APS European Society for Paediatric Research Society for Pediatric Research www.nature.com/pr

SYSTEMATIC REVIEW OPEN

Floods and droughts and pediatric malnutrition in low-income countries: a systematic review and meta-analysis

Adriano La Vecchia[1,2]✉, Eleonora Borrione[3,6], Benedetta Esposito[3,6], Mattia Baglioni[4], Carlo Agostoni[1,3], Cristiana Berti[1,7] and Anna Comotti[5,7]

BACKGROUND: This study systematically reviewed and meta-analyzed the prevalence and risk of child malnutrition following extreme weather events in low- and lower-middle-income countries.
METHODS: We searched PubMed, EMBASE, and Cochrane Library for studies assessing child stunting, wasting, underweight, or overweight/obesity after extreme weather events. Random-effects models were used to pool prevalence and association estimates, with subgroup and sensitivity analyses by event type. Risk of bias was assessed using tools appropriate to study design.
RESULTS: Twenty-six studies, including over 320,000 children met the inclusion criteria, focusing exclusively on floods and/or droughts; none addressed overweight/obesity. The pooled prevalence of stunting, wasting, and underweight following extreme weather events was 39% (95% CI: 31–48%), 19% (95% CI: 12–28%), and 42% (95% CI: 22–64%), respectively. Wasting prevalence was higher after droughts than floods (22% vs. 13%, $p = 0.04$), while stunting did not differ by event type ($p = 0.68$). Meta-analyses revealed no significant long-term association between extreme weather events and stunting, though a transient increase in risk was observed within three months of flood exposure.
CONCLUSIONS: Child malnutrition remains highly prevalent in these settings. The complex climate-malnutrition link underscores the need for standardized exposure definitions and robust nutritional surveillance.

Pediatric Research; https://doi.org/10.1038/s41390-026-05411-8

IMPACT:

- This meta-analysis provides the first pooled prevalence estimates of wasting, stunting, and underweight after droughts and floods—19%, 39%, and 42%, respectively.
- Wasting was significantly higher following droughts than floods, suggesting possible climate- and geography-specific nutritional associations.
- Evidence linking extreme weather events to pediatric malnutrition in low- and lower-middle-income countries remains limited and inconsistent.
- Findings highlight major research gaps and the need for standardized definitions, baseline data, and climate-resilient nutrition strategies.

INTRODUCTION

Pediatric malnutrition remains a major global health challenge, affecting growth, development, and long-term health outcomes. Current estimates indicate that approximately 150.2 million (23.2%) children under 5 years of age are affected by stunting, and 42.8 million (6.6%) are affected by wasting.[1] Although only about half of the world's children under five reside in lower-middle-income countries (LMICs), these regions carry a disproportionate share of the burden, accounting for nearly two-thirds of stunted children and three-quarters of those with wasting. At the same time, the prevalence of pediatric overweight and obesity is rising globally, with particularly rapid increases observed in LMICs.[2] Consequently, pediatric populations are experiencing the "double burden of malnutrition", a condition in which undernutrition and overnutrition coexist.

Climate change is increasingly recognized as a driver of malnutrition. Nearly half of the world's children live in countries at extremely high risk of climate-related impacts, including heatwaves, floods, droughts, and tropical storms.[3] These events threaten food and nutrition security, disrupt health systems, and exacerbate inequities in LMICs, where fragile infrastructures and poverty limit resilience.[4,5] Extreme weather events can contribute

[1]Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Pediatric Area, Milan, Italy. [2]Department of Medicine and Surgery, University of Milan-Bicocca, Milan, Italy. [3]Department of Clinical Sciences and Community Health (DISCCO), University of Milan, Milan, Italy. [4]Freelancer in Social Sciences, Milan, Italy. [5]Occupational Medicine Unit, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy. [6]These authors contributed equally: Eleonora Borrione, Benedetta Esposito. [7]These authors jointly supervised this work: Cristiana Berti, Anna Comotti.✉email: adrianolvecchia@gmail.com

Received: 7 November 2025 Revised: 15 July 2026 Accepted: 4 August 2026
Published online: 02 September 2026

to child malnutrition through multiple pathways, including disruption of food production, reduced household food security, and increased risk of infectious diseases.[6] In particular, floods can increase the risk of gastrointestinal diseases, especially in settings with inadequate water, sanitation, and hygiene conditions or among displaced populations.[7] In 2024, extreme weather events were the primary driver of food crises in 18 countries, with over 96 million people facing high levels of acute food insecurity.[8]

Despite growing concern, few reviews have systematically quantified the effects of climate-related events on pediatric malnutrition, and most focus narrowly on undernutrition in children under five years of age.[9,10] To our knowledge, no review has comprehensively examined extreme weather events—including droughts, floods, tropical typhoons, or wildfires—nor addressed their impact across the full pediatric age range (0–17 years).

We therefore conducted a systematic review and meta-analysis to assess the effects of extreme weather events on malnutrition across the full pediatric age range (0–17 years) in LMICs.

METHODS

We conducted a systematic review of observational studies assessing the effects of extreme weather events on pediatric malnutrition in LMICs. The review protocol was registered in PROSPERO (CRD42024623330)[11] and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines.[12] The primary outcome was malnutrition, including undernutrition (stunting, wasting, underweight) and overnutrition (overweight, obesity).

Search strategy

We searched MEDLINE/PubMed, EMBASE, and Cochrane Library, using terms related to pediatric populations, malnutrition, and extreme weather events, combined with MeSH terms and Boolean operators. No filters were applied. The search strategy was iteratively refined during protocol development and piloted prior to the final search. The final comprehensive search was executed on 24 December 2024. The detailed search terms and strings are provided in the Supplementary Material (Appendix A). Reference lists of included studies and relevant reviews were also screened.

Eligibility criteria

Inclusion and exclusion criteria were based on the PICOS (Population, Interventions, Comparisons, Outcomes, Study Design) framework, which is detailed in Table S1 (Supplementary Material). Studies were included if they:

1. Were randomized or quasi-randomized controlled trials, or observational studies (cohort, case-control, cross-sectional).
2. Examined exposure to extreme weather events, as defined by the World Meteorological Organization. Extreme weather events were defined as severe meteorological or hydrological events that are rare for a particular place and time of year, occur over a relatively short period, and may result in substantial impacts on people, infrastructure, or ecosystems. Eligible events included droughts, floods, heatwaves, cold waves, tropical cyclones, hurricanes, tornadoes, wildfires, storms, and heavy precipitation events. Studies investigating long-term climate variability, climate change, or temperature and precipitation anomalies (e.g., mean temperature or rainfall anomalies) without exposure to an identifiable extreme weather event were not considered eligible.
3. Reported primary outcomes of malnutrition (stunting, wasting, underweight, overweight/obesity).
4. Included children and adolescents (<18 years) living in LMICs according to the World Bank classification for 2024/2025.[13]
5. Were published in English, French, Italian, Portuguese, or Spanish.

Mid-Upper Arm Circumference (MUAC) was considered an indicator of acute malnutrition and a proxy for wasting, while Body Mass Index (BMI)-for-age was considered an indicator of nutritional status among children aged over 5 years. However, MUAC-based outcomes were not included in the meta-analysis due to a lack of comparability with studies defining wasting based on weight-for-length/height z-scores; these results were therefore synthesized narratively. BMI-for-age outcomes were also not pooled in the meta-analysis for children older than 5 years due to the limited number of eligible studies in this age group.

Birth weight was included as a prespecified outcome in the registered protocol for studies assessing maternal exposure to extreme weather events during pregnancy; however, it was not considered in the present review, which aimed to synthesize evidence on postnatal malnutrition outcomes among the pediatric population (0–17 years of age). Additional outcomes, pre-specified in the study protocol, included acute gastrointestinal diseases (defined as diarrheal diseases and other gastrointestinal infections) and infant and young child feeding practices, including breastfeeding practices and complementary feeding indicators such as dietary diversity and meal frequency. However, the present manuscript focuses on primary nutritional outcomes; therefore, these additional outcomes are not reported.

We excluded qualitative studies, reviews, commentaries, modeling studies, and papers reporting only food security or agricultural metrics without nutritional outcomes.

Study selection. Data extraction, data synthesis, and quality assessment

Titles and abstracts were screened in Rayyan,[14] with full-text assessment of potentially eligible studies. Two reviewers independently performed screening (B.E. and E.B.), data extraction, and quality assessment, resolving disagreements by consulting a third reviewer (A.L.V.). Extracted data included study characteristics (year, country, design, sample size, population), exposure details (type, severity, duration of event), and outcomes (malnutrition measures). For each included study, data were extracted using a standardized form.

Two reviewers (B.E. and E.B.) independently assessed the possible risk of bias using the JBI (formerly Joanna Briggs Institute) checklist for cohort, cross-sectional, and case-control studies.

Meta-analysis

A meta-analysis was conducted when at least three studies reported the same combination of malnutrition type (wasting, stunting, underweight, overweight or obesity) and effect size measures (prevalence or risk estimate). Subgroup analyses were performed to differentiate results according to the type of event (drought or flood).

The pooled prevalence was estimated using a logit transformation approach. Definitions of malnutrition were accepted as reported in the original studies. When substantial discrepancies in definitions were identified, sensitivity analyses were conducted to assess the robustness of the findings.

For risk-based outcomes, the odds ratio (OR) was selected as the summary measure. When ORs were unavailable, risk ratios (RRs) were used as their best estimates.

Statistical heterogeneity among studies was assessed using the I^2 statistic, with values above 50% indicating substantial heterogeneity. In such cases, a random-effects model was applied to account for between-study variability.

RESULTS

The initial search yielded 2227 records. After removing duplicates and screening titles and abstracts, 57 full-text articles were selected. One article could not be retrieved, leaving 56 articles assessed for eligibility (Fig. 1). Twenty-six studies in total met the inclusion criteria and were included in the systematic review.

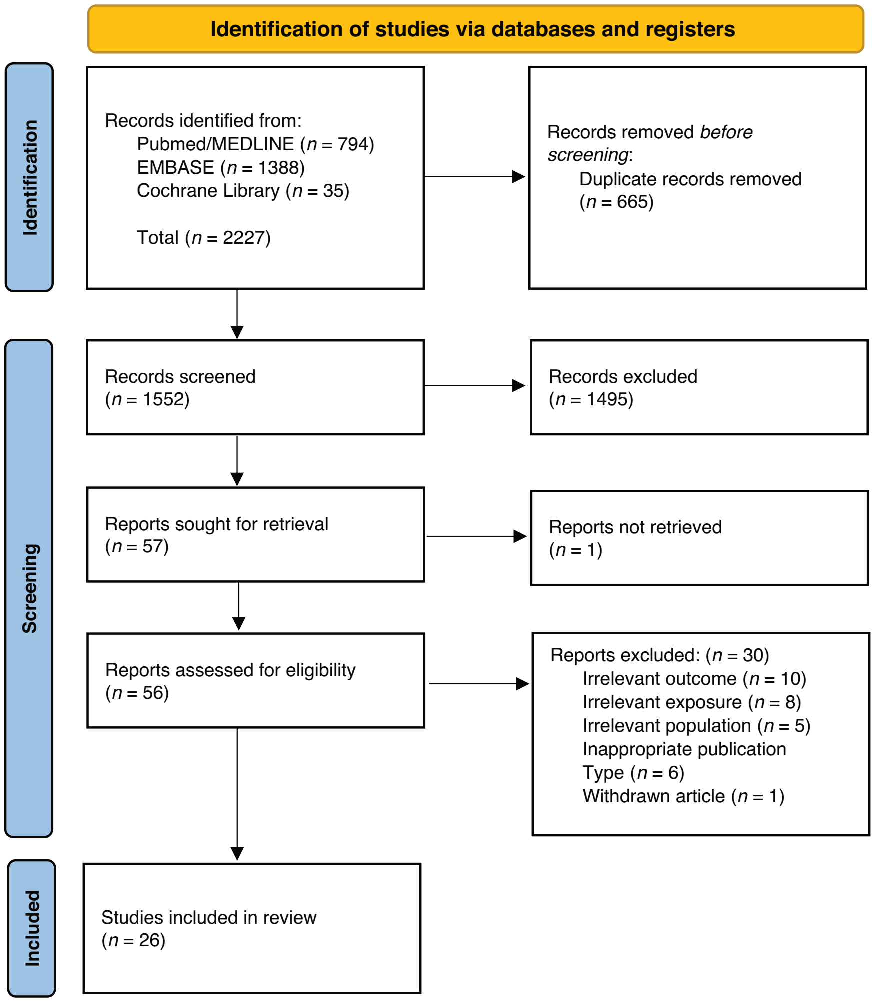

Fig. 1 PRISMA flow diagram of study selection process.

Table S2 (Supplementary Material) lists all full texts excluded with reasons and also notes one record that could not be retrieved. Details of the study characteristics are summarized in Table 1 and Table S3 (Supplementary Material). The included studies were published from 1993 through 2024. Sample sizes ranged from 103 to 320,479 participants (median 874, IQR 362–2111). Figure 2 shows the number of children included in the review by country. Most studies included children aged 0–5 years. Two studies included children up to 2 years,[15,16] three studies[17–19] included children up to 12 years, and one did not specify an age cut-off.[20]

Although the search strategy included terms for a broad range of extreme weather events (e.g., heatwaves, storms, tropical cyclones, heavy precipitation, and wildfires), only studies evaluating floods and droughts met the eligibility criteria and were included in the final review. Thirteen studies[15,17,21–31] examined the effects of drought, eleven[16,18–20,32–38] focused on floods, and two[39,40] investigated both drought and floods. Sixteen studies[17–19,21,25,26,28–33,36,38–40] investigated stunting, thirteen[20,23–26,28–30,35,37–40] examined wasting, eleven[16,19,25–31,38,39] focused on underweight, two on MUAC,[22,34] one on BMI for age,[19] and none assessed overweight/obesity.

The definitions for stunting, wasting, and underweight were generally consistent across studies, typically based on minus two standard deviations (-2SD) from the median expected value. The reference charts used varied over time, including the National Center for Health Statistics (NCHS) charts of 1977,[41] the Center for Disease Control and Prevention (CDC) charts,[42] and the World Health Organization (WHO) charts.[43] The specific chart reference for each study is provided in Table S3. The only exception to the -2SD cutoff was the study by Choudhury et al.,[16] which used a value inferior to the 61st percentile of the median of the NCHS 1977 growth chart reference.

The time interval between the exposure event and outcome assessment varied widely across studies, spanning from in utero or infancy exposure to assessments conducted months or years later (up to approximately 6 years).

The risk of bias was assessed using tools appropriate to each study design. Overall, most studies demonstrated a low-to-moderate risk of bias, with the most common concerns related to exposure measurement and potential confounding. A detailed appraisal is provided in Tables S4–S6 (Supplementary Materials).

Meta-analysis of the prevalence of malnutrition

Ten studies reported the prevalence of wasting after an extreme weather event,[20,23,24,26,28,30,35,37,38,40] ten reported the prevalence of stunting,[15,18,26,28,30,31,33,36,38,40] and eight reported the prevalence of underweight.[16,24,26–28,30,31,38] Meta-analyses were performed for all three outcomes.

For the prevalence of stunting, the estimate corresponding to the 5–60-month age group from ref. [18] was used, as it was the most comparable with the other studies. Moreover, two studies[30,31] investigated the same population and were included only once in the pooled estimate.[30] The pooled prevalence of wasting excluded ref. [20] because no clear age cut-off was

Table 1. Selected characteristics of the included studies ($n = 26$) assessing malnutrition after extreme weather events.

Author, Year (ref)	Country	Study type	Sample size	Age range	Results	
					Malnutrition prevalence in exposed	Risk measurement connected to exposure
Study Assessing Drought Exposure						
Amegbor et al.[21]	Uganda	cross-sectional	3624	0–5 years	NS	Exp(B) = 1.272 *for stunting, robust standard error = 0.141*
Bahru et al.[17]	Ethiopia	cohort	2000	5–12 years	NS	Long-term exposure to drought was negatively associated with HAZ (difference vs. non-exposed: −2.90; 95% CI: −2.97 to −2.83).
Bauer et al.[22]	Kenya	cross-sectional	924	0–5 years	NS	*A 1 SD increase in NDVI z-score is associated with a 0.52 SD increase in MUAC z-score.*
Carnell et al.[23]	Mali	cross-sectional	1798	0–5 years	28% of children were wasted.	NS
Dimitrova et al.[39]	India	cross-sectional	256,244	0–5 years	NS	Exposure to abnormally dry monsoon seasons during pregnancy and infancy was associated with a reduced risk of stunting (OR 0.95, 95% CI 0.91-1.00, and 0.97, 95% CI 0.93-1.00, respectively), and during infancy only, with a reduced risk of wasting (OR 0.89, 95% CI 0.83-0.95).
Kumar et al.[24]	India	cohort	3206	0–5 years	27.3% of children were wasted, 63.4% were underweight	NS
Le et al.[25]	Bangladesh	cohort	28,600	0–5 years	NS	In-utero drought exposure reduces HAZ, WHZ, and WAZ by 0.10–0.11 SD in children <5 years.
Mahapatra et al.[26]	India	cross-sectional	751	0–5 years	27.9% of children were wasted, 41.8% stunted, and 57.1% underweight.	NS
Mason et al.[27]	Multiple African Countries	case-control	93	6–59 months	25.8% of children are underweight	Underweight prevalence higher in drought years: +3.4 PP in Southern Africa (24.7% vs 21.3%) and +7.6 PP in the Horn (28.0% vs 20.4%).
Petscavage et al.[40]	Sub-Saharan African countries	cross-sectional	320,479	0–5 years	After exposure to any EWE, 13.0% (12.2% – 13.9%) of children were wasted, 34.3% (33.4–35.3%) stunted.	Drought exposure associated with reduced risk of stunting (RR = 0.94 [0.90–0.98] at 3 months; 0.90 [0.86–0.93] at 12 months) but increased risk of wasting (RR = 1.50 [1.40–1.61] at 3 months; 1.35 [1.26–1.44] at 12 months).
Renzaho et al.[28]	Mozambique	cross-sectional	874	6–59 months	8.0% (95% CI: 6.2–9.8) of children were wasted, 37.0% (33.8–40.2) stunted, and 26.9% (24.0–29.9) underweight.	NS
Shaw et al.[29]	India	cross-sectional	259,627	0–5 years	NS	SDCI[a] negatively associated with stunting burden ($\beta = -5.95$, $p = 0.015$), but not with wasting or underweight.
Singh et al.[30]	India	cross-sectional	903	0–5 years	28% of children were wasted, 53% stunted, and 60% underweight.	NS
Singh et al.[31]	India	cross-sectional	903	0–5 years	25.8% of children were stunted, and 38.5% underweight.	NS
Tadele et al.[15]	Ethiopia	cross-sectional	362	6–23 months	21.8% of children were stunted.	NS
Study Assessing Flood Exposure						
Choudhury et al.[16]	Bangladesh	cohort	888	3–23 months	11% of children were underweight.	Underweight increased from 5% to 11% post-flood.
Del Ninno et al.[32]	Bangladesh	cohort	499	0–59 months	NS	Flood-exposed children had lower HAZ than unexposed.

Table 1. continued

Author, Year (ref)	Country	Study type	Sample size	Age range	Results	
					Malnutrition prevalence in exposed	**Risk measurement connected to exposure**
Dimitrova et al.[39]	India	cross-sectional	256,244	0–5 years	NS	Exposure to floods during monsoon season during pregnancy or infancy was associated with an increased risk of stunting (OR 1.04, 95% CI 1.00-1.08, OR 1.04, 95% CI 1.01-1.07, respectively). Wasting showed no significant association (OR 0.91, 95% CI 0.83–1.00).
Gaire et al.[33]	Nepal	cohort	2111	0–5 years	Stunting prevalence was 31.6%	Floods were associated with an decreased risk of child stunting: OR = 0.57 (95% CI: 0.31–0.96) for severe and 0.66 (0.41–0.94) for moderate stunting.
Haq et al.[20]	Pakistan	cross-sectional	656	NS	Wasting prevalence was 10.1%.	NS
Haq et al.[18]	Pakistan	cross-sectional	298	0–12 years	Stunting prevalence was 50.7% (95% CI: 45.0–56.3) among children aged 5–60 months and 40.5% (36.9–44.4) among children aged 0–12 years.	NS
Haq et al.[34]	Pakistan	cross-sectional	298	6–59 months	46% of children had MUAC < 2 SD.	NS
Hossain et al.[35]	Bangladesh	cross-sectional	180	6–59 months	17% of children were wasted during the flood, 12% after 3 months.	NS
Petscavage et al.[40]	Sub-Saharan African countries	cross-sectional	320,479	0–5 years	13.0% (12.2% – 13.9%) of children were wasted, 34.3% (33.4%-35.3%) stunted.	Flood exposure associated with slightly increased risk of stunting (RR = 1.10 [1.05–1.15] at 3 months; 1.05 [1.02–1.08] at 12 months) and higher risk of wasting (RR = 1.66 [1.54–1.80] at 3 months; 1.48 [1.41–1.56] at 12 months).
Rahman et al.[36]	Bangladesh	cross-sectional	800	12–59 months	41.3% of children were stunted.	Stunting OR = 2.14 (1.53–2.28) for exposed vs. unexposed children.
Rodriguez-Llanes et al.[37]	India	cohort	900	6–59 months	Children in communities flooded in 2006 and 2008 had higher wasting prevalence (51.6%; 95% CI: 45.0–58.2) compared with children in villages flooded only in 2008 (41.4%; 95% CI: 26.4–56.4).	Children exposed to floods twice had higher prevalence of wasting compared with unexposed children (PR = 2.30; 95% CI: 1.86–2.85), similar to those flooded only in 2008 (PR = 1.94; 95% CI: 1.43–2.63).
Rodriguez-Llanes et al.[38]	India	cross-sectional	352	6–59 months	12.2% of children were wasted, 38.7% were stunted, 20.9% underweight.	Children in flooded households had higher prevalence of stunting (PR = 1.60; 95% CI: 1.05–2.44) and underweight (PR = 1.86; 95% CI: 1.04–3.30) compared with children in non-flooded households.
Rosinger et al.[19]	Bolivia	cohort	103	2–12 years	NS	HAZ increased by 0.07 (95% CI: −0.05, 0.18), WAZ increased by 0.18 (95% CI: 0.09, 0.27), and BMI-for-age Z-score increased by 0.09 (95% CI: 0.01, 0.17). Children in distant communities lost WAZ and BMI-for-age Z-scores over two months post-flood, unlike children in nearby communities.

EWE extreme weather events, *HAZ* height for age Z-score, *MUAC* mid-upper-arm circumference, *NDVI* Normalized Difference Vegetation Index, *OR* odds ratio, *PP* percent points, *PR* prevalence ratio, *RR* relative risk, *SD* standard deviation, *SDCI* Scaled Drought Condition Index, *SPEI* standardised precipitation and evapo-transpiration index, *WAZ* weight for age Z-scores, *WHZ* weight for height Z-scores.

[a]Values range from 0 (severe drought conditions) to 1 (wet conditions). Therefore, negative regression coefficients indicate higher stunting under more severe drought conditions.

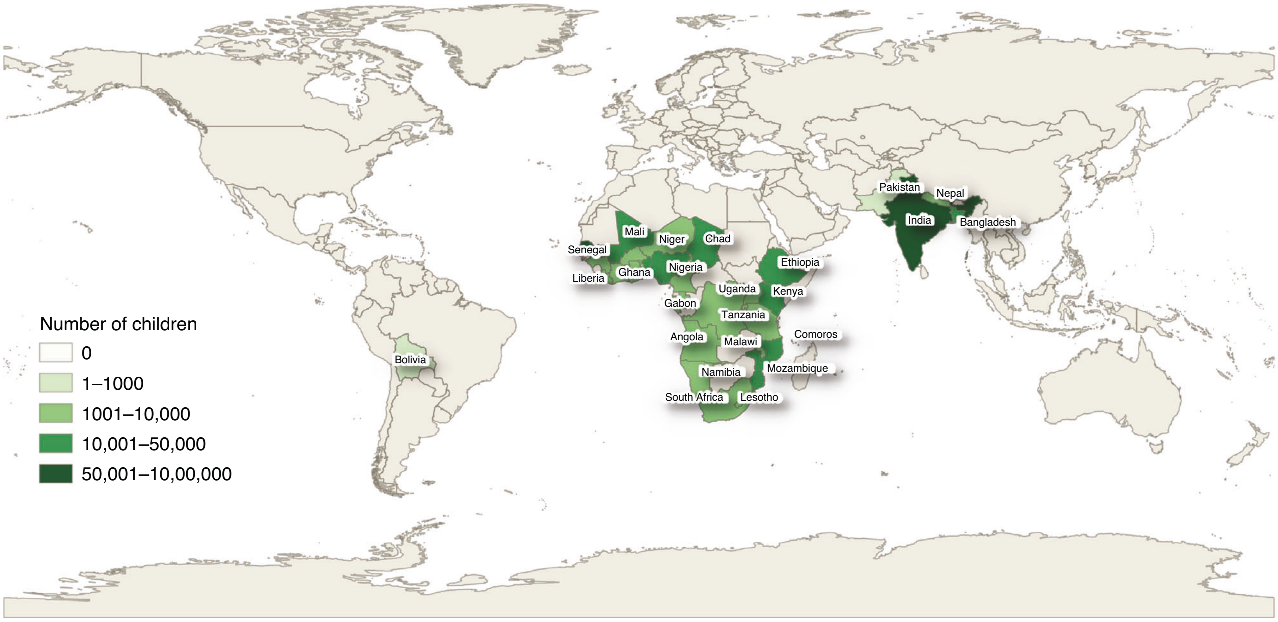

Fig. 2 Map showing the spatial distribution of participants included in the systematic review (*n* = 886,144). Map created using QGIS 3.44.3. The legend includes only the classes corresponding to those present in the image.

specified, and ref. [37] because prevalence estimates were reported separately for children exposed to one versus two flood events, preventing inclusion of a single non-overlapping estimate in the meta-analysis. The pooled prevalence of underweight did not include the study by Choudhury,[16] which was excluded after sensitivity analysis because the definition used differed from the others (being based on older reference standards and more consistent with a prevalence of severe underweight). Furthermore, to avoid duplicating data from an overlapping population, only one of the two studies by Singh et al.[30] was retained in the pooled estimate.

Therefore, three meta-analyses were conducted, including eight studies for wasting (three on floods[35,38,40] and five on droughts[23,24,26,28,30]), nine studies for stunting (five on floods[18,33,36,38,40] and four on droughts[15,26,28,30]), and six for underweight (one on floods[38] and five on droughts[24,26–28,30]).

The pooled prevalence of wasting, stunting, and underweight following an extreme weather event (either drought or flood) was 19% (95% CI: 12–28%), 39% (95% CI: 31–48%), and 42% (95% CI: 22–64%), respectively (Figs. 3–5). These estimates were based on 37,072, 32,948, and 6018 children, respectively. When the study by Choudhury et al.[16] was included in the sensitivity analysis, the pooled prevalence of underweight changed to 36% (95% CI: 22–64%), based on 6906 children (Fig. S1, Supplementary Material). When the study by Haq et al.[20] was included in the sensitivity analysis, the pooled prevalence of wasting changed to 18% (95% CI: 12–26%), based on 37,728 children (Fig. S2, Supplementary Material).

Subgroup analyses by type of event revealed no significant difference in stunting prevalence between drought- and flood-affected populations ($p = 0.68$). In contrast, the prevalence of wasting differed significantly ($p = 0.04$), with higher prevalence following droughts (22%) compared with floods (13%). Substantial heterogeneity was observed in all analyses ($I^2 > 95\%$).

Association between extreme weather events and malnutrition

Fifteen studies[16,17,19,21,22,25,27,29,32,33,36–40] assessed the association between malnutrition and extreme weather events. Among these six reported associations after drought exposure,[17,21,22,25,27,29] seven reported associations following flood exposure,[16,19,32,33,36–38] and two evaluated the risk of malnutrition following either drought or flood exposure.[39,40]

Drought exposure

Petscavage et al.[40] reported that exposure to drought during infancy was associated with an increased risk of wasting, with a relative risk (RR) of 1.50 (95% CI: 1.40–1.61) at 3 months and 1.35 (95% CI: 1.26–1.44) at 12 months after exposure. In contrast, Dimitrova et al.[39] found that exposure to an abnormally dry monsoon season during infancy was associated with a reduced risk of wasting among Indian children.

Regarding stunting, Petscavage et al.[40] observed a decreased risk at both 3 and 12 months following drought exposure, and Dimitrova et al.[39] also reported a lower risk of stunting after both in-utero and infancy exposure to abnormally dry monsoon seasons. Conversely, Shaw et al.[29] and Amegbor et al.[21] reported an increased risk of stunting following exposure, while Bahru et al.[17] found that long-term drought exposure was associated with lower height-for-age z-scores (HAZ).

For underweight, Mason et al.[27] found a higher prevalence during drought years, with increases of +3.4 percentage points in Southern Africa and +7.6 percentage points in the Horn of Africa. Similarly, Le et al.[25] reported that in-utero drought exposure was associated with lower weight-for-age z-scores (WAZ).

Finally, Bauer et al.[22] found that drought severity, measured by a reduction in the normalized difference vegetation index (NDVI), was associated with a 0.52 standard deviation decrease in MUAC.

Flood exposure

Petscavage et al.[40] found an increased risk of wasting among children exposed to floods, both at 3 and 12 months after the event, with RRs of 1.66 (95% CI: 1.54–1.80) and 1.48 (95% CI: 1.41–1.56), respectively. Similarly, Rodriguez-Llanes et al.[37] reported higher prevalence ratios (PRs) of wasting among children exposed to floods—both once and twice—compared with unexposed children, with PRs of 2.30 (95% CI: 1.86–2.85) and 1.94 (95% CI: 1.43–2.63), respectively. In contrast, Dimitrova et al.[39] found no statistically significant association between monsoon flood exposure and wasting (OR = 0.91, 95% CI: 0.83–1.00).

Regarding stunting, Petscavage et al.[40] found a slightly increased risk at both 3 and 12 months after flood exposure,

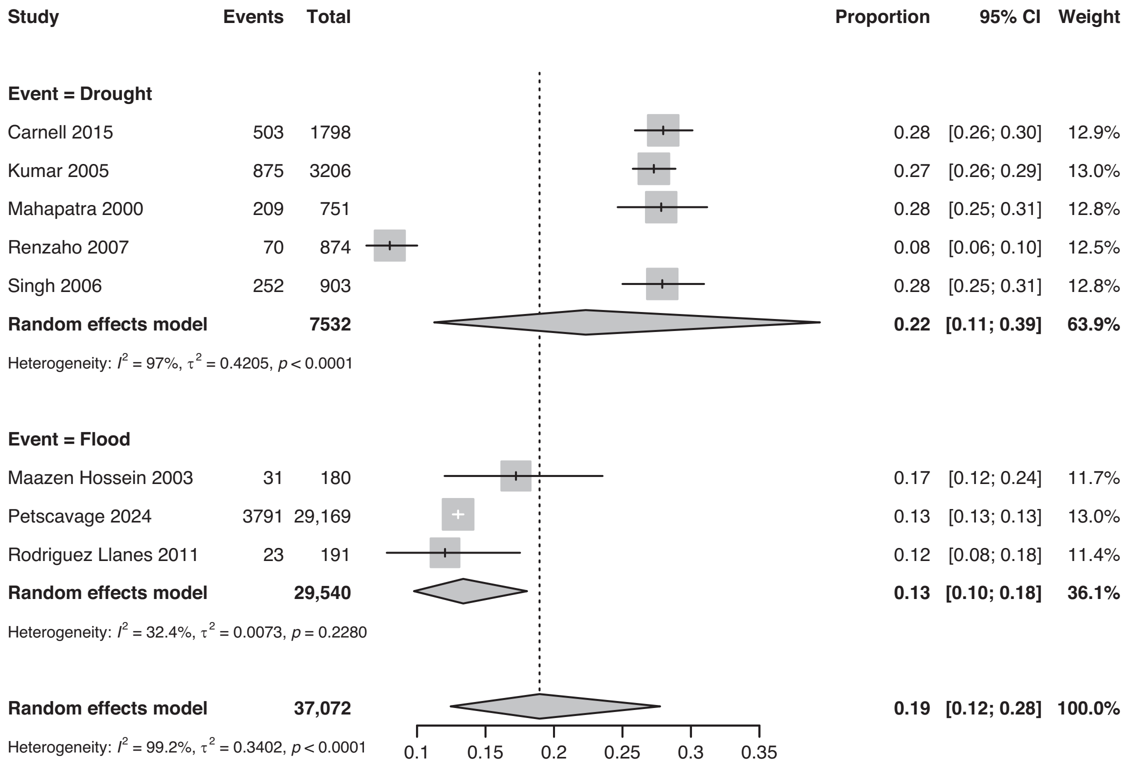

Fig. 3 Random-effects meta-analysis of the prevalence of wasting among children after an extreme weather event, divided by event type (drought or flood).

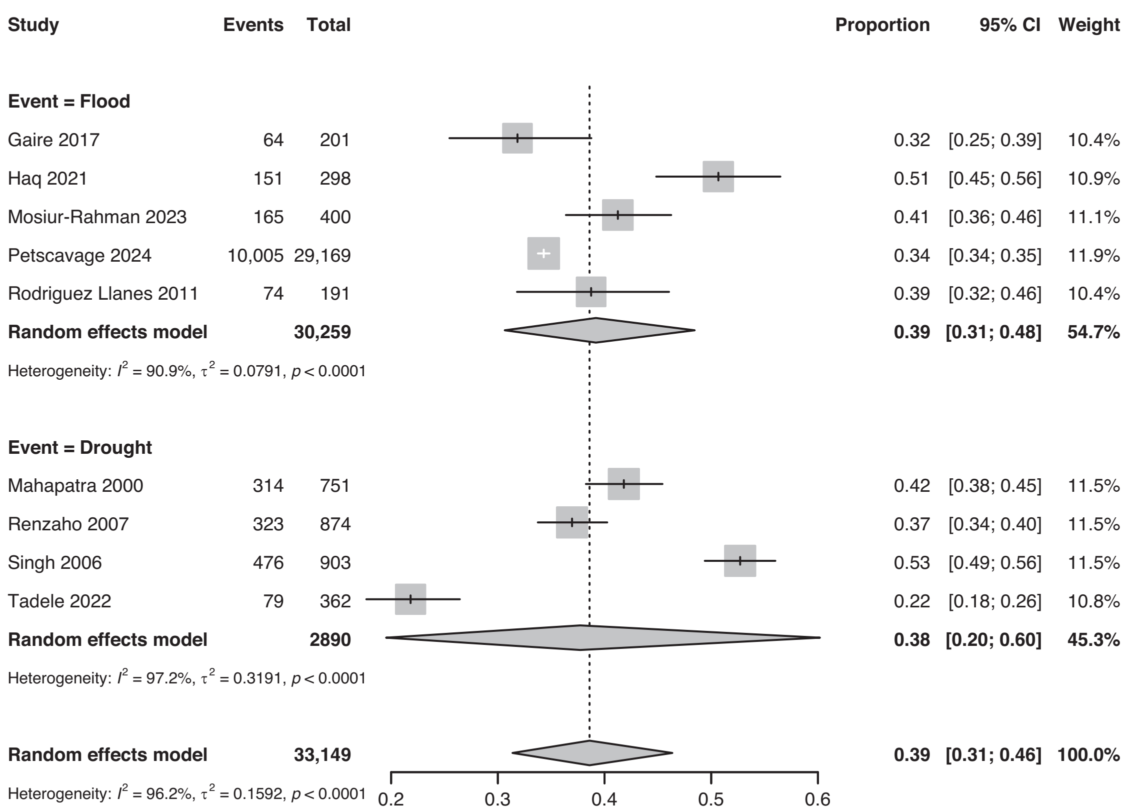

Fig. 4 Random-effects meta-analysis of the prevalence of stunting among children after an extreme weather event, divided by event type (drought or flood).

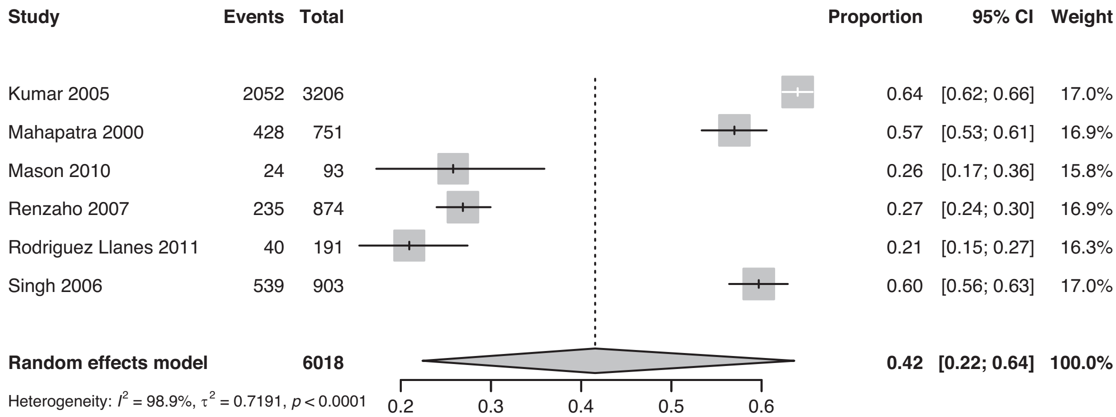

Fig. 5 Random-effects meta-analysis of the prevalence of underweight among children after an extreme weather event.

with RRs of 1.10 (95% CI: 1.05–1.15) and 1.05 (95% CI: 1.02–1.08), respectively. Dimitrova et al.[39] also reported a slight increased risk after both in-utero and infancy exposure, while Rahaman et al.[36] reported nearly a twofold increase in risk (OR = 2.14; 95% CI: 1.53–2.28) among exposed children. Rodriguez-Llanes et al.[38] also found a higher PR of 1.60 (95% CI: 1.05–2.44) in exposed compared with unexposed children. Consistent with these findings, Del Nino et al.[32] reported lower HAZ among exposed children, whereas Rosinger et al.[19] did not observe significant differences in HAZ between exposed and unexposed groups. Contrary to the general trend, Gaire et al.[33] identified a reduced likelihood of severe and moderate stunting among flood-exposed children (severe: OR = 0.57; 95% CI: 0.31–0.96; moderate: OR = 0.66; 95% CI: 0.41–0.94).

For underweight, Dimitrova et al.,[39] Choudhury et al.,[16] and Rodriguez-Llanes et al.[38] found increased prevalence or risk following flood exposure. In contrast, Rosinger et al.[19] observed higher WAZ among children after flood exposure; however, this effect was not evident in communities located farther from affected areas, where post-disaster aid distribution was limited.

Meta-analysis of associations between extreme weather events and stunting

Five studies provided risk estimates for stunting: four reported OR[21,33,36,39] and one reported RR.[40] Among these, one study[21] examined drought, two[33,36] investigated floods, and two[39,40] assessed both event types. Consequently, studies investigating both exposures[39,40] contributed data to both analysis groups.

Separate random-effects meta-analyses were performed for the risk of stunting following floods (four studies) and droughts (three studies). Petscavage et al.[40] reported results at both 3 and 12 months post-exposure; therefore, sensitivity analyses were conducted using each period.

The pooled OR for stunting was 1.08 (95% CI: 0.98–1.19) following floods and 0.96 (95% CI: 0.90–1.02) following droughts, indicating no statistically significant associations when considering the 12-month estimates. Using the 3-month data, the association with floods became statistically significant (OR = 1.12; 95% CI: 1.01–1.25), while the association with drought remained non-significant (OR = 0.95; 95% CI: 0.87–1.04). Forest plots for all analyses are presented in the Supplementary Material (Fig. S3–S5).

DISCUSSION

Across 26 studies including more than 320,000 children, the pooled prevalence of undernutrition following droughts and floods was substantial: 19% for wasting, 39% for stunting, and 42% for underweight. Wasting prevalence was significantly higher after droughts than after floods, while no difference was observed for stunting. Meta-analyses of risk estimates indicated no statistically significant long-term association between extreme weather events and stunting, although a small transient increase in risk was observed within three months of flood exposure. Considerable heterogeneity across studies underscores variability in exposure definitions, population contexts, and timing of outcome assessments.

Although the prevalence of malnutrition following extreme weather events varies depending on several factors—such as pre-event nutritional status, demographic characteristics (e.g., age and sex), incidence of gastrointestinal diseases, infant and young child feeding (IYCF) practices, and parental or socioeconomic conditions[44,45]—our pooled estimates provide a useful overall approximation, highlighting patterns and potential risk areas while underscoring the need for more context-specific data.

Our findings align with previous reviews, indicating inconsistent associations between drought and child undernutrition.[46] In contrast, our results regarding floods corroborate those of Agabiirwe et al.,[44] showing a stronger link between flooding and acute forms of undernutrition such as wasting. Taken together, current evidence suggests that floods are more likely to precipitate short-term nutritional crises, whereas droughts may exacerbate chronic food insecurity, particularly in already vulnerable regions.

The higher prevalence of wasting observed among drought-affected children suggests a distinct geographical and climatic pattern in the malnutrition–disaster relationship. In African contexts, drought—responsible for over 88% of all climate-related disasters on the continent[47]—was consistently associated with acute malnutrition and underweight,[22,27,40] likely due to its effects on agricultural productivity, water scarcity, and household food availability.[5] Interestingly, a South African study reported significant changes in child nutritional status during and after a severe drought, affecting all forms of malnutrition. The most pronounced increases were observed in stunting and obesity, which may reflect hidden hunger exacerbated by reduced food access and drought-related rises in food prices.[48] Droughts, which often represent a chronic environmental stressor in arid or semi-arid areas, may push already food-insecure populations into acute nutritional crisis even before conditions reach the threshold of an "extreme" event. This can trigger a vicious cycle in which food shortages and poor diet quality weaken immune function, heightening susceptibility to infections that further aggravate undernutrition.[47] Drought-related water scarcity can further exacerbate the situation by reducing the quality of drinking water[17] and impairing sanitation and hygiene practices.[48] Supporting these findings, a study not included in the present review because results from low- and lower-middle-income countries could not be separated from those of upper-middle-income countries found that drought exposure was associated with lower height-for-age Z-scores, further reinforcing the relationship between drought conditions and impaired child growth.[49]Conversely, in South Asian countries—where floods are more common—periodic inundations disrupt agro-food systems and essential infrastructure such as water, sanitation, and hygiene services.[50] These disruptions increase the risk of fecal–oral and vector-borne diseases, which in turn contribute to both acute and chronic forms of malnutrition. For example, in flood-affected areas of Pakistan, underweight prevalence was higher among children living in households without toilet facilities, and access to unimproved water sources was identified as a major risk factor.[51] Recurrent or prolonged flood exposure may also affect maternal and infant nutrition through persistent food insecurity and repeated infections, thereby indirectly influencing linear growth and stunting over time.[52] Similar intergenerational nutritional effects have been observed outside South Asia; for instance, evidence from Jamaica, a middle-income tropical setting, suggests that recurrent hurricanes during pregnancy are associated with poorer childhood weight-for-age and weight-for-height outcomes in early childhood, indicating broader vulnerability to repeated climate shocks.[53]

Overall, the causal link between extreme weather events and malnutrition remains complex and context-dependent, and is still open to discussion. At the same time, the high prevalence of malnutrition observed in low- and lower-middle-income countries is alarming. These countries are also those most frequently affected by extreme weather events. Such findings highlight the need for a coordinated, multilateral, and long-term response to the interlinked challenges of climate change, food insecurity, and child malnutrition. This response requires close coordination between humanitarian and development policymaking to ensure that rapid actions following extreme weather events are aligned with longer-term efforts to build climate resilience and reduce the carbon footprint of agri-food systems—efforts that both strengthen resilience to climate stressors and support a sustainable, low-carbon transition.[54] Integrating climate resilience into early childhood nutrition and health planning is essential to safeguard child growth and development. Priority actions include pre-allocating emergency financing, strengthening disaster risk reduction and preparedness, reinforcing local health and food systems, delivering integrated emergency support, and improving coordination across global, national, and community actors. These efforts should be guided by context-specific risk assessments and aligned with national climate, health, and nutrition strategies.[55] Strengthened preparedness systems—including evidence-based response planning, electronic malnutrition surveillance and improved early warning systems—are critical for timely action.[55–57] Anticipatory approaches using predictive analytics can enable early, pre-shock interventions that protect vulnerable households.[58] Sustained community engagement is also vital to maintaining essential nutrition and health services during climate shocks.[59] In climate-affected settings, responses should combine life-saving nutrition interventions (e.g., IYCF support, micronutrient supplementation, treatment of acute malnutrition) with measures that strengthen food security, health, and WASH systems. Across drought-, flood-, and cyclone-prone LMICs, priorities include climate-resilient health services, safe water and sanitation infrastructure, strengthened surveillance and immunization systems, and access to specialized nutritious foods to reduce climate-sensitive disease risks.[56] Support for climate-smart agriculture and livelihood recovery further helps households rebuild resilience and reduce vulnerability to future shocks.

Limitations

This review focused on studies conducted in countries classified as low- or lower-middle-income according to the World Bank. However, this classification is based solely on Gross National Income and encompasses substantial heterogeneity in climatic, geographical, demographic, and cultural conditions.[60] Although we applied strict inclusion criteria regarding study setting, some multi-country studies included a small proportion of participants from upper-middle-income countries. We retained studies when the contribution of participants from upper-middle-income countries was negligible and could be clearly identified. For example, in Petscavage et al., only 0.33% of the sample originated from South Africa, and this proportion was unlikely to influence the overall findings. Conversely, we excluded studies when data from eligible and non-eligible country income groups could not be separated and the proportion of participants from upper-middle-income countries could not be determined. For example, Cooper et al.,[49] which examined the association between drought exposure and child stunting, was excluded because the study combined data from countries across different income classifications and did not provide sufficient information to isolate results from low- and lower-middle-income countries. Consequently, we could not ascertain whether the study population met our predefined eligibility criteria. We were unable to retrieve the full text of one study conducted after a drought in India. With a small sample size (555 children) and being over 30 years old, its exclusion is unlikely to have materially influenced the pooled estimates.[61]

Definitions of both exposure and outcome were not fully consistent across studies, reflecting the absence of universally accepted scientific criteria for what constitutes an "extreme weather event",[62] as well as variability in the growth charts used to assess nutritional status Although this review focused on identifiable extreme weather events, a broader conceptualization of climate-related exposures, including precipitation and temperature anomalies without a discrete extreme event, could capture additional evidence and may lead to different estimates of the association between climatic exposures and child nutritional outcomes. In addition, the time interval between exposure and outcome assessment varied substantially among studies, potentially introducing bias in effect estimates.

Research gaps

Research on the impact of extreme weather events on childhood overnutrition in LMICs remains limited, despite a more than fourfold increase in overweight prevalence among 5–19-year-olds in low-income countries and a threefold increase in lower-middle-income countries between 2000 and 2022.[63] Natural disasters, extreme temperatures, heavy rainfall, and seasonal variations may increase the risk of overweight and obesity by exacerbating food insecurity or reducing physical activity, but current evidence is insufficient to establish causal links.[64]

By 2025, obesity had surpassed underweight among school-age children and adolescents in all regions except Sub-Saharan Africa and South Asia,[63] highlighting the urgent need for research into pediatric overnutrition. Studies on the effects of tropical storms, hurricanes, and wildfires on child malnutrition in LMICs are scarce, despite rising exposure to cyclones, extreme rainfall, and landscape fires in Africa, Asia, and small island nations.[65–67]

A standardized definition of extreme weather events, particularly droughts, is essential for accurately assessing their nutritional impact. Evidence is also limited for children older than 5 years, especially adolescents, whose vulnerabilities and nutritional needs differ from younger children. Addressing these gaps is critical to inform targeted interventions in the context of climate change. Finally, reproducibility in this field is constrained by the frequent absence of baseline data on nutritional status prior to extreme events, underscoring the need for longitudinal studies.

CONCLUSION

Wasting, stunting, and underweight remain highly prevalent among children living in low- and lower-middle-income countries affected by extreme weather events. The evidence linking such events to child malnutrition, however, remains limited and inconsistent. Major research gaps include the heterogeneity in definitions of extreme weather events, the diversity of reference growth charts used to define malnutrition, and the lack of reliable pre-event nutritional data. Addressing these gaps will be crucial to advancing understanding of how climate-related shocks affect child nutrition and to designing effective, context-specific interventions.

DATA AVAILABILITY

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

REFERENCES

1. UNICEF; WHO; World Bank Group (International Bank for Reconstruction and Development). *Levels and Trends in Child Malnutrition: UNICEF/WHO/World Bank Group Joint Child Malnutrition Estimates. Key Findings of the 2025 Edition* (UNICCEF, 2025).
2. Zhang, X. et al. Global prevalence of overweight and obesity in children and adolescents: a systematic review and meta-analysis. *JAMA Pediatr.* **178**, 800–813 (2024).
3. UNICEF. *The Climate Crisis is a Child Rights Crisis: Introducing the Children's Climate Risk Index* (UNICEF, 2021).
4. Fanzo, J. C. & Downs, S. M. Climate change and nutrition-associated diseases. *Nat. Rev. Dis. Prim.* **7**, 90 (2021).
5. Agostoni, C. et al. Interlinkages between climate change and food systems: the impact on child malnutrition-narrative review. *Nutrients* **15**, 416 (2023).
6. Myers, S. S. et al. Climate change and global food systems: potential impacts on food security and undernutrition. *Annu Rev. Public Health* **38**, 259–277 (2017).
7. Alderman, K., Turner, L. R. & Tong, S. Floods and human health: a systematic review. *Environ. Int.* **47**, 37–47 (2012).
8. Food Security Information Network (FSIN), Global Network Against Food Crises (GNAFC). *Global Report on Food Crisis 2025 [Internet]*. [cited 2 Feb 2026]. Available from: https://wfp.tind.io/record/130664 (FSIN/GNAC, 2025).
9. Lieber, M. et al. A systematic review and meta-analysis assessing the impact of droughts, flooding, and climate variability on malnutrition. *Glob. Public Health* **17**, 68–82 (2022).
10. Desta, D. T., Teferra, T. F. & Gebremedhin, S. The effect of rainfall and temperature patterns on childhood linear growth in the tropics: systematic review and meta-analysis. *Int. J. Environ. Res. Public Health* **21**, 1269 (2024).
11. La Vecchia, A. et al. Impact of extreme weather events on malnutrition among children and adolescents in low- and middle-income countries [Internet]. Available from https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42024623330 (2024).
12. Page, M. J. et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, **71** (2021).
13. Eric, M., Kathryn, E. Y., Shwetha, G. E. World Bank country classifications by income level for 2024–2025 [Internet]. Available from: https://blogs.worldbank.org/en/opendata/world-bank-country-classifications-by-income-level-for-2024-2025 (2024).
14. Ouzzani, M., Hammady, H., Fedorowicz, Z. & Elmagarmid, A. Rayyan—a web and mobile app for systematic reviews. *Syst. Rev.* **5**, 210 (2016).
15. Tadele, T. T., Gebremedhin, C. C., Markos, M. U. & Fitsum, E. L. Stunting and associated factors among 6-23 month old children in drought vulnerable kebeles of Demba Gofa district, southern Ethiopia. *BMC Nutr.* **8**, 9 (2022).
16. Choudhury, A. Y. & Bhuiya, A. Effects of biosocial variables on changes in nutritional status of rural Bangladeshi children, pre- and post-monsoon flooding. *J. Biosoc. Sci.* **25**, 351–357 (1993).
17. Bahru, B. A., Bosch, C., Birner, R. & Zeller, M. Drought and child undernutrition in Ethiopia: a longitudinal path analysis. *PloS One* **14**, e0217821 (2019).
18. Haq, I. U. et al. Prevalence and determinants of stunting among preschool and school-going children in the flood-affected areas of Pakistan. *Braz. J. Biol. Rev. Brasleira Biol.* **82**, e249971 (2021).
19. Rosinger, A. Y. et al. When the flood passes, does health return? A short panel examining water and food insecurity, nutrition, and disease after an extreme flood in lowland Bolivia. *Am. J. Hum. Biol. J. Hum. Biol. Counc.* **35**, e23806 (2023).
20. Haq, I. U. et al. Risk factors of wasting-based malnutrition in the flood-affected areas of Pakistan: a cross-sectional study. *Ecol. Food Nutr.* **63**, 343–354 (2024).
21. Amegbor, P. M., Zhang, Z., Dalgaard, R. & Sabel, C. E. Multilevel and spatial analyses of childhood malnutrition in Uganda: examining individual and contextual factors. *Sci. Rep.* **10**, 20019 (2020).
22. Bauer, J. M. & Mburu, S. Effects of drought on child health in Marsabit District, Northern Kenya. *Econ. Hum. Biol.* **24**, 74–79 (2017).
23. Carnell, M. A. & Guyon, A. B. Nutritional status, migration, mortality, and measles vaccine coverage during the 1983–1985 drought period: Timbuktu, Mali. *J. Trop. Pediatr.* **36**, 109–113 (1990).
24. Kumar, S. & Bhawani, L. Managing child malnutrition in a drought-affected district of Rajasthan-a case study. *Indian J. Public Health* **49**, 198–206 (2005).
25. Le, K. & Nguyen, M. Droughts and child health in Bangladesh. *PloS One* **17**, e0265617 (2022).
26. Mahapatra, A. et al. Nutritional status of preschool children in the drought-affected Kalahandi district of Orissa. *Indian J. Med. Res.* **111**, 90–94 (2000).
27. Mason, J. B. et al. Impact of drought and HIV on child nutrition in Eastern and Southern Africa. *Food Nutr. Bull.* **31**, S209–S218 (2010).
28. Renzaho, A. M. N. Mortality rates, prevalence of malnutrition, and prevalence of lost pregnancies among the drought-ravaged population of Tete Province, Mozambique. *Prehosp. Disaster Med.* **22**, 26–34 (2007).
29. Shaw, S., Khan, J. & Paswan, B. Spatial modeling of child malnutrition attributable to drought in India. *Int. J. Public Health* **65**, 281–290 (2020).
30. Singh, M. B., Fotedar, R., Lakshminarayana, J. & Anand, P. K. Studies on the nutritional status of children aged 0–5 years in a drought-affected desert area of western Rajasthan, India. *Public Health Nutr.* **9**, 961–967 (2006).
31. Singh, M. B., Lakshminarayana, J., Fotedar, R. & Anand, P. K. Childhood illnesses and malnutrition in under five children in drought affected desert area of western Rajasthan, India. *J. Commun. Dis.* **38**, 88–96 (2006).
32. del Ninno, C. & Lundberg, M. Treading water. The long-term impact of the 1998 flood on nutrition in Bangladesh. *Econ. Hum. Biol.* **3**, 67–96 (2005).
33. Gaire, S., Delbiso, T. D., Pandey, S. & Guha-Sapir, D. Impact of disasters on child stunting in Nepal. *Risk Manag Health. Policy* **9**, 113–127 (2016).
34. Haq, I. U. et al. Risk factors of Mid-upper Arm Circumference (MUAC) based child malnutrition in the flood-affected areas of Pakistan: a cross-sectional study. *Ecol. Food Nutr.* **60**, 491–507 (2021).
35. Hossain, S. M. & Kolsteren, P. The 1998 flood in Bangladesh: is different targeting needed during emergencies and recovery to tackle malnutrition? *Disasters* **27**, 172–184 (2003).
36. Rahman, M. et al. Factors mediating the association between recurring floods and child chronic undernutrition in northern Bangladesh. *Nutrient* **119**, 112300 (2024).
37. Rodriguez-Llanes, J. M., Ranjan-Dash, S., Mukhopadhyay, A. & Guha-Sapir, D. Flood-exposure is associated with higher prevalence of child undernutrition in rural Eastern India. *Int. J. Environ. Res. Public Health* **13**, 210 (2016).
38. Rodriguez-Llanes, J. M. et al. Child malnutrition and recurrent flooding in rural eastern India: a community-based survey. *BMJ Open* **1**, e000109 (2011).
39. Dimitrova, A. & Bora, J. K. Monsoon weather and early childhood health in India. *PloS One* **15**, e0231479 (2020).
40. Petscavage, K., Mutua, M. K., Wagner, A. L. & Treleaven, E. Associations between extreme weather events and child undernutrition: evidence from sub-Saharan Africa, 2010-2019. *J. Epidemiol. Community Health* **79**, 359–365 (2025).
41. Hamill, P. V. et al. NCHS growth curves for children birth-18 years. United States. *Vital-. Health Stat.* **11**, 1–74 (1977).
42. Kuczmarski, R. J. et al. 2000 CDC growth charts for the United States: methods and development. *Vital-. Health Stat.* **11**, 1–190 (2002).
43. WHO Multicentre Growth Reference Study Group WHO Child Growth Standards based on length/height, weight and age. *Acta Paediatr.* **450**(Suppl 2006), 76–85 (1992).
44. Agabiirwe, C. N., Dambach, P., Methula, T. C. & Phalkey, R. K. Impact of floods on undernutrition among children under five years of age in low- and middle-income countries: a systematic review. *Environ. Health* **21**, 98 (2022).
45. Phalkey, R. K. et al. Systematic review of current efforts to quantify the impacts of climate change on undernutrition. *Proc. Natl. Acad. Sci. USA* **112**, E4522–E4529 (2015).
46. Belesova, K. et al. Drought exposure as a risk factor for child undernutrition in low- and middle-income countries: A systematic review and assessment of empirical evidence. *Environ. Int.* **131**, 104973 (2019).
47. Lombe, P., Carvalho, E. & Rosa-Santos, P. Drought dynamics in Sub-Saharan Africa: impacts and adaptation strategies. *Sustainability* **16**, 9902 (2024).
48. Drysdale, R. E., Bob, U. & Moshabela, M. Coping through a drought: the association between child nutritional status and household food insecurity in the district of iLembe, South Africa. *Public Health Nutr.* **24**, 1052–1065 (2021).
49. Cooper, M. W. et al. Mapping the effects of drought on child stunting. *Proc. Natl. Acad. Sci. USA* **116**, 17219–17224 (2019).
50. Li, P. et al. Flood exposure contributes to under-five mortality in low- and middle-income countries. *One Earth* **8**, 101305 (2025).
51. Haq, I. U. et al. Preparedness to combat determinants of underweight-based child malnutrition in flood-affected areas of Pakistan. *BioMed. Res Int* **2022**, 6464901 (2022).

52. Hanson, M. A. & Gluckman, P. D. Early developmental conditioning of later health and disease: physiology or pathophysiology? *Physiol. Rev.* **94**, 1027–1076 (2014).
53. Beuermann, D. W. & Pecha, C. J. The effects of weather shocks on early childhood development: evidence from 25 years of tropical storms in Jamaica. *Econ. Hum. Biol.* **37**, 100851 (2020).
54. Romanello M. et al. The 2025 report of the Lancet Countdown on health and climate change. *Lancet* 2025;S0140673625019191.
55. Zangerl, K. E. et al. Child health prioritisation in national adaptation policies on climate change: a policy document analysis across 160 countries. *Lancet Child Adolesc. Health* **8**, 532–544 (2024).
56. Center S. et al. The impact of climate change on public health in humanitarian settings [Internet]. [cited 4 Feb 2026]; Available from: https://gatesopenresearch.org/documents/8-71 (2024).
57. Berti, C. & La Vecchia, A. Temporal trend of child stunting prevalence and food and nutritional surveillance system. *J. Pediatr.* **99**, 99–100 (2022).
58. United Nations Office for Disaster Risk Reduction, United Nations Office for the Coordination of Humanitarian Affairs. Briefing Note: Anticipatory Action—an innovative tool at the intersection of disaster risk reduction and humanitarian response. Available from: https://www.undrr.org/publication/briefing-note-anticipatory-action-innovative-tool-intersection-disaster-risk-reduction (2024).
59. Domingo, A. et al. Examining the role of community health workers amid extreme weather events in low- and middle-income countries: a scoping review. *Public Health* **236**, 133–143 (2024).
60. Lencucha, R. & Neupane, S. The use, misuse and overuse of the "low-income and middle-income countries" category. *BMJ Glob. Health* **7**, e009067 (2022).
61. Ramnath, T. & Krishnamachari, K. A. Anthropometric measurements, deficiency signs and their relationship under drought conditions. *Indian J. Matern Child Health Publ. Indian Matern Child Health Assoc.* **4**, 42–47 (1993).
62. Cattiaux, J. & Ribes, A. Defining single extreme weather events in a climate perspective. *Bull. Am. Meteorol. Soc.* **99**, 1557–1568 (2018).
63. United Nations Children's Fund. Child Nutrition Report 2025: Feeding profit: how food environments are failing children [Internet]. United Nations; [cited 4 Feb 2026]. Available from: https://www.un-ilibrary.org/content/books/9789211594577 (2025).
64. Guo, M. et al. Impacts of climate change on childhood obesity: an updated systematic literature review. *BMJ Open* **15**, e104383 (2025).
65. Guo, Y. et al. Cyclone exposure and mortality risk of children under 5 years old: an observational study in 34 low- and middle-income countries. *PLoS Med.* **22**, e1004735 (2025).
66. Xue, T. et al. Associations between exposure to landscape fire smoke and child mortality in low-income and middle-income countries: a matched case-control study. *Lancet Planet Health* **5**, e588–e598 (2021).
67. Food Security Information Network (FSIN), Global Network Against Food Crises (GNAFC). Global Report on Food Crises 2025 September Update [Internet]. FSIN/GNAC; [cited 4 Feb 2026]. Available from: https://wfp.tind.io/record/131041 (2025).

AUTHOR CONTRIBUTIONS

A.L.V. conceptualized and designed the study and data collection methodology, performed data curation, conducted formal analysis and data interpretation, wrote the original draft, and reviewed and edited the manuscript. E.B. and B.E. performed data curation and reviewed and edited the manuscript. M.B. provided expert subject domain input (social science) and reviewed and edited the manuscript. C.A. provided expert subject domain input (pediatric nutrition) and reviewed and edited the manuscript. C.B. conceptualized the study and reviewed and edited the manuscript. A.C. conducted formal analysis, performed data interpretation, and reviewed and edited the manuscript. All authors read and approved the final manuscript.

FUNDING

This study was partially funded by the Italian Ministry of Health - Current research IRCCS.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s41390-026-05411-8.

Correspondence and requests for materials should be addressed to Adriano La Vecchia.