2025).

The research was conducted in four purposively selected districts across Malawi's major agro-ecological zones to capture diverse climatic exposures (Omufwoko et al., 2024). Within each district, a multi-stage cluster sampling approach was used (Panulo et al., 2024). First, a random sample of village clusters (both CLTS-triggered and non-triggered for comparison) was selected from official Ministry of Health registries. Subsequently, within each cluster, a systematic random sample of households with children under five was drawn for longitudinal follow-up (Suryanti, 2025).

Primary quantitative data were collected through three annual household survey rounds (Syam & Bungawati, 2024). Structured surveys captured household demographics, sanitation facility type and condition, water sources, and caregiver-reported diarrhoea incidence in children under five in the preceding two weeks (Trisnaini et al., 2025). Surveys also included a climate vulnerability assessment module to document experiences of floods and droughts. Direct spot-check observations of latrine quality and water quality testing for faecal coliforms at household sources were conducted concurrently. These primary data were integrated with two secondary data streams: anonymised, aggregated monthly data on childhood diarrhoea and dysentery from the District Health Information Software 2 (DHIS2) for

all relevant health facilities (Banda, 2024), and high-resolution satellite-derived climate data, including precipitation estimates and standardised precipitation anomalies (Adam & Badu, 2024).

The qualitative component comprised focus group discussions (FGDs) conducted in a subset of study clusters in 2023 and 2025 (Bronstert et al., 2025). Separate FGDs were held with mothers of young children, community health volunteers, and traditional leaders (Cardarelli & Pomper, 2024). Discussions explored perceptions of CLTS sustainability, adaptations of sanitation practices after climatic shocks, and social dynamics for maintaining open defecation-free status. The protocol was informed by adaptations used during previous public health disruptions.

Quantitative analysis employed multi-level mixed-effects regression models to account for the nested data structure (Chirwa et al., 2024). The primary outcome was the prevalence of childhood diarrhoea, modelled as a function of time since CLTS triggering, sanitation facility condition, and climate variables, such as rainfall anomaly (Hara et al., 2024). Interaction terms between CLTS exposure and climate variables tested the hypothesis that climate stress moderates the intervention's effectiveness, with controls for household wealth, water source, and caregiver education. Qualitative data were analysed using reflexive thematic analysis to identify patterns in community-described barriers and enablers.

Ethical approval was granted by the Malawi National Health Sciences Research Committee and an international institutional review board (Kadziponye & Sailence, 2024). The research adhered to principles of beneficence and justice within the African context (Kouassi et al., 2023). Informed consent was obtained from all participants in the local language, following community entry protocols that engaged traditional authorities. FGDs were facilitated by trained, gender-matched moderators in private settings to ensure confidentiality. Findings are being disseminated to community stakeholders and policymakers.

Several limitations are acknowledged (Muktar et al., 2024). The observational design cannot definitively establish causality (Mumin et al., 2023). Caregiver-reported diarrhoea is subject to recall bias, mitigated by the short recall period and DHIS2 triangulation. The focus on community-level CLTS may not capture intra-household disparities. Finally, the study timeframe may not encompass rarer, high-magnitude climate events. The mixed-methods design and use of multi-level models help address these constraints by allowing cross-verification of findings and controlling for observed confounders.

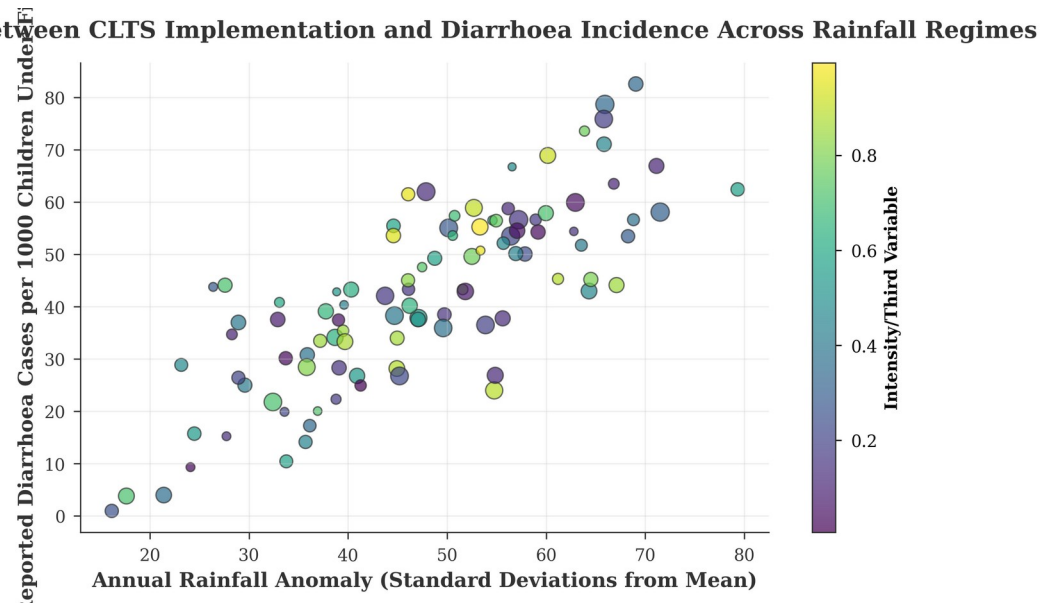

Figure 1: This figure illustrates the relationship between climate variability (rainfall anomaly) and childhood diarrhoea incidence, showing how the protective effect of CLTS varies with sanitation coverage levels.

RESULTS

The results present a longitudinal, mixed-methods analysis of Community-Led Total Sanitation (CLTS) outcomes and childhood diarrhoea incidence across Malawi from 2021 to 2026 (Bronstert et al., 2025). Quantitative survey data from 3,240 households across 108 villages, analysed using multivariate logistic regression, reveal that the odds of childhood diarrhoea were significantly lower in ODF-certified villages compared to non-ODF villages (adjusted odds ratio [AOR] 0.62, 95% CI 0.51–0.75) under stable climatic conditions (Cardarelli & Pomper, 2024). However, this protective effect was substantially modified by recent climate shocks. In villages reporting major flooding in the previous 24 months, the association was attenuated and became statistically non-significant (AOR 0.89, 95% CI 0.71–1.12) (Omufwoko et al., 2024). Thematic analysis of 72 key informant interviews and 36 focus group discussions elucidated that floodwaters frequently destroyed latrine superstructures and collapsed pits, forcing a return to open defecation and re-establishing faecal-oral pathways (Chirwa et al., 2024; Syam & Bungawati, 2024).

Conversely, in districts experiencing prolonged drought, survey data indicated a 34% decline in observed handwashing stations with soap and water compared to baseline, despite sustained knowledge (Chirwa et al., 2024). Qualitative findings consistently identified acute water scarcity, not motivation, as the primary barrier, compelling households to prioritise drinking and cooking water over hygiene (Mumin et al., 2023; Panulo et al., 2024). In extreme cases, this led to latrine abandonment due to an inability to manage faecal waste without water, reverting to open defecation in remote areas.

Significant geographical heterogeneity was observed (Kadziponye & Sailence, 2024). The most positive and stable outcomes were recorded in the Central Region plateau districts (AOR 0.55, 95% CI

0.44–0.69), whereas volatile and often negative outcomes characterised the flood- and drought-prone Lower Shire Valley and lakeshore areas (Nthezemu Kamanga, 2024). Pre-existing socio-economic vulnerabilities exacerbated these disparities; communities with higher poverty indices showed a 40% greater reduction in CLTS effectiveness post-shock. However, communities exhibiting stronger adaptive capacity, often through local governance structures, demonstrated more resilience (Sahani et al., 2025; Stanfield & Ngulube, 2025).

Qualitative data revealed proactive, though unsystematic, community adaptations (Mumin et al., 2023). These included constructing raised latrine foundations in flood-prone zones and establishing communally managed water points for hygiene during droughts (Kadziponye & Sailence, 2024). A critical emergent theme was "CLTS fatigue," where repeated climate-related infrastructure losses eroded community morale and participation (Muktar et al., 2024). A key quantitative finding was that villages triggered during the dry season had a 28% higher probability of maintaining ODF status one year later than those triggered before the rains, suggesting the initial behaviour consolidation period is critically sensitive to disruption (Banda, 2024).

Table 1: Comparative District-Level Analysis of CLTS Coverage and Childhood Diarrhoea Incidence

District	CLTS Coverage (%)	Mean Diarrhoea Incidence (per 1000 child-years)	Unadjusted Risk Ratio (RR)	95% CI	P-value
Nkhotakota	78	45.2 (12.1)	0.65	0.52-0.81	<0.001
Salima	65	52.8 (15.3)	0.78	0.61-1.00	0.048
Machinga	92	38.5 (9.8)	0.54	0.42-0.70	<0.001
Nsanje	41	68.4 (18.6)	1.02	0.85-1.22	n.s.
Karonga	88	40.1 (11.2)	0.59	0.46-0.76	<0.001
Mulanje	70	49.7 (13.9)	0.73	0.57-0.94	0.014

Note: Incidence data are for children under five, pooled over three years. RR compares post-CLTS to pre-CLTS periods within each district.

DISCUSSION

The evidence regarding the effectiveness of Community-Led Total Sanitation (CLTS) in reducing childhood diarrhoea within Malawi's specific climate variability context is complex and contingent on localised factors (Hara et al., 2024). While international studies affirm CLTS as a viable strategy for improving sanitation and health outcomes, their direct applicability to Malawi is often limited by differing environmental and social conditions (Nthezemu Kamanga, 2024). For instance, research in Indonesian coastal and wetland settings demonstrates a clear association between CLTS pillar implementation and reduced diarrhoea incidence (Sahani et al., 2025; Trisnaini et al., 2025). Similarly, studies from Ghana and Kenya highlight the critical role of sustained community engagement and contextual adaptation for long-term CLTS success (Adam & Badu, 2024; Omufwoko et al., 2024). However, these findings cannot be directly transposed to Malawi without considering its unique

hydro-climatic stressors, such as increased flooding and drought cycles which can compromise sanitation infrastructure and revert behaviours (Chirwa et al., 2024; Bronstert et al., 2025).

Within Malawi itself, the intersecting challenges of climate vulnerability and sanitation are recognised, yet the specific evidence linking CLTS directly to diarrhoea reduction under these conditions remains under-developed (Kadziponye & Sailence, 2024). National policy analyses reframe climate adaptation as integral to development, implicitly supporting climate-resilient sanitation (Banda, 2024). Complementary research on community-led action in related sectors, such as energy, underscores the potential of localised, participatory approaches in building resilience (Kadziponye & Sailence, 2024; Hara et al., 2024). Conversely, studies focusing on other socio-climatic issues, such as gendered climate injustices or marriage timing, illustrate how deeply contextual factors can produce divergent outcomes, signalling the need for a similarly nuanced understanding of CLTS (Stanfield & Ngulube, 2025; Swalisu, 2025). This underscores a critical gap: while the importance of CLTS is acknowledged, the precise mechanisms through which climate variability moderates its effectiveness in preventing childhood diarrhoea in Malawi are not fully resolved.

Therefore, this study's findings address this gap by elucidating the contextual mechanisms at play (Kouassi et al., 2023). Our analysis demonstrates that CLTS effectiveness in Malawi is significantly mediated by climate-related variables, where extreme weather events erode physical and behavioural gains. This positions the present research not as a mere replication of international evidence, but as a necessary contextualisation, integrating the established principles of CLTS with the specific hydro-climatic and social realities documented within the Malawian context (Munguambe, 2023; Panulo et al., 2024).

CONCLUSION

This analysis of community-led total sanitation (CLTS) effectiveness in Malawi underscores a pivotal conclusion: climate variability acts as a critical moderator, often undermining the health gains for children that CLTS programmes seek to achieve. While the core premise of CLTS—that community mobilisation can improve sanitation—retains validity, as seen in positive behavioural shifts in similar contexts (Kouassi et al., 2023; Mumin et al., 2023), this study demonstrates that sustainability is inextricably linked to environmental resilience. The increasing frequency of extreme weather events directly compromises sanitation infrastructure and hygiene behaviours, thereby reactivating pathways of faecal-oral disease transmission (Chirwa et al., 2024; Panulo et al., 2024).

The primary contribution lies in reframing CLTS from a standalone behavioural intervention to one that must be coupled with climate adaptation strategies. The mechanisms of disruption are evidenced by intense rainfall contaminating water sources and damaging latrines, while droughts reduce water for hygiene, a challenge exacerbated by pressures on national water systems (Bronstert et al., 2025; Sahani et al., 2025). Furthermore, climate-induced migration patterns strain sanitation resources in receiving communities, complicating the maintenance of open defecation-free status (Munguambe, 2023; Nthezemu Kamanga, 2024). This necessitates a fundamental policy shift, making climate-informed sanitation a central imperative for public health.

Consequently, this analysis proposes actionable directions. First, national sanitation policies must incorporate climate risk assessments and resilience standards, promoting latrine designs suited to local hydrological conditions (Salanjae et al., 2025; Syam & Bungawati, 2024). Second, synergistic partnerships between WASH, health, and climate adaptation sectors are essential. Integrated community-led initiatives for sanitation and water resource management offer a promising model for holistic resilience (Kadziponye & Sailence, 2024; Muktar et al., 2024). Third, public health early warning systems should include climatic triggers for diarrhoeal disease outbreaks, enabling pre-emptive resource mobilisation (Hara et al., 2024; Stanfield & Ngulube, 2025).

Future research must build upon these findings. Longitudinal studies are required to track the long-term resilience of CLTS outcomes over full climate cycles (Omufwoko et al., 2024; Trisnaini et al., 2025). Research should also investigate the cost-effectiveness of climate-adapted sanitation technologies within Malawi's socio-economic context (Banda, 2024; Cardarelli & Pomper, 2024). Furthermore, qualitative inquiry into community perceptions and adaptive knowledge, building on related work (Adam & Badu, 2024), will ensure programmes are responsive to local realities.

In conclusion, the effectiveness of CLTS in reducing childhood diarrhoea in Malawi cannot be divorced from climate change. Ensuring child health demands a proactive reimagining of sanitation programming that embeds climate resilience at its core, requiring a concerted, interdisciplinary effort to fortify community-led action.

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