Foundation

Global Safety Evidence Centre

Disaster early warning systems: What works and who gets left behind?



Safety Science

Evidence Review

Briefing

1. The quick read

Extreme weather and climate-related events are increasing in frequency and intensity, causing substantial loss of life, injuries, displacement, livelihood disruption and economic damage. Early warning systems have been widely used for mitigating the impact of extreme weather events, and several individual studies have assessed their effectiveness in improving outcomes. However, there is very limited comprehensive synthesis of evidence from these studies to establish whether existing early warning systems work, for whom, at what cost, and the conditions that facilitate their successful implementation.

We conducted a comprehensive systematic review of the available literature to assess the effectiveness of existing early warning systems, their cost-effectiveness, the barriers and enablers to their successful implementation, and the views of target populations regarding their usefulness. The research was guided by a consultation group of experts in systematic review methods as well as practitioners and researchers in disaster risk management, to ensure that the findings are relevant to policy and practice.

The systematic review included synthesis of 111 studies published between 1995 and 2026, covering 54 countries and a wide range of hazards – including floods, cyclones, hurricanes or typhoons, droughts, extreme heat, earthquakes, tsunamis, landslides and wildfires. Most of the early warning systems were operated at the national level, but community-based or locally operated systems were particularly common in lower-income settings and were often focused on mitigating the impact of flooding or heavy rains.

The findings:

- **Early warning systems can reduce the impact of extreme weather and climate events**, but the strength of evidence varies by outcome, hazard type and implementation context.
- **Effectiveness depends less on the level at which the system is operated** – that is whether it is a national, community-based/local, regional, or global system – **and more on whether warnings are trusted**, timely, actionable, locally appropriate and accessible to the populations or communities that are most at risk.
- **Evidence on the effect of early warning systems in reducing deaths was mixed or unclear**. We found only one study – on tsunami early warning systems – that showed reduction in deaths.
- **For reduction in illnesses or injuries**, the evidence shows targeted benefits, such as fewer cardiac-related ambulance call-outs during extreme heat events or fewer typhoon-related injuries, but findings were inconsistent across studies.
- **For reduction in asset losses**, there was strong positive effect of early warning systems, particularly for flood-related losses. The evidence shows that warning lead time of one-hour or more, improved preparedness knowledge and early action can reduce building content damages and economic losses.
- **There were limited impact evaluations** which have looked at the effect of early warning systems on outcomes such as loss of livelihood, and most studies used less robust research methods to assess effectiveness.
- **The evidence was evenly distributed between middle-income and high-income economies**, with a much smaller number from low-income countries. Evidence on the effectiveness of early warning systems from low-resource settings was more limited compared with evidence on implementation of early warning systems, which mostly originated from those settings.
- **Evidence on the benefit of early warning systems for different populations and settings was limited**. Many studies did not consistently report participant characteristics, but where reported, the evidence shows that gender, age, education, language, disability, occupation and trust in institutions can shape access to and understanding of early warnings and related preparedness action.
- **Early warnings were more likely to lead to improved outcomes when they were delivered through multiple channels**, in local languages, by trusted intermediaries, and included clear instructions on what people should do to protect themselves.

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- **Receiving a warning does not guarantee protective action**. Systems are more likely to reduce harm when warnings are connected to household and community plans, evacuation routes, accessible shelters, support for people who need assistance, and pre-agreed roles and resources.
- **Implementation barriers** included limited infrastructure, poor communication channels, low trust, lack of local ownership, insufficient preparedness capacity and weak institutional coordination.
- **Only a small number of studies assessed cost-effectiveness of early warning systems,** but evidence from these studies shows that the benefits of adopting an early warning system far outweigh investment costs, with consistent evidence of cost-effectiveness seen across different hazards and income settings.

Early warning systems are important disaster risk reduction tools, but warning coverage alone is not sufficient. Their benefits depend on whether warnings are received, trusted and understood, and whether people have the knowledge, resources, authority and practical support to act.
The findings reinforce the need for people-centred, end-to-end systems across the four Early Warnings for All pillars: disaster risk knowledge; detection, observation, monitoring and forecasting; warning dissemination and communication; and preparedness and response capability.
Investment should connect timely alerts to practical guidance, inclusive and locally appropriate communication, household and community preparedness, evacuation support, local capacity and anticipatory action.

Future research should use robust designs for evaluating effectiveness where feasible, report outcomes and population characteristics consistently, and include analyses of the differential effectiveness across diverse population groups to understand who benefits from early warning systems, who is missed and why. More impact evaluations are needed from low- and middle-income countries on the effectiveness of early warning systems, particularly for mortality, morbidity and livelihood outcomes.

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2. Why this is important

The 2026 World Risk Poll report, From Alert to Agency, shows that one out of every five adults globally were impacted by a disaster in the past five years, with heavy rain or flooding cited as the most common cause of disaster impact, followed by tropical storms and earthquakes[1].

Early warning systems are widely promoted core components of disaster risk reduction as they support communities, governments and organisations to take timely action before hazards develop. They have been defined as an integrated system for hazard monitoring, forecasting, risk assessment and communication that enables communities, individuals, and governments to take timely action to reduce the impact of impending hazardous events[2].

This research is important because, although many individual studies have examined the benefits of early warning systems, there has been limited systematic synthesis of what works, for whom, under what conditions, and at what cost. We used robust systematic review methodology to comprehensively assess the effectiveness of disaster early warning systems and how best they can be implemented to improve outcomes.

The systematic review findings are intended to support practitioners, funders and policymakers by identifying the conditions under which early warning systems are more likely to reduce disaster impacts.

3. The research

Researchers at the Lloyd's Register Foundation Global Safety Evidence Centre conducted a systematic review with the aim to:

1. Collate and synthesise evidence on the effectiveness of early warning systems, the barriers and enablers to their successful implementation, and the experiences and views of communities regarding their usefulness and acceptability
2. Assess the components of early warning systems that are associated with improved outcomes
3. Explore 'for whom' early warning systems are effective by assessing variations in effectiveness for different populations, communities, or regions

The research questions were:

1. **What works and for whom**: What is the effectiveness of early warning systems in reducing the impact of extreme weather- and climate-related events?
    a. What are the different types of early warning systems that have been used?
    b. What is the effectiveness of different types of early warning systems in reducing the impact of extreme weather- and climate-related events?
    c. What are the demographics and characteristics of communities served by these early warning systems? Which early warning systems are more or less effective for different populations, communities, and regions?
2. **How**: What elements or components of these early warning systems are associated with reductions in loss of life and assets?
3. **At what cost**: What is the cost-effectiveness of adopting early warning systems for reducing the impact of extreme weather- and climate-related events?
4. **Implementation:** What are the enablers and barriers to successful implementation of early warning systems?
5. **User perspectives**: What are the views and experiences of target populations, organisations and governments regarding the acceptability and usefulness of early warning systems?

1 Lloyd's Register Foundation. (2026). World Risk Poll Report 2026. From alert to agency: What turns warnings into action? *https://doi.org/10.60743/yx1k-t541*

2 United Nations Office for Disaster Risk Reduction (UNDRR) (2017). The Sendai Framework Terminology on Disaster Risk Reduction. "Early warning system". *https://www.undrr.org/terminology/early-warning-system*

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The systematic review process and methods

The systematic review was guided by a consultation group made up of systematic review methods experts, as well as practitioners and researchers with expertise in disaster risk management. Group members were consulted three times during the project – at protocol development, interim findings, and final reporting. The research team worked collaboratively with the consultation group to ensure appropriate use of language and terminology, and to co-produce recommendations from the review findings.

A protocol was developed and registered on the Open Science Framework[1] before commencing the review.

The systematic review included studies on early warning systems for weather- and climate-related hazards, including floods, cyclones, storms, tsunamis, wildfires, droughts, heatwaves, earthquakes and volcanic eruptions. To assess the effectiveness and cost-effectiveness of early warning systems, we looked at quantitative impact evaluations, including:

- Quasi-experimental studies
- Longitudinal studies
- Randomised controlled trials
- Economic evaluations

To assess implementation conditions and user perspectives of early warning systems, we looked at:

- Qualitative studies
- Mixed methods studies
- Implementation and process evaluations

To ensure global coverage of the existing evidence, there were no restrictions on the geographical location of studies, and we included studies published in the academic literature and on relevant organisational websites. We also put out a call for evidence to capture relevant unpublished studies. The search for evidence targeted studies in all languages; however, only studies in the English language were included due to translation constraints.

We used Covidence – a web-based software platform for streamlining and managing the conduct of systematic reviews – for conducting literature searches, quality assessment and data extraction. Three researchers screened titles, abstracts and full texts, with each paper assessed by two researchers for eligibility. Disagreements were resolved through discussion or by the lead researcher. Data were extracted using a customised template covering study details, population, intervention, outcomes, study findings, population characteristics and early warning system components. Data extraction was conducted by one reviewer and checked by another.

The quality of the studies was assessed using appropriate tools, with each study examined independently by one researcher and checked by another researcher. Full details on the systematic review methods can be found in the accompanying technical report.

1 Kumah, E. A., Oparah, C., Musella, M., & Onanaye, B. (2025). Effectiveness of disaster early warning systems in reducing the impact of extreme weather- and climate-related events. *https://doi.org/10.17605/OSF.IO/78VPY*

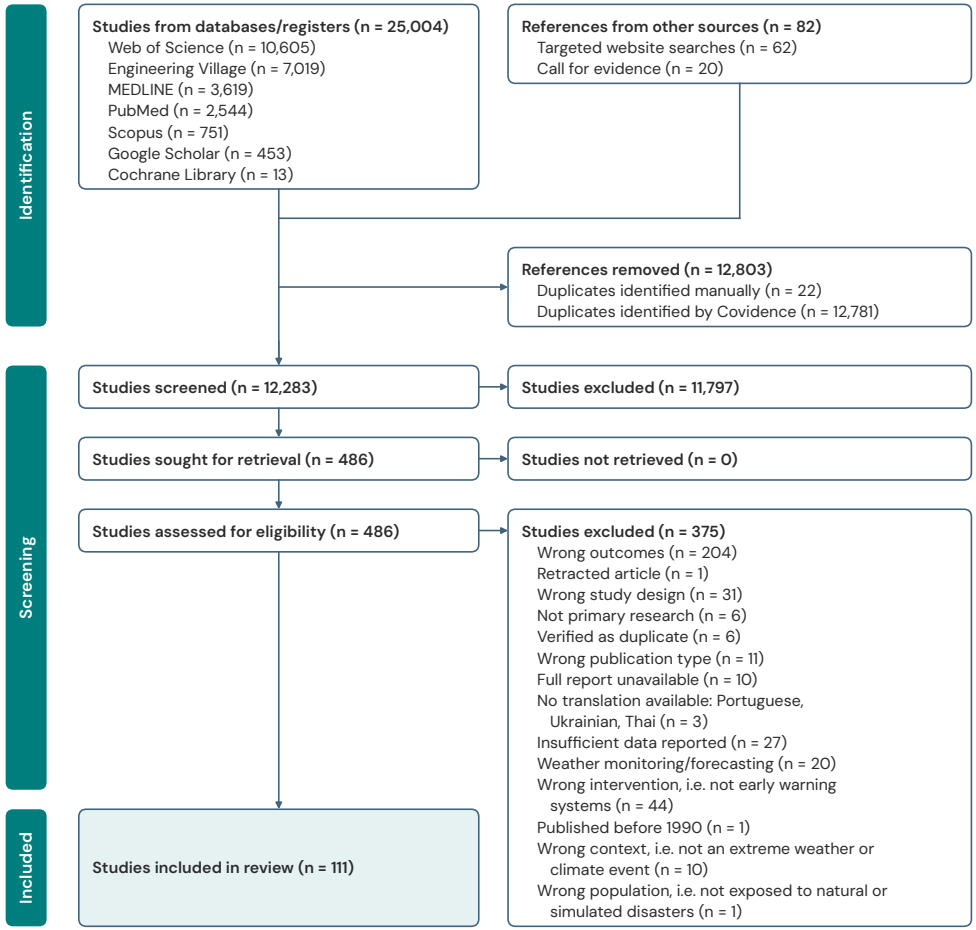
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4. The findings

Selection of studies

The search for evidence resulted in a total of 25,086 papers. After removing duplicate papers, we examined 12,283 papers and included 111 studies in the systematic review for analysis. The processes for selecting studies and reasons for excluding studies are shown in Figure 1.

Figure 1. Selection of studies (PRISMA flow diagram)



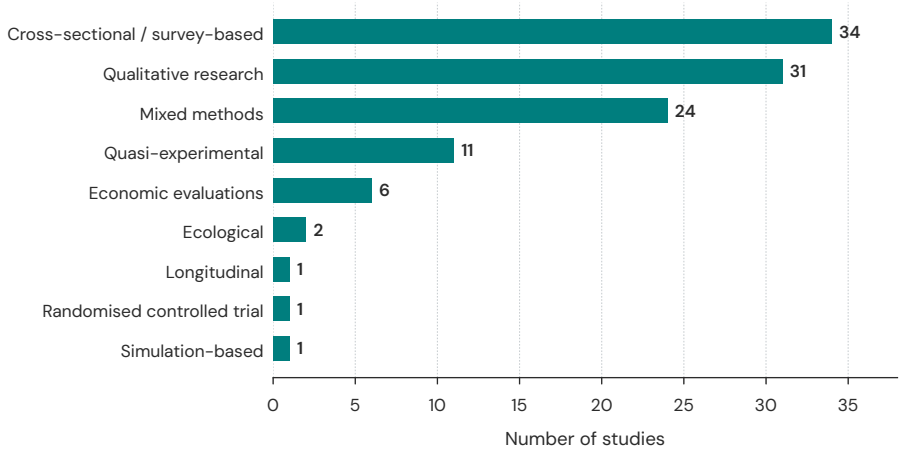
State of the evidence base

Of the 111 included studies, 55 provided evidence on effectiveness and cost-benefits of early warning systems; 78 studies provided evidence on implementation and user perspectives; and 22 studies had evidence on all aspects.

Most of the studies used designs that are best suited for exploring perceptions, experiences and associations rather than evaluating the causal impact of early warning systems. Studies designed to test cause-and-effect were only few, with 11 quasi-experimental studies, one longitudinal study, two ecological studies, and one randomised controlled trial. This is characteristic of the evidence base on disaster early warning systems, which mainly relies on prospective or retrospective observational cohorts to assess effectiveness, as robust experimental studies may not always be feasible or ethical.

The designs used by included studies are presented in Figure 2.

Figure 2. Designs of included studies



The studies were published between 1995 and 2026, with the majority of them published from 2020 onwards, and 2024 recording the most publications.

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Figure 3. Year of publication of included studies

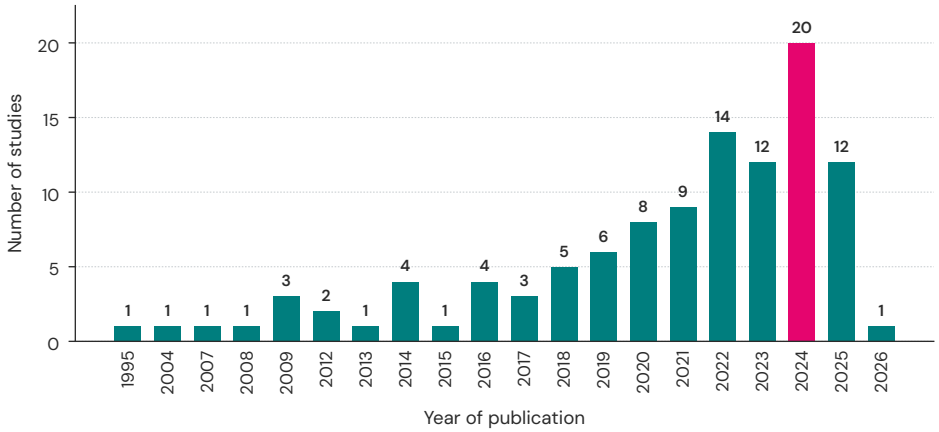
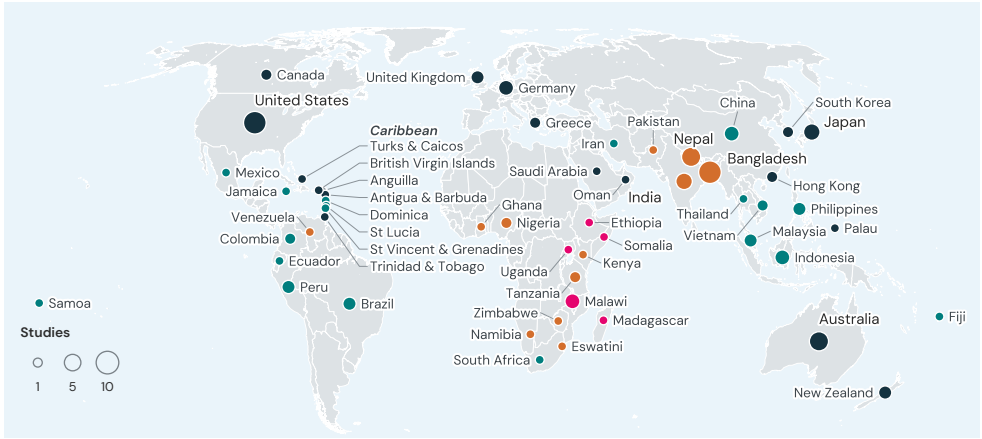


Figure 4. Geographic distribution of included studies



High income 17 countries

United States	10
Australia	7
Japan	5
Germany	4
New Zealand	3
United Kingdom	3
Canada	2
Greece	2
Hong Kong	2
South Korea	2
Antigua and Barbuda	1
British Virgin Islands	1
Oman	1
Palau	1
Saudi Arabia	1
Trinidad and Tobago	1
Turks and Caicos Islands	1

Not classified 1 territory

Anguilla	1

Upper-middle income 19 countries

China	4
Indonesia	4
Brazil	3
Malaysia	3
Peru	3
Philippines	3
Colombia	2
Vietnam	2
Dominica	1
Ecuador	1
Fiji	1
Iran	1
Jamaica	1
Mexico	1
Samoa	1
South Africa	1
St Lucia	1
St Vincent & Grenadines	1
Thailand	1

Lower-middle income 12 countries

Bangladesh	10
Nepal	7
India	5
Nigeria	2
Tanzania	2
Eswatini	1
Ghana	1
Kenya	1
Namibia	1
Pakistan	1
Venezuela	1
Zimbabwe	1

Low income 5 countries

Malawi	4
Ethiopia	1
Madagascar	1
Somalia	1
Uganda	1

***Note**: 54 countries and territories from 111 studies; bubble size and the bars show the number of studies in each. Studies conducted in more than one country are counted once for each country. Income groups follow the World Bank FY2027 classification; Anguilla is not classified.*

Geographically, the studies spanned 54 distinct countries, and the most represented countries included the United States (US), Bangladesh, Australia, Nepal, Japan, China, India, Indonesia, and Malawi, with one study covering 98 countries globally.

When categorised by World Bank income level, included studies were evenly distributed between middle-income and high-income economies, with a much smaller number from low-income countries. In particular, methodologically robust quantitative studies were more focused in high-income countries compared to qualitative studies, which mostly originated from lower-middle and low-income countries. Thus, evidence on the effectiveness of early warning systems from low-resource settings was more limited compared with evidence on implementation of early warning systems, which mostly originated from those settings. The geographic distribution of included studies, showing the countries in which studies were conducted and the World Bank income group of the countries, is shown in Figure 4.

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Funding landscape of early warning systems research

Funding source of early warning systems research was reported in 79 of the studies, and these varied considerably, with government and national research funding agencies emerging as the most common funders, followed by university/academic funding agencies, and international organisations (for example, the World Bank, United Nations, and the European Union).

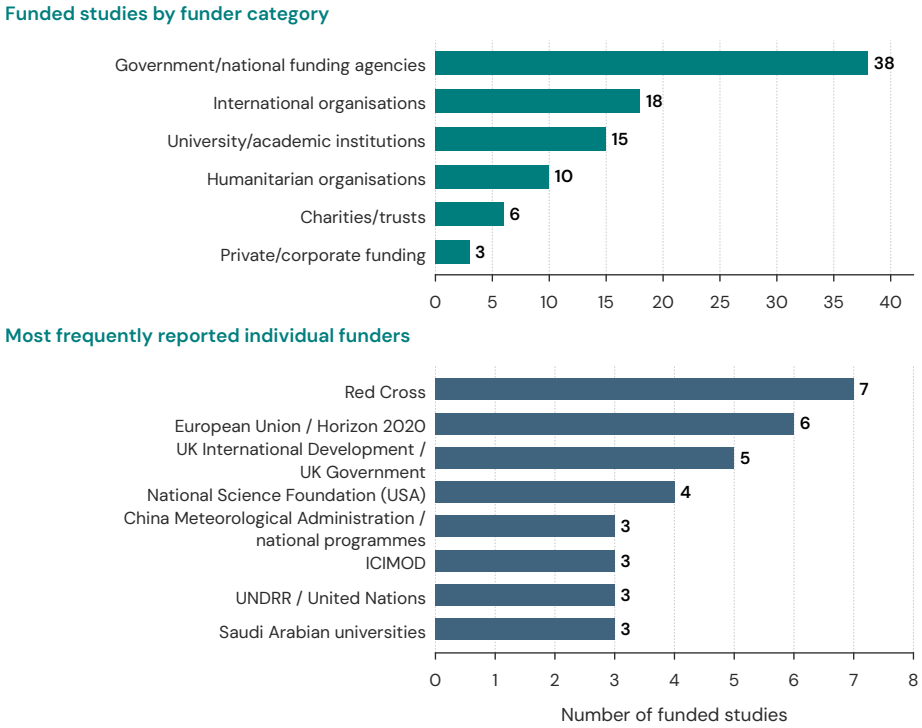
When we looked at the breakdown of government/national research funding agencies, the United Kingdom (UK) government – through the Foreign, Commonwealth, and Development Office (FCDO), UK Aid, and UK Research and Innovation (UKRI) – provided the most funding by a slight margin, followed by the US National Science Foundation, the Chinese National Science/Research Funding, and New Zealand research funders. Details of the funding sources and the number of studies for each category are shown in Figure 5.

Key findings

This section summarises findings from each of the research questions that were assessed in the systematic review. These include findings on:

- The different types of early warning systems that have been studied
- The effectiveness of existing early warning systems
- The demographics and characteristics of communities/populations served by existing early warning systems
- Populations/communities that benefit from early warning systems, and those left behind
- The components of early warning systems that are associated with effective outcomes
- The cost-effectiveness of early warning systems
- The barriers and enablers to the successful implementation of early warning systems
- The views of target populations and institutions regarding the usefulness and acceptability of existing early warning systems

Figure 5. Funding landscape of early warning systems research



Note: Counts reflect reported funding sources; some studies reported more than one funder; ICIMOD: International Centre for Integrated Mountain Development; UNDRR: United Nations Office for Disaster Risk Reduction

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Types of early warning systems

We used the classification profile recommended by the United Nations Office for Disaster Risk Reduction and the International Science Council (UNDRR-ISC)[1], to group the different types of early warning systems that were evaluated in included studies by hazard type and the level at which the system was operated.

We found that:

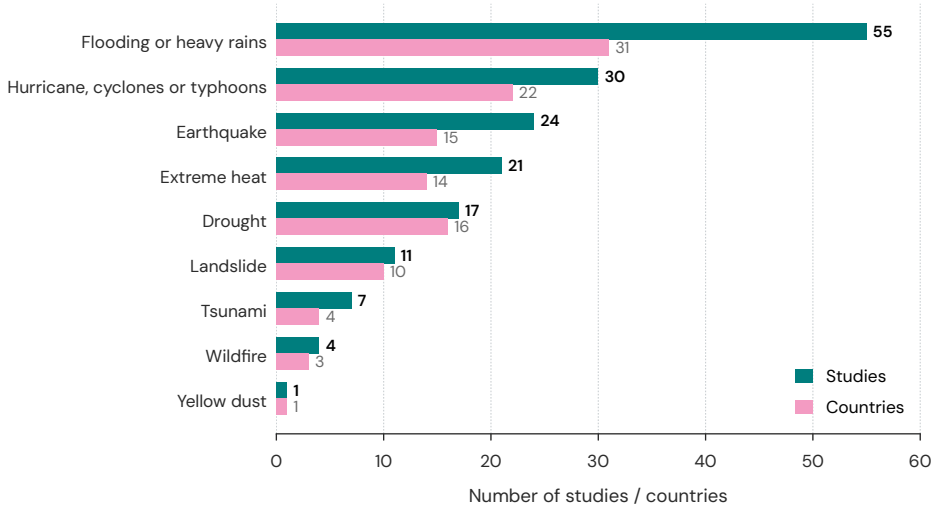
- **National early warning systems** were by far the most commonly evaluated, appearing in **83 of the 111 included studies**. These were typically operated by national meteorological, hydrological, geological, agricultural, health, or disaster management agencies. National systems were more evenly distributed across country income groups, with implementation in both low-resource and high-income settings.
- **Community/local or people-centred early warning systems** were evaluated in **17 studies**. These were usually operated at local or municipal level, often with community involvement. Most community-based early warning systems were focused on mitigating flood risk and were mainly implemented in lower- and middle-income settings, particularly in Southern/East Africa and South/Southeast Asia.
- **Regional early warning systems** were evaluated in **six studies**. These included systems operating across regions or groups of countries, such as drought, famine, cyclone, or multi-hazard programmes.
- **Global early warning systems** were evaluated in **five studies**, all of which were earthquake warning systems, particularly crowdsourced or smartphone-based earthquake detection networks.

Regarding the type of **hazard covered**, national systems were the broadest, covering all hazard categories identified in the review. Hydrometeorological hazards dominated the evidence base, with most nationally operated systems addressing flooding, heavy rain, cyclones, storms, drought, and/or extreme heat. Community/locally based early warning systems were also mainly focused on hydrometeorological hazards, especially floods. Regional systems covered a broad range of hazards across hydrometeorological, geological, and biological hazards.

In summary, the evidence is heavily weighted towards **national-level systems** and **hydrometeorological hazards**, while community/local, regional, and global systems are much less represented. The evidence also shows a geographical pattern: community/local systems were mostly evaluated in lower- and middle-income settings, whereas national systems were implemented across country income groups.

The different hazard types researched and the countries in which they were studied are shown in Figure 6.

Figure 6. Hazards covered by included studies



Note: Some countries appear under more than one hazard type.

1 See UN-SPIDER early warning systems classification here: *https://un-spider.org/risks-and-disasters/early-warning-systems#no-back*

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How effective are the different types of early warning systems in reducing the impact of extreme weather and climate events?

Evidence on the effectiveness of early warning systems is **mixed**, and effectiveness varies by **outcome, hazard type and operational level**.

- **Mortality:** evidence on reduction in deaths was limited and inconsistent. Of the impact evaluations that assessed mortality outcomes, most found either no effect or mixed effects, particularly for extreme heat warning systems. One tsunami early warning study found a significant reduction in mortality, but evidence for floods, typhoons and heat was less consistent.
- **Morbidity:** evidence on reduction in injuries and illnesses shows positive benefits of early warning systems, such as reduced typhoon-related injuries where rural loudspeaker warning coverage increased, and reduced cardiac-related ambulance call-outs during extreme heat warnings. However, other studies found no effect or mixed effects.
- **Loss of livelihoods:** only one study assessed livelihood-related outcomes, using community ratings of perceived flood early warning effectiveness in reducing crop and livestock damage. The findings showed modest or low perceived effectiveness, but the study used a descriptive approach, and findings were not statistically tested to assess effectiveness.
- **Loss of assets:** we found strong evidence of effectiveness of early warning systems in reducing asset losses. Flood early warning systems showed positive effects in reducing property and household asset losses, especially when warnings were received with sufficient lead time and accompanied by knowledge of what protective action to take. Evidence for cyclone, typhoon and drought early warning systems was more mixed. Some studies reported avoided damage or reduced economic loss, while others found no effect or worse outcomes when warnings were delivered through less reliable channels such as word of mouth.
- **Timely warning alerts:** timeliness of alerts mattered, but only when paired with preparedness knowledge and actionable guidance. Longer warning lead time alone did not always reduce losses. For floods, warning lead time was only effective when people knew what protective actions to take. For cyclones, shorter lead times were associated with worse housing outcomes, although findings differed across loss categories.
- **Accuracy of alerts:** there was very limited evidence on the impact of warning alert accuracy. The available studies relied on self-reported perceptions of whether warnings were accurate or believable.
- When assessed by **operational level**, most impact evaluations were focused on national early warning systems. These showed mixed results, with some positive, negative, no-effect and mixed findings. Only two impact evaluations were focused on community/local systems, both reporting no effect, while one study on regional early warning systems reported a positive effect. There was not enough robust evidence to conclude that one operational level is consistently more effective than another.

In summary, early warning systems are most beneficial when they provide **timely, accurate, trusted and actionable warnings**, supported by preparedness knowledge and multiple communication channels. A summary of the evidence for the effect of early warning systems by outcome and hazard type is shown in Figure 7.

Figure 7. Effectiveness of early warning systems by hazard type and outcome

Outcome	Flooding/ heavy rain	Cyclone/ hurricane/typhoon	Extreme heat	Tsunami	Drought	Earthquake
Mortality	1 study* No effect	1 study* No effect	4 studies* 2 no effect, 2 mixed	1 study Positive	No evidence	No evidence
Morbidity	1 study* No effect	1 study Positive	3 studies* 1 no effect, 2 mixed	No evidence	No evidence	No evidence
Loss of livelihoods	1 study Not statistically tested	No evidence	No evidence	No evidence	No evidence	No evidence
Loss of assets	2 studies* Positive	2 studies* 1 negative, 1 no effect	No evidence	No evidence	1 study Mixed	No evidence
Timely warning alerts	1 study* No effect	1 study Mixed	No evidence	No evidence	No evidence	1 study Not statistically tested
Accuracy of alerts	1 study Not statistically tested	1 study Not statistically tested	No evidence	No evidence	No evidence	No evidence

Positive · Negative · No effect · Mixed · No statistical testing

** Also supported by descriptive evidence*

Note: each cell shows the number of studies that provided statistically tested evidence of effectiveness. Descriptive findings are only shown for outcomes where no direction of effect can be assigned.

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What are the demographics and characteristics of communities served by these early warning systems?

Across the included studies, demographics and characteristics of populations and communities served by early warning systems were **poorly and inconsistently reported.** This limits the extent to which we can draw firm conclusions about who is being reached by different early warning systems. Population characteristics such as age, gender, disability, occupation, ethnicity, language, culture, religion, education and socio-economic status were rarely reported consistently. Where demographic data were available, they were often presented in different formats, making comparison across studies difficult.

Overall, the evidence shows that:

- **Age** was the most commonly reported characteristic, appearing in just over half of the included studies. Most study populations were adults. Extreme heat studies more frequently focused on older adults, while studies on floods, cyclones and earthquakes more often involved general adult populations who had experienced or been exposed to the hazard.
- **Gender** was reported in fewer than half of the studies. Where reported, the overall distribution of male and female participants was broadly balanced, but several studies were male-skewed. This was especially common in household surveys and administrative datasets, where household heads were often the unit of enrolment and were frequently male. Very few studies reported non-binary gender categories.
- **Ethnicity, race, language and culture** were rarely reported. When they were included, there were varied categories by setting. Studies in high-income countries tended to use ethnicity or race categories, while studies in lower- and middle-income countries more often reported language, caste or locally relevant groupings. This makes cross-study comparison difficult.
- **Occupation and livelihoods** were reported in fewer than one-third of studies. Where reported, studies in lower-resource settings commonly involved farmers, fishers, agricultural workers, pastoralists and herders, whose livelihoods were directly exposed to floods, cyclones and droughts. Studies of national or regional systems more often included practitioners, policymakers, government officials, meteorologists, disaster management officers and volunteers.
- **Education** was reported in only around one-fifth of studies. Reported educational levels ranged from no formal education or primary education, often in rural or lower-income settings, to tertiary education. Reporting was inconsistent across the studies, making it difficult to identify strong patterns.
- **Disability and religion** were very rarely reported. Only a small number of studies included disability data, and even fewer reported religion. Where disability was reported, it included physical or mobility impairments, mental illness, and blindness or visual impairment.
- There were no reports of protected characteristics including sexual orientation, pregnancy/maternity, and gender reassignment.

In summary, the communities served by early warning systems in the evidence base were diverse geographically and socio-economically, but the review found a major evidence gap in how well populations are described. This means the evidence is limited for assessing whether early warning systems are equitably reaching groups who may be more exposed or vulnerable, including older people, disabled people, women, people experiencing language barriers, and those with lower levels of education or limited access to communication channels. Nevertheless, findings from the 2026 World Risk Poll[1] show that disasters do not affect everyone equally, and vulnerability directly defines the severity of disaster impact. The poll found low-income countries to have been most impacted by disasters in the past five years, and within these countries, the burden fell even further on the most vulnerable, with 37% of adults with primary education or less being impacted compared with 20% of those with higher education.

1 Lloyd's Register Foundation. (2026). World Risk Poll Report 2026. From alert to agency: What turns warnings into action? *https://doi.org/10.60743/yx1k-t541*

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Who benefits from early warning systems – and what features matter?

The evidence indicates that **no single type of early warning system is consistently more or less effective for all populations, communities or regions**. Effectiveness depends less on whether a system is national, community-based, regional or global, and more on whether warnings are accessible, trusted, timely, understandable and linked to feasible protective actions.

We found that:

- Across the evidence, the strongest pattern is that early warning systems are more effective when they use **multiple communication channels**, are delivered through **trusted local intermediaries**, use **local languages**, and are adapted to community needs.
- Early warning systems relying mainly on formal, digital or written communication may be less effective for groups with lower literacy, limited internet, mobile phone access, or weaker links to official institutions.
- Evidence of differential effectiveness by population group was limited and mixed. Some studies found gendered differences in access and awareness, with women less likely than men to know about or participate in early warning systems in some settings.
- Age-related findings were also mixed: older people were sometimes more likely to receive or value warnings, but older adults remained highly vulnerable to extreme heat-related mortality.
- Education was associated with better awareness and access in some studies, while language barriers reduced the usefulness of text-based warnings where alerts were not provided in local languages.
- Regional and contextual differences emerged as important factors for early warning systems' effectiveness. Community and locally owned systems appeared especially relevant in rural, lower-income settings with frequent exposure to severe hazards, but evidence on their impact was limited. Most of the statistically tested evidence covered nationally operated systems; however, effects varied by hazard, outcome and implementation quality.

Overall, the review found **very limited evidence on differential effectiveness**, particularly for disabled people, those experiencing language barriers, low-income groups and other underserved communities. The features of early warning systems that make them more or less effective are summarised in Table 1.

Table 1. Features that improve or reduce effectiveness, by population characteristic

Population characteristic (evidence count)	Features that improve effectiveness	Features that reduce effectiveness
Gender (9)	• Multi-channel delivery • Women's participation • Female intermediaries	• Formal-only channels • Exclusion from committees • Assumptions of equal household access
Age (9)	• Active response support • Check-ins • Cooling access • Age-targeted plans	• Alert-only systems • Self-protection assumptions • Smartphone-only approaches
Ethnicity/race/language (4)	• Local-language and culturally tailored messages • Trusted community intermediaries • Indigenous/local knowledge	• Single-language SMS/text • One trusted source assumed
Education/literacy (3)	• Pictorial/audio/verbal warnings • Door-to-door relay • Simple actionable content	• Text-heavy technical warnings
Disability (1 + qualitative)	• Multi-sensory alerts • Sign-language/accessibility formats • Evacuation support	• Siren/radio only • Single-modality • No support to evacuate
Occupation/livelihood (2)	• Livelihood-specific advice • Anticipatory action	• Generic warnings not tied to exposure or response options
Setting/income level (2)	• Community-owned systems • Regional pooling for small/island states	• Infrastructure-dependent national systems • Remote/poor coverage gaps
Informal settlements (2)	• Community-embedded heat warnings • Local cooling/resource guidance	• City-wide alerts assuming AC/ cooling/media access
Hard-to-reach/underserved communities (7)	• Local/traditional knowledge • Multi-channel dissemination • Pre-positioned response • Co-design	• National dissemination only • Infrastructure-dependent single-channel alerts

Note: evidence count shows number of contributing studies

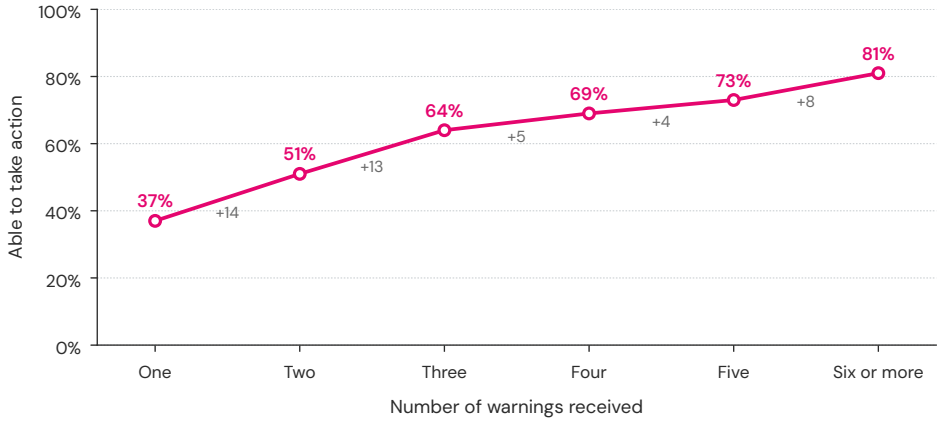
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What components of early warning systems are associated with reductions in loss of life and assets?

The evidence shows that:

- Early warning systems reduce loss of life and assets when warnings are **timely, trusted, actionable and linked to preparedness**.
- **Lead time mattered, but only when communities also knew what protective action to take**. For floods, warnings issued at least one hour before an event reduced asset losses only when accompanied by preparedness knowledge. For cyclones, shorter lead times were linked to worse housing outcomes, while warning source also had an impact: informal word of mouth from relatives, neighbours or village assemblies was associated with greater losses than more formal or reliable channels such as mobile phones, radio, television, and newspapers.
- Early warning systems that combined alerts with evacuation planning, preparedness training, community engagement and accessible communication channels were more likely to support protective action.
- Other important components included **multi-channel communication**, **trusted intermediaries**, **accurate and locally relevant and understandable messages**, and **clear guidance on what to do**. This finding corresponds with that of the 2026 World Risk Poll which found that people's ability to act was shaped by the number of warnings received and the use of multiple channels. The poll found that of those who received early warning, 37% could act on it with one warning, rising to 51% with two warnings and 64% with three warnings.

Figure 8. Ability to act based on number of warnings received (among those impacted by a disaster and received early warning)



***Source**: World Risk Poll Report 2026. From alert to agency: What turns warnings into action? Available at: https://doi.org/10.60743/yx1k-t541*

How cost-effective are early warning systems?

Findings on the cost-effectiveness of early warning systems show potentially substantial economic benefits, but confidence is limited by the small number of studies and weaknesses in the approaches that were used to assess cost effectiveness.

We found that:

- Across the studies, early warning systems were generally associated with favourable benefit–cost outcomes, particularly for flood, cyclone, heat and multi-hazard systems.
- Reported benefits included avoided damages to housing, agriculture, livestock, infrastructure and household assets, as well as reduced health service use during extreme heat.
- Some studies estimated high returns on investment, with benefits substantially outweighing implementation costs. For example, flood and cyclone early warning systems were associated with avoided losses through early action, better preparedness and evacuation, while heat warning systems were associated with high estimated savings through fewer ambulance call-outs, hospital admissions and emergency department visits.

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Overall, early warning systems appear cost-effective, but the strength of evidence is limited and context specific. The evidence was largely based on modelling, case studies and descriptive cost–benefit estimates rather than robust comparative economic evaluations. Across the studies, assumptions about avoided losses, warning accuracy, uptake of protective action and return periods varied considerably, which limits how much confidence we can have in the evidence.

What are the enablers and barriers to successful implementation of early warning systems?

We found that successful implementation of early warning systems depended on both technical capacity and social/institutional conditions. **Key enablers** were **community participation**, trusted local actors, clear communication pathways, and warning messages that are timely, actionable, locally relevant and delivered in languages people understand. Implementation was also supported by **multi-channel dissemination**, preparedness training, evacuation planning, strong links between warning and response systems, and effective coordination between meteorological, disaster management, local government and community organisations. In addition, strong governance, supportive legislation and policies, multi-stakeholder partnerships and clear responsibilities enabled coordinated warning delivery and response.

The **main barriers** were **limited trust**, unclear or delayed warnings, false alarm, weak infrastructure, poor access to communication technologies, and low literacy or language mismatch. In some settings, people received warnings but did not know what action to take or lacked the resources to act. Institutional barriers included weak governance, fragmented roles, weak coordination, limited funding, poor equipment maintenance and insufficient local capacity.

Social inequalities also shaped implementation: women, disabled people, older people, people with lower education, underserved communities and those experiencing language barriers were less able to access, understand or respond appropriately to warnings.

Overall, the evidence shows that early warning systems are most successfully implemented when they are **people-centred, inclusive, locally adapted, trusted and connected to practical preparedness and response capability**. Confidence in the evidence rating ranged from moderate to high, showing that the supporting evidence is likely to be trustworthy with very minor concerns. The enablers and barriers are summarised in Table 2.

Table 2. Enablers and barriers to successful implementation of early warning systems

Theme	Enablers	Confidence rating	Barriers	Confidence rating
1. Community engagement and trust	Community participation; trusted local actors; co-design and local ownership	High	Limited trust; exclusion from decision-making; weak community buy-in	High
2. Communication and message design	Clear, timely, actionable messages; local languages; accessible formats	High	Unclear or delayed warnings; language mismatch and low literacy; inaccessible formats	High
3. Channels and technology	Multi-channel dissemination; reliable radio, SMS, sirens and local networks; redundancy	High	Weak infrastructure; unreliable equipment; limited internet/mobile access; over-reliance on single channels	High
4. Preparedness and response capacity	Preparedness training; evacuation planning and drills; clear guidance on actions	High	Lack of knowledge on what to do; limited resources to act; weak evacuation/ support systems	Moderate
5. Governance and coordination	Coordination between meteorological, disaster management, local government and community organisations; clear roles	High	Fragmented responsibilities; weak coordination; insufficient funding; poor maintenance	High
6. Inclusion and equity	Inclusive design for women, older people, disabled people, linguistic minorities and remote communities	Moderate	Social norms and inequalities; digital exclusion; remote or marginalised groups less able to access, understand or act on warnings	Moderate

***Note**: 'Confidence rating' refers to the level of confidence that can be placed in the systematic review findings on enablers and barriers to successful implementation of early warning systems. Refer to the technical report for details about how this was rated.*

Successful early warning system implementation is people-centred, inclusive, locally adapted, trusted, and linked to practical preparedness and response capacity.

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What are the views and experiences of target populations, organisations and governments regarding the acceptability and usefulness of early warning systems?

The evidence shows that early warning systems are generally viewed as **acceptable and useful** when they are trusted, timely, locally relevant and linked to clear actions. People valued warnings that gave enough time to prepare, evacuate, protect assets or check on others. Usefulness was strongest where messages were understandable, delivered through familiar and trusted channels, and reinforced by community networks, local leaders or emergency services.

However, experiences were uneven across the evidence. Some communities reported delayed, inaccurate, incomplete or confusing warnings, which reduced trust and limited action. Digital and text-based systems were less useful for people with limited internet connectivity, low literacy, language barriers, disability-related access needs, or limited phone ownership. In several settings, people preferred multi-channel systems that combined formal alerts with radio, sirens, local volunteers, social networks and face-to-face communication.

Organisations and governments generally recognised early warning systems as important for preparedness and disaster risk reduction, but highlighted operational challenges, including weak infrastructure, fragmented coordination, limited funding, unclear responsibilities and insufficient local capacity.

Overall, the findings indicate that acceptability and usefulness depend less on the technology alone and more on whether warnings are **credible, inclusive, actionable, locally adapted and connected to practical preparedness and response support**.

What is the quality of the evidence?

Most of the studies were assessed as high quality (low risk of bias), although quality varied by study design:

- The only included randomised controlled trial study was assessed as having 'some concerns', mainly due to lack of a pre-specified analysis plan.
- Most non-randomised experimental studies – that is, the quasi-experimental, ecological, longitudinal and simulation-based studies – were rated low-to-moderate risk of bias, with a small number assessed as having serious limitations. There were four studies with low risk of bias, eight with moderate risk of bias, two with serious risk, and one with critical risk of bias.
- Most of the qualitative studies were rated methodologically strong, with only four (out of 31) rated poor quality. Across the qualitative studies, common methodological weaknesses included limited reporting of ethical considerations, sampling, target population, analysis plans and researcher reflexivity/positionality.
- Of the six included economic evaluations, four were rated methodologically sound, while two had poor methodological quality, mainly due to limitations in analytical rigour.
- The cross-sectional/survey-based studies were rated moderate-to-high methodological quality. However, studies using mixed methods designs varied in methodological quality, with weaknesses often related to poor integration of qualitative and quantitative components and limited handling of divergences.

Overall, the findings show that while much of the evidence base is methodologically robust, there are some methodological limitations—particularly around confounding, selective reporting, analytical rigour and poor integration of mixed methods study components. These need to be considered when interpreting the evidence.

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5. Recommendations

Implications for policy

- **Strengthen institutions and governance**: embed early warning systems in official plans and legal frameworks to enhance stronger institutional and government funding support in low-resourced disaster-prone regions.
- **Invest in dissemination and response capability, not just detection**: direct funding towards improving warning dissemination and communication, and particularly, preparedness and response capability – the features most associated with improved outcomes – rather than focusing investment on only detection, monitoring and forecasting technologies.
- **Ensure multi-channel, local language delivery of early warning systems**: systems must be required to combine official and community communication channels and to disseminate warnings in local languages and accessible formats. In this way, reach will not be dependent on literacy, access to a single technology (e.g., smartphone) or knowledge of a common national language.
- **Make inclusion a design and implementation requirement for all early warning systems:** ensure that early warning systems are gender- and disability-inclusive (e.g.., uses sign language, multi-sensory alerts, and supports women's participation in community warning committees).
- **Prioritise low-resource, high-exposure settings**: support community-based systems in low-income countries, which the evidence shows are effective and affordable, but remain under-funded and under-researched.
- **Fund early warning systems as ongoing services**: provide sustained funding, training and legal/institutional backing for early warning systems rather than through one-off projects. This will help address the funding, capacity and governance barriers that were identified across the evidence.

Implications for practice

- **Make early warning messages clear, specific and actionable**: provide location-specific early warning information that users can relate to local conditions, communicate accurately and clearly, and tailor content differently for different population groups.
- **Promote community awareness and invest in education**: provide targeted disaster risk education to specific groups such as youth and the elderly, and work collaboratively with community actors to raise awareness and knowledge on disaster preparedness and protective action.
- **Use multiple, complementary dissemination channels** to communicate warning information, combining official channels (e.g., TV, radio, newspaper) with existing community-based communication approaches (e.g., loudspeaker systems).
- **Pair early warnings with preparedness and response capability**: ensure warnings are disseminated with sufficient lead time with a pre-planned response strategy.
- **Build and use trusted intermediaries, avoid over-alerting and frequent false alerts**: communicate warnings through locally trusted people and institutions, avoid over-alerting and frequent false alerts, which erode trust.
- **Plan for hard-to-reach communities and power/technology failures**: anticipate network failures and power outages, especially in low-resource settings, and build community-level dissemination and response.

Implications for future research

- **Report participant demographics as standard**: this should include reports on disability, gender, language, ethnicity, and other key population characteristics that can impact the effectiveness of early warning systems.
- **Use rigorous experimental and quasi-experimental impact evaluations** to assess effectiveness of early warning systems, particularly in low- and middle-income settings where the evidence on effectiveness is limited.
- **Include observed costs and benefits in economic evaluations of early warning systems wherever feasible**, and ensure modelling studies are methodologically strong and transparent.
- **Focus future research efforts on the under-studied features of successful early warning systems** – risk knowledge, response capability, underserved community reach and low-resource, high exposure settings which are most often susceptible to disasters.

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Appendix. Definition of terms

Term	Description
GRADE	GRADE (Grading of Recommendations Assessment, Development and Evaluation) is a tool that helps researchers to assess how much confidence we can have in findings from quantitative studies.
GRADE-CERQual	GRADE-CERQual (Grading of Recommendations Assessment, Development and Evaluation – Confidence in the Evidence from Reviews of Qualitative Research) is a tool that helps researchers to check how much confidence we can have in findings from qualitative studies.
Impact evaluation	An impact evaluation provides information about the changes that can be attributed to an intervention, programme or service. These changes can be negative and positive, intended and unintended, or direct and indirect. Impact evaluation helps researchers to answer questions about what works, for whom, and why.
Meta-analysis	A meta-analysis is a statistical method that combines findings from multiple independent studies to produce a single, more robust conclusion about the effect of a particular intervention, programme, or practice.
Narrative synthesis	Narrative synthesis is an approach for analysing and summarising results from multiple studies using texts and words, and helps to provide an overall assessment of the strength of the evidence about the effectiveness of a specific intervention(s)
PROGRESS-Plus	It is an acronym used to identify population characteristics that stratify access to opportunities, and health and safety outcomes. It includes Place of residence, Race/ethnicity/culture/language, occupation, gender and sex, religion, education, socio-economic status, social capital, age, disability, and sexual orientation
PRISMA-Equity	It is a checklist that provides reporting guidance to help improve the transparency and quality of systematic reviews with a focus on equity and underserved populations.
Quasi-experimental study	A study design used to evaluate the impact of an intervention on target populations without random assignment of participants to intervention and control groups.
Randomised controlled trial	A study design used to show the effectiveness and efficiency of an intervention on target populations by assigning participants to one of two groups: the intervention/experimental group (that is, the group receiving the intervention that is being evaluated), and the control or comparison group (that is, the group receiving an alternative intervention or no intervention).
Risk of bias in studies/ Quality of the evidence	As part of the systematic review process, the quality of each study included in the review is assessed using checklists such as the Cochrane Risk of Bias tool. This helps researchers to understand whether the methods used in the study are transparent. Checking the transparency of the methods used allows researchers to judge the trustworthiness, reliability and relevance of the findings from each study.
Systematic Review	A systematic review is a type of research that uses rigorous methods to collect evidence from multiple research studies and summarises them to answer a research question

About this briefing

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Authors: Elizabeth Adjoa Kumah, Chizoba Oparah, Margherita Musella, Busayo Onanaye.

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Further reading

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Lloyd's Register Foundation, 71 Fenchurch Street, London, EC3M 4BS, United Kingdom

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