PLOS Climate

RESEARCH ARTICLE

Household sanitation access before and after an extreme weather event: Tropical Cyclone Freddy in rural Malawi

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OPEN ACCESS

Citation: MacLeod C, Sidira G, Kapazga T, Njolomole P, Panulo M, Vigneri M, et al. (2025) Household sanitation access before and after an extreme weather event: Tropical Cyclone Freddy in rural Malawi. PLOS Clim 4(10): e0000721. https://doi.org/10.1371/journal.pclm.0000721

Editor: Erin Coughlan de Perez, Tufts University / Red Cross Red Crescent Climate Centre, UNITED STATES OF AMERICA

Received: February 4, 2025

Accepted: September 15, 2025

Published: October 17, 2025

Data availability statement: The dataset and code to reproduce results are available via the LSHTM data repository at https://doi.org/10.17037/DATA.00004722.

Abstract

This study is embedded within the Water, Sanitation, and Hygiene for Everyone programme in Chiradzulu District, Malawi, where one programme area achieved Open Defecation Free (ODF) status in December 2022 following a Community-Led Total Sanitation (CLTS) intervention. In March 2023, Tropical Cyclone Freddy made landfall in Chiradzulu District, causing widespread damage to essential infrastructure. This study compares household sanitation access, classified according to the WHO/UNICEF Joint Monitoring Programme (JMP) sanitation ladder, before and after the cyclone in a rural area of southern Malawi. Household surveys were administered in the same 311 households at programme baseline in April 2022, prior to CLTS implementation, and at 10-month follow-up in June 2023, three months after Cyclone Freddy. ODF status verification data were also used to estimate pre-cyclone sanitation access. These data were used to estimate the proportion of household sanitation facilities that collapsed and became unusable due to the cyclone. The types of JMP sanitation facilities most prone to collapse and those most likely to be reconstructed three months after the cyclone are also reported. Of the 311 households surveyed, 5% had access to basic sanitation, 3% to limited sanitation, and 92% relied on unimproved sanitation prior to Cyclone Freddy. Following the cyclone, 68% of households reported that their sanitation facility, primarily unimproved, had collapsed. Three months later, 36% of surveyed households had no sanitation facility at all, while 50% relied on unimproved sanitation. Among the 211 households whose facility collapsed, 43% rebuilt an unimproved facility. These findings underscore the vulnerability of

Funding: This work was supported by World Vision US (grant number 34730 to RD). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: The authors have declared that no competing interests exist.

sanitation infrastructure to tropical cyclones, which can cause affected communities to resort to unsafe sanitation practices or rebuild facilities that remain vulnerable to future cyclones. Improving the resilience of household sanitation infrastructure to extreme weather is critical to protecting public health, particularly in the context of climate change.

Introduction

Climate variability contributes to the increasing frequency of extreme weather events [1]. Among these are tropical cyclones, which are powerful, rotating storms that form over tropical oceans [2]. They are characterised by extreme rainfall and strong winds, which can cause hazards such as storm surges and flooding [3,4]. Such events may result in widespread damage to infrastructure, including houses, roads, and hospitals, essential services such as electricity and water supply, and the environment [5]. Tropical cyclones are also associated with higher risk of infectious diseases, particularly intestinal infections, due to contaminated drinking water and disrupted sanitation and hygiene services [6]. Diarrhoea, cholera, and dengue fever are the predominant communicable diseases reported following cyclonic events [7–9].

The World Health Organization (WHO) and UNICEF Joint Monitoring Programme (JMP) sanitation ladder is a globally recognised framework for classifying sanitation service levels [10]. The JMP categorises sanitation facilities as either improved or unimproved, based on the extent to which they hygienically separate human excreta from human contact. Unimproved facilities include pit latrines without a slab or platform, hanging latrines, and bucket latrines [10]. These facilities pose significant public health risks and are associated with adverse outcomes such as diarrhoea, acute respiratory infections, undernutrition, and soil-transmitted helminthiasis [11–14]. Beyond physical health, unimproved sanitation has negative impacts on educational attainment, cognitive development, mental well-being, and quality of life [15–17]. In contrast, improved sanitation facilities provide a more substantial barrier against human exposure to faecal pathogens [11,18]. Examples include flush or pour-flush toilets connected to piped sewer systems, septic tanks, or pit latrines; ventilated improved pit latrines; composting toilets; and pit latrines with slabs [10]. The JMP further distinguishes three levels of service of improved sanitation: limited (shared with other households), basic (not shared), and safely managed sanitation (not shared and where excreta are safely managed) [10]. Despite progress, as of 2024, 3.4 billion people globally lacked access to safely managed sanitation services, with over two billion relying on only basic or limited sanitation, 555 million using unimproved facilities, and 354 million practising open defecation by disposing faeces in the environment, such as in fields or forests [10].

Tropical cyclones undermine progress toward Sustainable Development Goal 6.2 on water, sanitation, and hygiene (WASH) and pose significant health risks to affected communities [8]. They can disrupt all aspects of the sanitation service chain in both sewered networks and non-sewered systems, including onsite sanitation facilities such as septic tanks and pit latrines [19]. In sewered networks, flooding and extreme rainfall may cause stormwater overflows and sewer blockages due to sand, debris, or solid waste [19]. In non-sewered systems, inundated septic tanks and pit latrines can result in pit latrine wall collapse or overflow, leading to widespread environmental faecal contamination [20]. Extreme winds may also uproot trees, damaging sewer pipes and latrine superstructures and rendering sanitation facilities inaccessible or non-operational [19,21,22]. Without access to sanitation facilities, people may resort to alternatives (e.g., using their neighbours' toilet or public facilities) or practice open defecation (defecating in fields, forests, bushes, bodies of water, or other open spaces), increasing exposure to harmful pathogens and the risk of diarrhoeal disease [23]. The risk of infectious disease outbreaks following flooding events is high in areas with poor WASH services [24].

Some studies and programme reports qualitatively document the impacts of cyclones, heavy rainfall, and flooding on sanitation infrastructure [25,26], while others hypothesise that certain sanitation technologies may be more resilient to climate shocks [20,21,27,28]. However, few studies have quantitatively assessed the impacts of tropical cyclones or related hazards on sanitation systems [29,30]. For example, household surveys in a suburb of Dakar, Senegal, found that 86% of respondents reported damage to or inaccessibility of improved household sanitation facilities (e.g., septic tanks or cesspits) after flooding [29], while in Burkina Faso, 20% of surveyed latrines – primarily unimproved pit latrines constructed during a CLTS programme – collapsed after heavy rains [30]. Quantifying the magnitude of cyclone impacts on sanitation infrastructure and services is essential for identifying the most vulnerable facilities and informing climate-resilient sanitation decisions.

Few studies have examined household sanitation facility reconstruction decisions following tropical cyclones [31,32]. In Ethiopia, a study of 380 flood-affected households found that 43% did not reconstruct a latrine. Among those who did, households were more likely to build an improved facility if they had larger household sizes and if the head of household was older and had higher educational attainment [32]. In Mozambique, latrine rebuilding was associated with psychosocial factors and a sense of connection to other community members [31]. Understanding household reconstruction decisions and investment can inform strategies to sustain and expand sanitation coverage following cyclonic events.

Aim and objectives

This study aimed to quantify household sanitation access before and after Cyclone Freddy in a rural area of southern Malawi using routine monitoring and evaluation data from two local non-governmental organisations. The objectives were to: (1) quantify the damage caused by Cyclone Freddy to household sanitation infrastructure; (2) identify which types of sanitation facilities were most likely to collapse; and (3) determine which types of sanitation facilities were most likely to be rebuilt within three months following the cyclone.

Materials and methods

Study setting and population

This study was conducted in Traditional Authority (TA) Likoswe, one of ten administrative regions in Chiradzulu District, Malawi (Fig 1A and 1B). Chiradzulu District, located in the Southern Region of Malawi [33], is approximately 25 km from Blantyre, the country's commercial and industrial centre. The district is predominantly rural, with a population of approximately 350,000, an average annual temperature of 27 °C, and approximately 1,100 mm of annual precipitation [34]. TA Likoswe, on the western side of the district, has a population of about 76,000 across 142 villages [33]. In 2019, 47% of households in TA Likoswe lacked access to sanitation [33].

Community-Led Total Sanitation (CLTS) in Chiradzulu District, Malawi

This study was embedded within the Chiradzulu District Water, Sanitation, and Hygiene for Everyone (W4E) programme, implemented by World Vision and Water for People in partnership with the Government of Malawi. W4E was a three-year

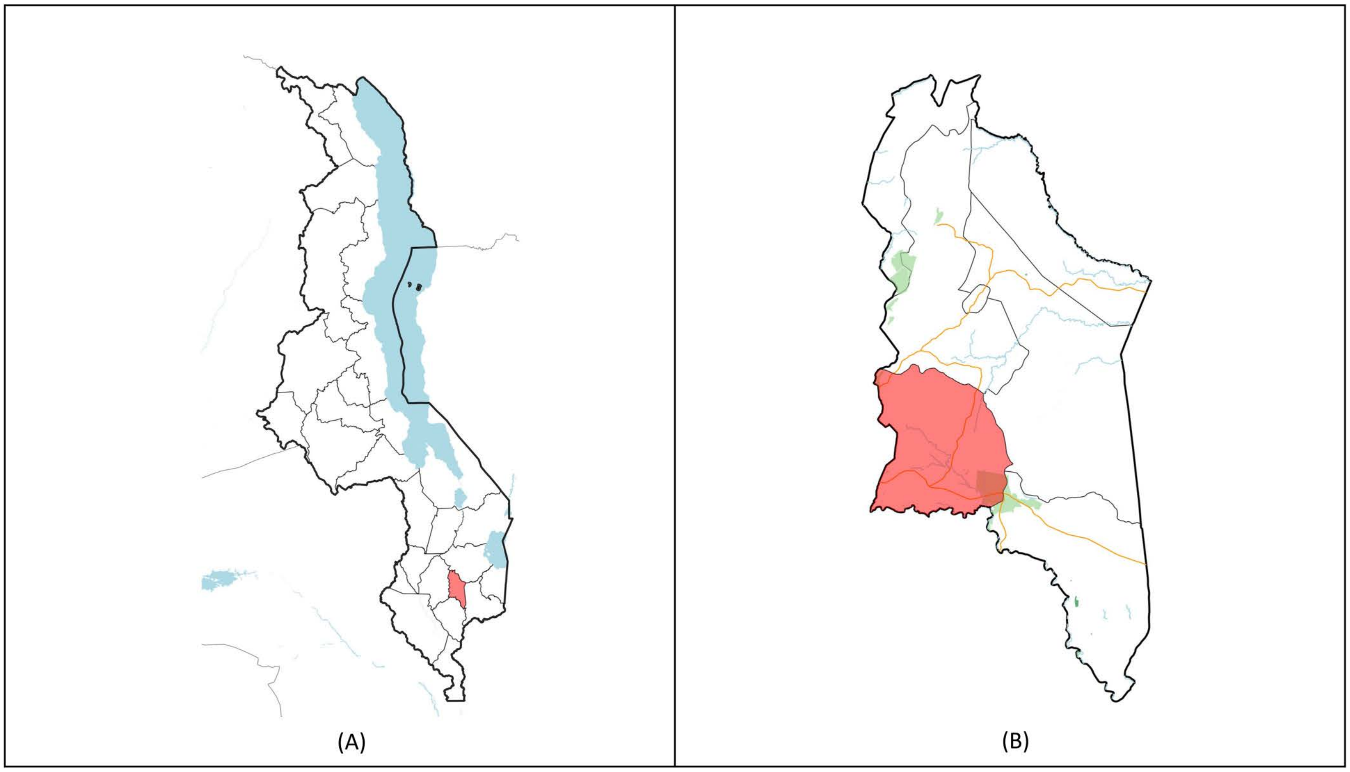

Fig 1. Maps of Chiradzulu District and TA Likoswe, Malawi. (A) Map of Malawi with Chiradzulu District highlighted in red; **(B)** Map of Chiradzulu District, Malawi, with TA Likoswe, situated on the western side of Chiradzulu District, highlighted in red. The base layer was obtained from Database of Global Administrative Areas (GADM) (available from: https://gadm.org/download_country.html). The terms of use can be found here: https://gadm.org/license.html. Road and waterbody features were obtained from OpenStreetMap under the Open Database License (available from: https://www.openstreetmap.org).

https://doi.org/10.1371/journal.pclm.0000721.g001

initiative (2022–2024) aimed at expanding access to drinking water, sanitation, and hygiene services across Chiradzulu District. TA Likoswe was included in the first phase of W4E, which ran from April to December 2022. Intervention activities primarily focused on Community-Led Total Sanitation (CLTS), supplemented by sanitation marketing and hygiene promotion campaigns.

CLTS is an approach that emphasises behaviour change and community self-enforcement to eliminate open defecation [35]. It is a widely adopted strategy for generating demand for sanitation and achieving open defecation-free (ODF) status at the community level. Introduced in Malawi in 2008, CLTS remains a key component of the national sanitation and hygiene strategy aimed at eliminating open defecation nationwide [33]. Within the W4E programme, CLTS was primarily delivered by government-employed Community Health Workers (CHWs), also known as village-level Health Surveillance Assistants (HSAs).

CLTS was implemented according to the official CLTS handbook and followed three broad implementation phases [35]: pre-triggering (assessment of existing social and physical conditions to tailor triggering activities), triggering (collective action toward ending open defecation), and follow-up (monitoring the outcomes of the triggering phase) [35]. Triggering events in TA Likoswe took place in April 2022, with follow-up visits beginning approximately two weeks later and continuing until ODF status was achieved. TA Likoswe was declared ODF by the Government of Malawi in December 2022, signifying universal sanitation coverage of any sanitation type at that time. The Government of Malawi defines ODF as no human faeces visible in the environment, with at least 95% of households having a latrine that is in good condition and shows evidence of use [36]. As part of the W4E programme, World Vision collected ODF data, reporting the number of households per village with improved and unimproved latrines.

Cyclone Freddy

Tropical Cyclone Freddy made landfall in southern Malawi on 11 March 2023 [37]. The World Meteorological Organization declared it the longest-lasting tropical cyclone on record, lasting 36 days and generating the highest accumulated cyclone energy [37]. The cyclone travelled over 8,000 km, with winds reaching or exceeding 55 km/h. In Malawi, Cyclone Freddy brought torrential rains of 500–1,000 mm over four days [38], with southeastern Malawi – including Chiradzulu District – among the hardest hit. The heavy rains triggered multiple floods and landslides in the district and caused extensive damage to roads, bridges, houses, schools, and health centres [39]. At the time, Malawi was experiencing one of the worst cholera outbreaks in recent history [39]. The President of Malawi declared a 'State of Disaster' in ten districts of the southern region, including Chiradzulu District and TA Likoswe, due to the extreme rainfall, flooding, and strong winds associated with the cyclone.

Sample size

Household surveys were conducted in 311 households in TA Likoswe at programme baseline and at a one-year follow-up. Households were randomly selected at baseline using a population-level sampling frame developed by the W4E implementation team and were re-interviewed in June 2023. No formal sample size calculations were performed for this study. Instead, the sample size was determined by the number of records that could be linked between baseline and follow-up using a unique household identification number.

Data collection

Household surveys were administered as part of World Vision's routine monitoring and evaluation of the W4E programme at baseline and at the programme mid-point. The baseline survey was conducted in April 2022, prior to CLTS implementation activities. The follow-up survey took place in June 2023, approximately three months after Cyclone Freddy and with the same households as at baseline. The survey comprised questions with pre-coded responses to capture information on household characteristics, WASH facilities, and practices. Specific questions on household sanitation facilities were included in both surveys. The 2023 follow-up survey additionally asked whether a household sanitation facility had collapsed due to Cyclone Freddy and the reasons for collapse or continued functionality. Responses were recorded on tablets using forms in mWater (mWater Foundation, New York, NY), a data collection platform for WASH programmes. The forms were provided in English and Chichewa, the local language. Personally identifiable participant information was removed, and data were encrypted and stored on a secure server. Pre-cyclone ODF status data for TA Likoswe were shared by World Vision.

Variable definitions

Household sanitation facilities were classified according to the JMP sanitation ladder as safely managed, basic, limited, unimproved, or no sanitation facility [10]. A collapsed household sanitation facility was defined as the failure or breakdown of a latrine during or after the cyclone as a result of rainfall or flooding, regardless of damage to the latrine superstructure from extreme winds. A rebuilt sanitation facility was defined as a newly constructed or rehabilitated sanitation facility within three months of the previous facility collapsing and could be intended for temporary or long-term use. Latrine design choice included pre-coded responses capturing the reasons a household selected a particular sanitation facility (e.g., durability, cost, or common practice in the community). The two household characteristic variables included in this study were the 'number of people in the household' and the 'presence of children under five'.

Estimated sanitation coverage prior to Cyclone Freddy

To estimate household sanitation access in TA Likoswe prior to Cyclone Freddy, we combined data from the baseline survey with ODF status data from World Vision. TA Likoswe was declared ODF eight months after the baseline survey, suggesting that all households in the TA had at least access to an unimproved sanitation facility. We were unable to link the ODF verification data to the households included in the survey. Therefore, we assumed that households with no sanitation at baseline transitioned to unimproved sanitation as a result of the CLTS intervention, and that none transitioned to limited or basic sanitation. This assumption was informed by a parallel controlled before-and-after trial of W4E, which found little to no change in basic or limited sanitation coverage associated with the interventions [40], as well as ODF status reports indicating that 90% of households in TA Likoswe had unimproved sanitation facilities following the CLTS intervention. For households with a basic or limited sanitation facility at baseline, we assumed that these households remained at the same JMP sanitation level after the CLTS intervention.

Data analysis

The primary outcome, whether a sanitation facility collapsed, was calculated as a proportion. We estimated the proportion of households at each step of the JMP sanitation service ladder before and after Cyclone Freddy. A log-binomial regression model was used to assess the probability of each sanitation facility type collapsing due to the cyclone. Risk ratios with 95% confidence intervals and p-values are reported. We also assessed whether household characteristics – the number of people in the household and presence of children under five – were associated with rebuilding any type of sanitation facility. Data were cleaned and analysed in STATA v18 (StataCorp, College Station, Texas, USA). The dataset and code to reproduce results are available in the London School of Hygiene and Tropical Medicine open access data repository [41].

Ethics

The W4E project was approved by the Chiradzulu District Council under a project agreement between the District Council and the W4E project implementation team. The agreement covered all aspects of project implementation, including approval of programme baseline data collection by World Vision and Water for People. Ethical approval was also obtained from the London School of Hygiene and Tropical Medicine Research and Ethics Committee (Ref. 27929) and the Malawi National Committee on Research in the Social Sciences and Humanities (Ref. NCST/RTT/2/6) for the London School of Hygiene and Tropical Medicine and Malawi University of Business and Applied Sciences to (i) conduct secondary data analysis of W4E programme baseline and follow-up data; and (ii) directly engage in the W4E programme follow-up data collection, including adaptation of survey tools and sampling strategy. Consent was obtained from community leaders, and informed written consent was obtained from all household survey respondents.

Inclusivity in global research. Additional information regarding the ethical, cultural, and scientific considerations specific to inclusivity in global research is included in the supporting information (S1 Checklist).

Results

Prior to Cyclone Freddy, an estimated 92% (n = 284) of surveyed households in TA Likoswe had unimproved sanitation, 3% (n = 10) had limited sanitation, and 5% (n = 17) had basic sanitation (Table 1). Pit latrines without slabs were the most common type of unimproved sanitation facility. During the two-month cyclone period, 68% (n = 211) of household sanitation facilities collapsed (i.e., rendered unusable due to pit latrine walls collapsing) (Fig 2). Of the 211 collapsed facilities, 3% (n = 6) were classified as basic and 1% (n = 2) as limited (Table 2). Unimproved sanitation facilities were the most affected (96%, n = 203) and were over twice as likely to collapse compared to improved facilities (Risk Ratio 2.4; 95% confidence interval [CI]: 1.34–4.33; p = 0.003).

Table 1. Percentage of households (N = 311) at each level of the JMP sanitation service ladder before and after Cyclone Freddy.

JMP sanitation ladder	Pre-cyclone, % (n)	Post-cyclone, % (n)
Basic	5% (17)	6% (19)
Limited	3% (10)	8% (24)
Unimproved	92% (284)	50% (156)
No sanitation	0% (0)	36% (112)

https://doi.org/10.1371/journal.pclm.0000721.t001

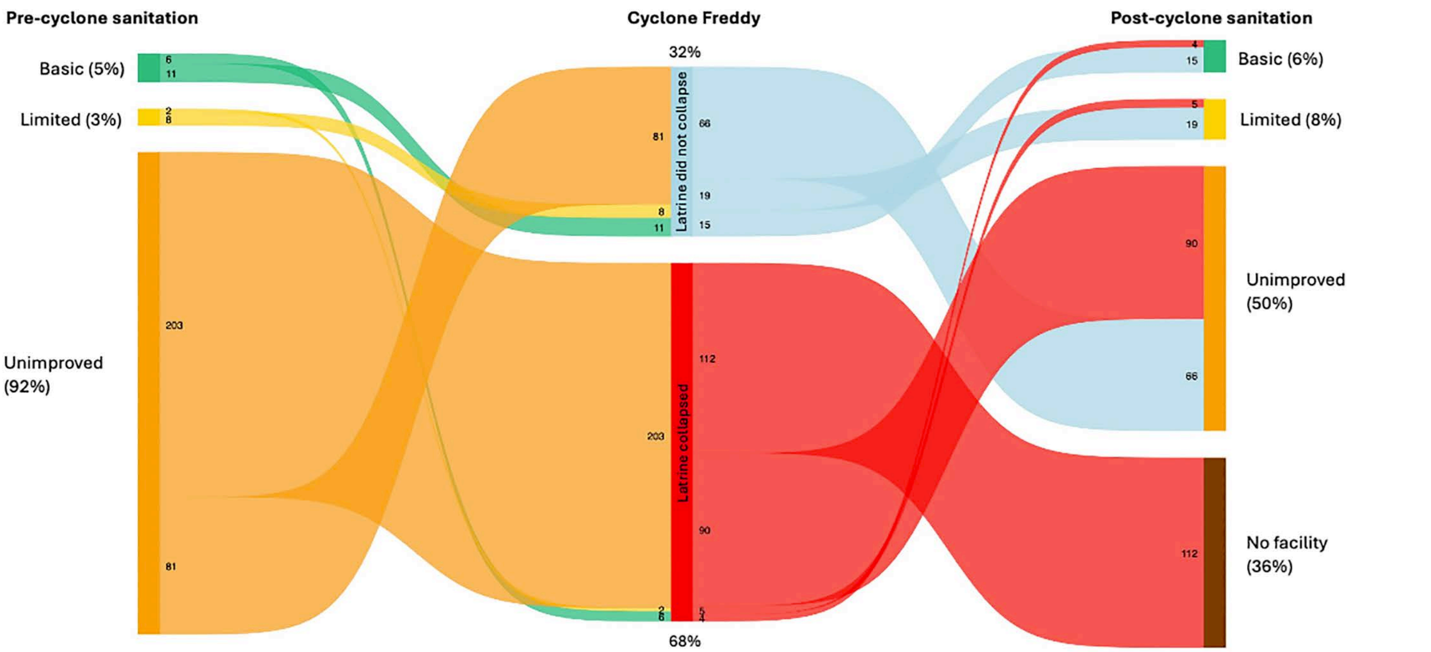

Fig 2. Sankey diagram illustrating household sanitation access by JMP sanitation ladder category before and after Cyclone Freddy, with the middle state representing the number of facilities that collapsed due to the cyclone.

https://doi.org/10.1371/journal.pclm.0000721.g002

Table 2. Percentage of household sanitation facilities significantly damaged or collapsed due to Cyclone Freddy, and relative risk of unimproved facilities collapsing compared to improved facilities (basic and limited).

JMP sanitation ladder	% of collapsed latrines (n)	Risk ratio	95% CI	p-value
Unimproved	96% (203)	2.4	1.34–4.33	0.003
Limited	1% (2)	–	–	–
Basic	3% (6)	–	–	–

https://doi.org/10.1371/journal.pclm.0000721.t002

Three months after Cyclone Freddy, most households had either an unimproved sanitation facility (50%, n = 156) or no sanitation facility at all (36%, n = 112) (Fig 2; Table 1). Among the 211 households whose sanitation facility collapsed during the cyclone, nearly half (47%, n = 99) had rebuilt a facility within three months. The majority of these rebuilt facilities were unimproved (91%, 90/99), while a small proportion were limited (5%, 5/99) or basic (4%, 4/99). Nonetheless, more than half of affected households (53%, n = 112) were without a sanitation facility three months post-cyclone (Fig 3).

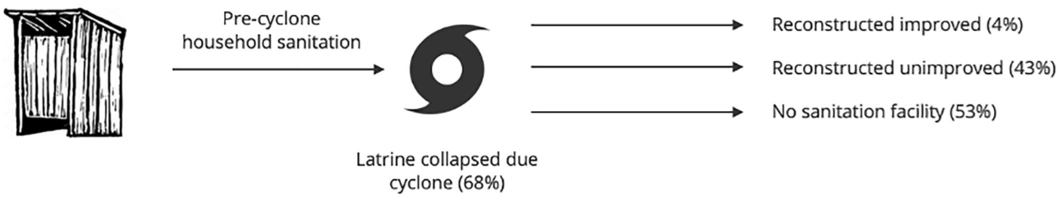

Fig 3. Household sanitation access in TA Likoswe at the follow-up survey, approximately three months after Cyclone Freddy, among households whose latrine collapsed during the cyclone (n = 211).

https://doi.org/10.1371/journal.pclm.0000721.g003

Households reported various reasons for both the collapse of their sanitation facility and their rebuilding decisions. Among households whose latrine did not collapse (n = 100), 60% (n = 60) attributed this to the use of durable materials, while 6% (n = 6) reported that the cyclone was less severe in their community compared to others. Among those who rebuilt an unimproved facility (n = 90), 63% (n = 57) reported using inexpensive materials, whereas 10% (n = 9) stated that they used more durable materials. Neither household size nor the presence of children under five was associated with rebuilding a latrine ($p > 0.05$).

Discussion

Tropical Cyclone Freddy damaged over half of household sanitation facilities in a rural area of Malawi, highlighting the vulnerability of household sanitation infrastructure to extreme weather. Similarly, another study reported that nearly one million people across 14 districts of Malawi lost access to WASH services following the cyclone, with household latrines more severely affected than public and school latrines [42]. In this study, unimproved sanitation facilities, particularly pit latrines without slabs, were more likely to collapse than improved sanitation facilities. This finding aligns with infrastructure and expert assessments, which identify unimproved pit latrines as highly vulnerable to flooding because pits can overflow or collapse [27,43,44]. The key difference between unimproved and improved facilities lies in the latrine substructure rather than the superstructure. Pit latrines without slabs consist of a rudimentary, unlined hole in the ground without a squatting slab, platform, or seat, making them prone to overflow or structural failure during flooding [10]. This increases exposure to faecal pathogens and the risk of environmental contamination [8], as well as the likelihood of cholera and other infectious disease outbreaks during heavy rains and floods [43,45]. In contrast, improved sanitation facilities include a squatting slab or platform made from durable materials (e.g., concrete, bricks, stone, metal, or wooden planks) that fully cover the pit. These features provide greater safety and resilience against extreme rainfall and strong winds [30].

Although most sanitation facilities in this study were damaged by the cyclone, adaptations to pit latrines can increase their resilience [43]. For example, raising the plinth, coating pits with cement or mud to prevent erosion, and constructing smaller or shallower pits can reduce the risk of collapse [28,43]. Other on-site sanitation technologies, such as pour-flush latrines and septic tanks, are also vulnerable to flooding, as both can become non-functional when inundated [27]. Nevertheless, design modifications can similarly reduce the risk of overflow in these systems [43]. Understanding the specific vulnerabilities of different sanitation technologies, along with potential adaptations, is essential for guiding infrastructure promotion in future programmes.

The results also highlight the ongoing impacts of extreme weather events, such as Tropical Cyclone Freddy, on household sanitation access. Our findings are consistent with studies in other rural areas, which report that households often do not immediately rebuild or repair latrines damaged by heavy rainfall or flooding [31,32]. In the interim, households without sanitation may resort to open defecation or use a neighbour's latrine while awaiting to reconstruct their own [31]. Tropical Cyclone Freddy caused extensive damage to homes and crops, leaving communities without access to basic necessities such as shelter and food [42]. Consequently, households faced trade-offs between meeting immediate needs and investing in sanitation. In TA Likoswe, competing priorities for shelter and food may have limited the resources available for rebuilding household sanitation facilities.

Various factors can influence whether a household chooses to rebuild a latrine. In Mozambique, physical factors (e.g., soil condition), socio-demographic factors (e.g., education level), and social factors (e.g., social cohesion) were all associated with latrine reconstruction following heavy rainfall in 2015 [31]. While the drivers of household sanitation reconstruction in this setting remain unclear, further research on why households rebuild unimproved pit latrines, which remain vulnerable to tropical cyclones, or opt for higher-quality sanitation facilities could inform future CLTS and broader sanitation interventions.

Extreme weather events may limit the sustainability and cost-effectiveness of sanitation interventions that rely on small or incremental improvements in coverage, such as CLTS. Because CLTS does not promote any specific sanitation technology, it often leads to widespread adoption of unimproved facilities that are not resilient to extreme weather [44,46]. Following Cyclone Freddy, W4E partners prioritised latrine rehabilitation and construction, increasing staff and field costs associated with the intervention. The average lifetime of a standard pit latrine is approximately 10 years, depending on user numbers and operation and maintenance practices [47]. However, this lifespan is reduced in settings vulnerable to extreme weather, such as TA Likoswe. Consequently, the life-cycle costs of sanitation interventions in cyclone-prone areas are likely underestimated.

CLTS, as originally designed, focuses on expanding sanitation coverage of any type and may not be suitable in settings that require climate-resilient facilities. Future interventions that promote inclusive, climate-resilient sanitation technologies could help minimise interruptions in access and reduce slippage to open defecation [21,48]. In Malawi, unrestricted cash transfers to households affected by Tropical Cyclone Freddy enabled rapid responses to loss and damage [49]. While these transfers were primarily used for rebuilding homes and securing food [49], future research could explore their potential role in supporting household sanitation reconstruction or subsidising resilient facilities.

We note the following limitations of our study. First, we assumed that the households without a sanitation facility at baseline transitioned to unimproved sanitation due to the CLTS intervention, and that households with unimproved, limited, or basic sanitation at baseline did not move up or down the sanitation ladder. This assumption arose because we could not link surveyed households to World Vision' s ODF dataset. As unimproved sanitation was the most vulnerable to Cyclone Freddy, some facilities classified as unimproved may have been improved, potentially leading to an overestimation of the cyclone's impact. Another limitation is the absence of qualitative data to understand household sanitation reconstruction decisions, including whether rebuilt facilities were intended for temporary or permanent use. Consequently, this study provides only a snapshot of the extent of Cyclone Freddy's damage to household sanitation in a specific CLTS programme area. Our sample size of 311 households in TA Likoswe may also limit the generalisability of findings to other W4E programme areas. Finally, three months post-cyclone is a relatively short period for households to rebuild latrines or recover from an extreme weather event. Nonetheless, the substantial gap in household sanitation access three months after the cyclone still poses a significant public health risk to the community.

Conclusion

This study underscores the vulnerability of sanitation infrastructure to a tropical cyclone, which can force affected communities to switch to unsafe sanitation practices or rebuild facilities that remain vulnerable to future extreme weather events. Sanitation programmes should prioritise the resilience of infrastructure, even in settings with high sanitation coverage. Climate-resilient sanitation is essential for reducing the burden of disease in cyclone-prone areas, especially in the context of climate change.

Supporting information

S1 Checklist. Inclusivity in global research.
(DOCX)

Author contributions

Conceptualization: Robert Dreibelbis, Kondwani Chidziwisano.

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Writing – review & editing: Gray Sidira, Timeyo Kapazga, Panganani Njolomole, Mindy Panulo, Marcella Vigneri, Tracy Morse, Robert Dreibelbis, Kondwani Chidziwisano.

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