Report

The impact of climate change on education outcomes: A systematic review

Akanksha Bapna, Rachel Marcus, Diana Jimenez Thomas Rodriguez and Donya Khosravi

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ODI Global
4 Millbank
London SW1P 3JA
United Kingdom

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About the authors

Akanksha Bapna is a Senior Research Fellow in the Climate and Sustainability Programme at ODI Global

Rachel Marcus is a Senior Research Fellow in the Gender Equality and Social Inclusion Programme at ODI Global

Diana Jimenez Thomas Rodriguez is a Senior Research Officer in the Gender Equality and Social Inclusion Programme at ODI Global

Donya Khosravi is a Research Officer in the Climate and Sustainability Programme at ODI Global

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Abbreviations

ASER	Annual Status of Education Report
BMI	Body Mass Index
DRR	Disaster Risk Reduction
EiE	Education in Emergencies
ELA	English Language Arts
ENLACE	Evaluación Nacional de Logros Académicos en Centros Escolares
INPRES	Indonesian Primary School Construction Programme
IPCC	Intergovernmental Panel on Climate Change
LMICs	Low and middle-income countries
MHPSS	Mental health and psychosocial support
NREGA	National Rural Employment Guarantee Act
PAHs	Polycyclic aromatic hydrocarbons
PISA	Programme for International Student Assessment
PROGRESA	Programa de Educacion, Salud y Alimentacion
PSAT	Preliminary Scholastic Aptitude Test
PSNP	Productive Safety Net Programme
PTSD	Post-traumatic stress disorder
Pp	Percentage Point
PPVT	Peabody Picture Vocabulary Test
SD	Standard deviation
TIMMS	Trends in International Mathematics and Science Study
UNFCCC	United Nations Framework Convention on Climate Change

Glossary

Ages and Stages Questionnaire: A screening tool to assess a child's developmental progress, including communication, motor skills and problem-solving.

Climate hazards: The potential occurrence of climate-related physical events or trends that may cause damage and loss. These include increased rainfall variability, floods, droughts, landslides, extreme temperatures, cyclones or hurricanes and wildfires.

Cloze test: Test that measures reading comprehension and vocabulary. It assesses a person's ability to understand context and fill in missing words in a text.

Econometric studies: Studies that use statistical and mathematical models to understand the relationship between random variables.

Education outcomes: Achievements or results associated with an individual's educational trajectory. These include those related to access (such as school enrolment), attainment (such as years of schooling completed) and learning (such as numeracy and literacy skills).

Height-for-age z score: Statistical measure that indicates how far a child's height is from the median height of other children of the same age and sex. This measure is expressed in standard deviations.

Peabody Picture Vocabulary Test: Test that measures speech comprehension and vocabulary knowledge.

Raven's test: Also known as the Raven's Progressive Matrices, this is a nonverbal test used to assess abstract reasoning.

Standard deviation: In statistics, a measure of dispersion that indicates how far, on average, each data point deviates from the mean. A small standard deviation means data points are less spread out, while a large standard deviation means data points are spread out over a wider range.

Weight-for-age score: Statistical measure that indicates how far a child's weight is from the median weight of other children of the same age and sex. This measure is expressed in standard deviations.

Part 1
Background, methodology and overview of studies

1 Introduction

Human-induced climate change is increasing the frequency and intensity of extreme weather events, leading to widespread adverse impacts on people and nature, well beyond natural climate variability. Extremes of temperature and rainfall, droughts and fire weather are now being attributed to human-made climate change with high confidence. These extreme weather events cause substantial damage to life and infrastructure, and have severe negative impacts on nutrition, education and human health (IPCC, 2022). On current trajectories, the world is on track to experience 2.7°C warming above pre-industrial levels within the next century, far above the global goal of 1.5°C (Climate Action Tracker, 2021). The most vulnerable individuals and systems are also the ones most impacted by these extreme events (IPCC, 2022).

Education is critical for human development, including in the context of climate change (Leoni, 2025). Beyond improving understanding of climate change (Fagan and Huang, 2019; Simpson et al., 2021), education helps individuals develop skills and knowledge and increases their productivity and earning potential, improving adaptive capacity and resilience to climate-linked events (Ara Begum et al., 2022; Birkmann et al., 2022). Education can empower individuals to make choices that influence consumption patterns (Cordero, Centeno and Todd, 2020; Yao et al., 2020; Acharibasam and McVittie, 2023) and improve resilience, adaptation and even mitigation policies, and has been associated with pro-climate beliefs (Angrist, Winseck et al., 2024). Education can therefore have long-term impacts on climate change mitigation efforts.

Although the impacts of climate change on ecosystems and biodiversity, food systems and agriculture, health and infrastructure are widely acknowledged, the effects on education and learning outcomes are under-prioritised in international discourse. Education does not hold space on negotiating floors of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). There is no common understanding of the types of interventions that should be supported to build climate-resilient education systems (Munnelly, Tammi and Martinez, 2023).

Over the past few years, the education and climate communities have begun to recognise that climate variability and climate change can undermine educational attainment, including through increased engagement of children in the labour market, reduced household income and undernutrition, impacting access to schooling as well as learning capacity (IPCC, 2022). In-depth understanding of the scale and type of impacts is however lacking.

This systematic review was undertaken to understand the impacts of climate change on children's education in low and middle-income countries (LMICs). It is the first global systematic review to cover the major climate hazards – floods, rainfall variability, droughts, cyclone, hurricanes and typhoons and temperature variations and wildfires – and their impacts on children's education. The review addresses the following research questions:

- What are the actual or potential, direct or indirect, adverse effects of climate change and environmental degradation on children's learning in LMICs?

- What is known about the nature and scale of these effects on children's learning in LMICs?
- What are the mechanisms or pathways by which climate change and environmental degradation are actually or potentially, directly or indirectly, affecting children's learning in LMICs?
- What promising interventions promote learning resilience (at individual, community or system level)?

This study makes distinct contributions to the literature in that: 1) it covers all major climate-linked hazards and excludes geophysical disasters, such as earthquakes and volcanic eruptions, such that the focus on human-linked climate change is central; 2) it clearly outlines pathways to impact, and highlights heterogenous effects on different demographic groups; 3) drawing on these findings, it discusses interventions that can help address the impacts on education; and 4) it is based on quantitative studies that identify causal linkages.

1.1 Motivation

As research at the climate change and education intersection has gained momentum, a number of reviews – systematic and otherwise – have been published concurrently. For example, Baez et al. (2010) examines the impacts of disasters in general, and the impact on human capital including health and education. Codjoe and Atiglo (2020) study the impacts of flooding, extreme heat and drought on five key Sustainable Development Goals (SDGs) including education (Goal 4). A desk review by the Nordic Consulting Group addresses the bidirectionality of the climate–education nexus, with a strong focus on mediators rather than direct impacts on education outcomes (Nordic Consulting Group, 2024). Eze et al. (2024) examine the influence of environmental shocks and child labour on children's educational outcomes and include shocks such as death as part of the study. They do not disaggregate impacts across various shocks as this review does. Prentice et al. (2025) give examples of the main ways in which climate change can affect education outcomes as well as the underlying mechanisms, but is not a systematic review. Weng et al. (2020) reviews the impacts of climate change on education, but is limited to Cambodia, Vietnam and Laos. Kagawa and Selby (2024) review the impact in the context of emergencies. Pal et al. (2023) assess the vulnerability and resilience of school education to hazards (including earthquakes) specifically from a disaster risk reduction (DRR) perspective. Apart from Baez et al., which was published in 2010 – prior to the publication cutoff for this study – all of the reviews were published post-2020, with several emerging during this systematic review. The latest and the most comprehensive is Venegas Marin, Schwarz and Sabarwal (2024). This systematic study adds a comprehensive understanding of differentiated impacts across demographics. It places emphasis on deriving inferences from quantitative studies and provides an in-depth understanding of interventions to address the impacts of climate change on education.

1.2 Conceptual framework

As Figure 1 shows, climate hazards interact with existing socioeconomic, cultural and geopolitical vulnerabilities and exposure via various direct

and indirect mechanisms[1] (which the study refers to as mediators or pathways) to affect educational outcomes. The framework draws on that developed by the IPCC (Begum et al., 2022), in which climate risks result from the interaction of hazard, exposure and vulnerability as defined below:

Hazard: The potential occurrence of a physical event or trend that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. It includes both slow- and rapid-onset climate shocks and stresses. This is used to organise the data and the report structure.

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. This is used to understand the heterogenous effects on various demographic groups.

Exposure: The people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure or economic, social or cultural assets in places and settings that could be adversely affected. This aspect allows for focus on interventions and mechanisms that can offset the impacts of climate change on education.

The framework further integrates climate hazards with three types of education outcomes:

Learning outcomes: This encompasses cognitive outcomes, literacy, numeracy and any standardised assessment outcomes. These have been separately assessed from access and attainment to tease out the specific impacts on learning and provide granularity to the report.

Educational access: Who participates in education and how learners progress through the education system from early childhood education to adult education. Understanding this is essential to develop education policies that benefit all learners.

Educational attainment: Gauged by the percentage of the population with formal qualifications at various levels. This often acts as a proxy for human capital and individual skill levels (OECD, 2024).

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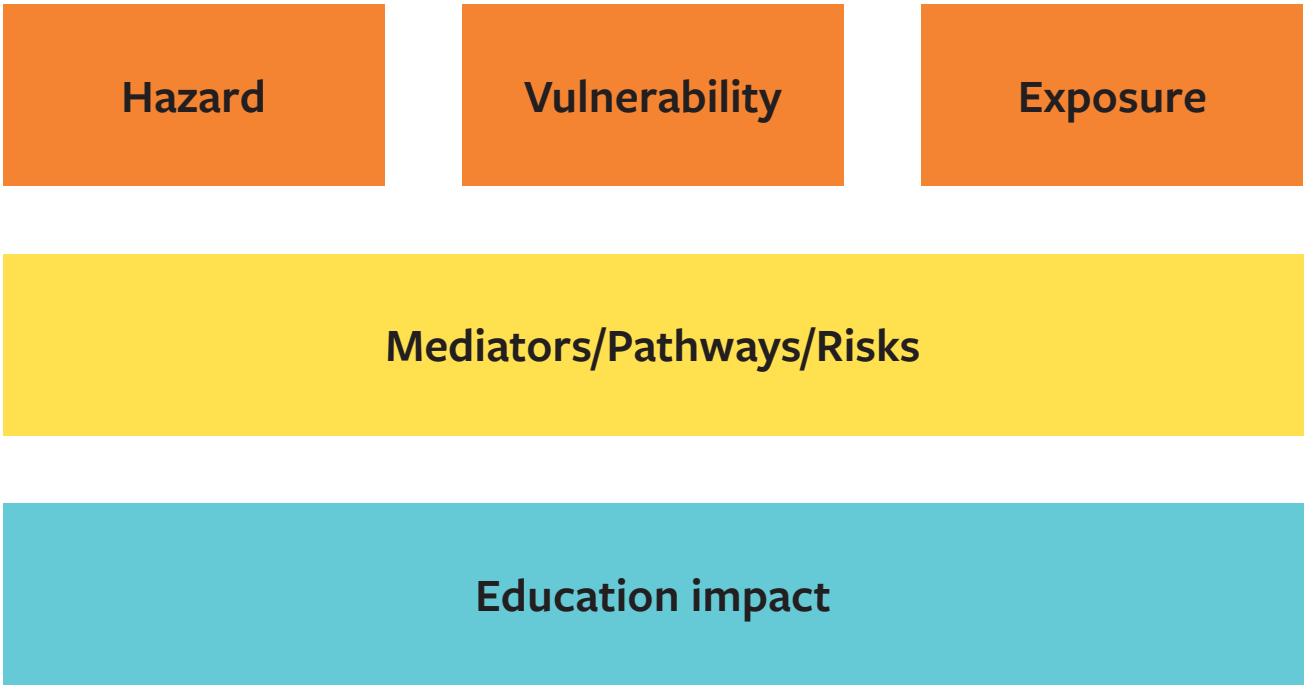
1 Climate hazards can impact education through various direct and indirect pathways. These pathways have been outlined in the literature (Kousky, 2016; Hanna and Oliva, 2016; Weng Boey Chun et al., 2020; Bellony and Powers, 2021), and can be direct – i.e. those that directly affect learning capacity such as cognition – or indirect, such as impacting household income, which in turn could lead to households reducing investment in school education.

Figure 1 Summary conceptual framework for the systematic review



1.3 How to use this report

This report is structured in three main parts. Part 1 discusses the methodology for the review and provides an overview of the studies included in the analysis. Part 2 outlines evidence of the impacts of climate change by hazard (rainfall shocks, floods, drought, cyclone, temperatures and wildfires). Part 3 synthesises findings across hazards, focusing on the mechanisms that lead to impacts on educational outcomes, and heterogenous effects by age, gender and socio-economic background. It then outlines evidence on interventions to protect educational resilience in the context of climate change, synthesises key findings and identifies knowledge gaps.

2 Methodology

The systematic review was conducted based on protocols adapted from the Cochrane handbook (Higgins, 2024). This section outlines the methodology in detail.

2.1 Search logic

Based on the study's analytical framework and preliminary searches, a comprehensive list of search terms was developed. Climate hazard terms were identified based on the IPCC classification and expanded via expert inputs. The hazard search terms used were those related to drought, heavy rainfall, flooding, extreme heat, extreme cold, wildfires, storms (including cyclones, hurricanes and typhoons), coastal erosion and landslides.

Education search terms included those related to access (such as enrolment, attendance, drop-out), attainment (completion) and learning (performance, numeracy, literacy, transferable, digital and other cognitive skills). Appendix 1, Table A1.1 contains the full list of search terms.

Exposure, vulnerability and mediator terms were not used in the searches but were instead used to code the studies (see Section 2.7).

Search strings were then composed as follows:

[climate hazard term] + ["impact "] + [education outcome term]

In addition, general search strings were also run: one set using 'climate change' instead of specific climate hazards, and a second set using three general education terms. These search strings were composed as follows:

["climate change"] + ["impact"] + [education outcome term]

[climate hazard term] + ["impact "] + [general education term (education, school, learning)]

All searches were conducted in English. Some of the results included Spanish, Portuguese and French, but subsequent screening led to exclusion of these results based on pre-determined criteria.

2.2 Protocol

The protocol for the study was developed based on standard systematic review criteria and followed the Population, Intervention, Comparison, Outcome and Study time frame (PICOS) framework as outlined by the Cochrane Library. Details of inclusion and exclusion criteria within each are outlined in Table 1.

Table 1 Inclusion and exclusion criteria

Element	Inclusion criteria	Exclusion criteria
Population (P):	Education systems in LMICs. Including formal and non-formal education, ECE, primary and secondary levels. Insights from high income countries covered in other systematic reviews/relevant related literature can be included as needed.	Tertiary education – both higher education and post-secondary TVET or if data was not disaggregated from higher education data.
Interest/ Intervention (I):	Climate hazards that can impact education, education systems and learning outcomes directly and indirectly. Initiatives that seek to strengthen learning outcomes (at individual, community or system level). These must either explicitly express education resilience-strengthening objectives or must clearly respond to climate-related challenges (e.g. extreme weather events or slow-onset effects).	Non-climate linked hazards such as oil spills, air pollution, plastic pollution, among others.
Comparison (C) (Methodology)	Experimental or quasi-experimental studies. Qualitative and simple quantitative studies (percentages) used as supporting evidence.	Quantitative studies that used simple differences such as t-tests.
Outcomes (O)	Studies reporting on learning outcomes, such as foundational skills, social-emotional learning, digital skills, climate literacy and awareness, exam results or qualifications. Studies reporting on other education measures such as enrolment, attendance, completion, drop-out and access.	Climate-linked studies showing impact on human outcomes other than education and no direct links to education (e.g. impacts to mental health but not to education outcomes).
Timeframe	Studies published from 2010 onwards as the bulk of relevant literature has been published after this year.	
Type of literature	Academic and grey literature Primary studies Systematic reviews Languages: English only (due to large volume of sources found) Conference papers	Masters' theses PhD theses unless extremely relevant to the topic Individual papers on a case-by-case basis (i.e. unpublished papers if the source could not be authenticated) Intervention papers that directly address a mediator without connecting to education/ learning outcome (i.e. mental health interventions).

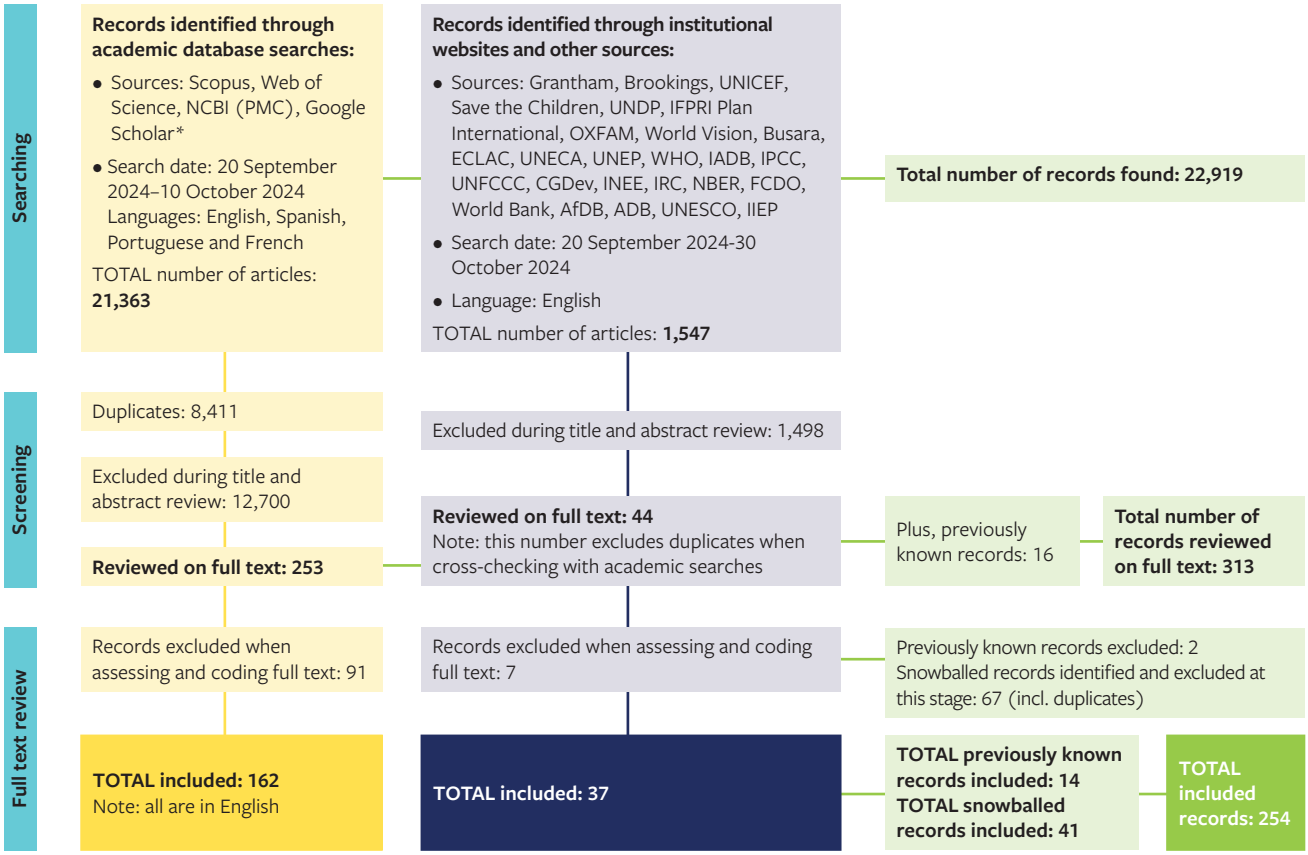
2.3 Databases and searches

A number of databases as well as specific websites were tested in a preliminary search phase. The databases that were used for the searches are listed in Table A1.2 in Appendix 1 with reasons for selection or rejection. The final set of academic databases included Scopus, Web of Science, NCBI (PMC) and Google Scholar. Hand searches were undertaken on the institutional websites outlined in Table A1.3 in Appendix 1. The search strings used in the academic searches were not used for hand searches due to the variation in website interfaces. Instead, the searches were restricted to all papers on climate and education. Documents were manually scanned and included based on relevance. For websites with more than 150 results, the first 50 documents were scanned. If there were relevant results, the next 50 were assessed, until no relevant results appeared in a set of 50 papers.

2.4 Screening

As shown in Figure 2, there were a total of 21,363 results from academic sources and 1,547 from grey literature, reaching a total number of 22,919 sources. Before proceeding to screen the results, 8,410 duplicates were excluded. The remaining papers were screened using the inclusion and exclusion criteria outlined in the protocol (see Section 2.2). First, 13,073 papers were screened for title and abstract resulting in a selection of 373 studies. This set was then screened on full text, leaving 254 papers in the final study set.

Figure 2 Prisma report



2.5 Full text review

The criteria outlined in Table 1 were also used for reviewing the 373 studies in detail. Studies were assessed for relevance and consistency with the PICOS criteria and included or excluded, accordingly. Studies using econometric methods (e.g. Ordinary Least Squares (OLS) regressions, logistic and probit regressions, difference-in-difference analysis, propensity score matching, instrumental variables) examining the impact of climate hazards on education outcomes, or the impact of initiatives to reduce the impacts of climate change on education, were selected as the core of the review. Mixed methods, other quantitative studies and qualitative studies were included as supporting material. Any study that used a sample size of less than 20 (both qualitative and quantitative), was unclear in its methodology or was not a quasi-experimental study was excluded.

The Mixed Methods Assessment Tool (MMAT) is designed for assessing primary research studies and systematic reviews, but is less suitable for distinguishing between studies based on secondary data and the criterion was therefore not used for this review.

2.6 Snowballing and gap-filling searches

Following the main search phase and coding, some additional searches were run to attempt to fill the gaps identified. Well-known and highly cited references, rigorous reviews and econometric papers known to the research team were used to add additional studies to the review. Further, during the full text review, references were snowballed from included studies. A total of 127 records were found through this process. The 44 snowballed papers that met all the inclusion criteria were then added to the final pool of papers. A subsequent snowball search on snowballed papers was not conducted. A short additional search was conducted in google and google scholar in June 2025 to identify further intervention studies.

2.7 Coding and analysis

As can be seen in Figure 2 the final pool of papers includes 254 studies, with 90 econometric studies forming the core of our analysis. See Appendix 4 for details of the studies included in this review.

Based on the preliminary searches, research terms outlined in Appendix 1, an initial reading of papers, expert inputs, insights from the Education in Emergencies (EiE) literature, as well as the IPCC glossary, a detailed set of coding terms was developed. The terms were themed according to geography, hazard type, methodology (including sample size), stakeholder type and level of education system impacted, mediating pathways (differentiated as direct and indirect[2]) and education impacts. Education impacts were classified as impacts on learning outcomes (literacy, numeracy, standardised assessments and other cognitive and socioemotional skills), access (including attendance and physical access) and attainment (graduation rates and years of schooling). Impacts were also differentiated by gender and other relevant vulnerabilities. The same code set was used for intervention studies.

2 Pathways to impact were thematically differentiated into direct and indirect mediators. Direct mediators were defined as those that directly impact learning capacity, such as impact on cognition, whereas indirect mediators include impacts on, for example, household income.

The coding was cross-checked through a two-tiered process. Papers were first randomly allocated for coding to the research team. Post-coding, the papers were redistributed based on hazard type for analysis, allowing at least two researchers to cross-check the majority of the papers.

The core of the analysis was derived from quantitative papers with quasi-experimental methods. This was supplemented with qualitative and mixed-methods papers. Among the studies of interventions, only those using econometric methods to examine the impacts of interventions on education outcomes in the context of climate change were used to draw key inferences.

2.8 Challenges and limitations

The main limitations of this study are that it is not a meta-analysis and therefore does not draw out quantitative insights of impact size. As the studies reviewed use diverse measures across climate hazards, and report on varied measures of educational impacts and learning outcomes, making comparisons between the impacts of different hazards challenging. A meta-analyses would need to be hazard-specific, as can be seen in recent work on the impacts of heat on learning (Prentice et al., 2025). While there is variation and debate about effective impact, in education, effect sizes of 0.1 standard deviation (SD) or more can be considered meaningful. This review therefore used 0.1 SD as a threshold for reporting effects (Evans and Yuan, 2020). Finally, while this study clearly outlines evidence of the actual and potential impacts of climate change on education, it does not account for the attribution of the extreme weather event to climate change, which is covered by the field of attribution science.

Part 2
Impacts of climate change on educational outcomes

This part of the report presents the evidence on impacts of various climate hazards on education outcomes.

3 Overview of studies

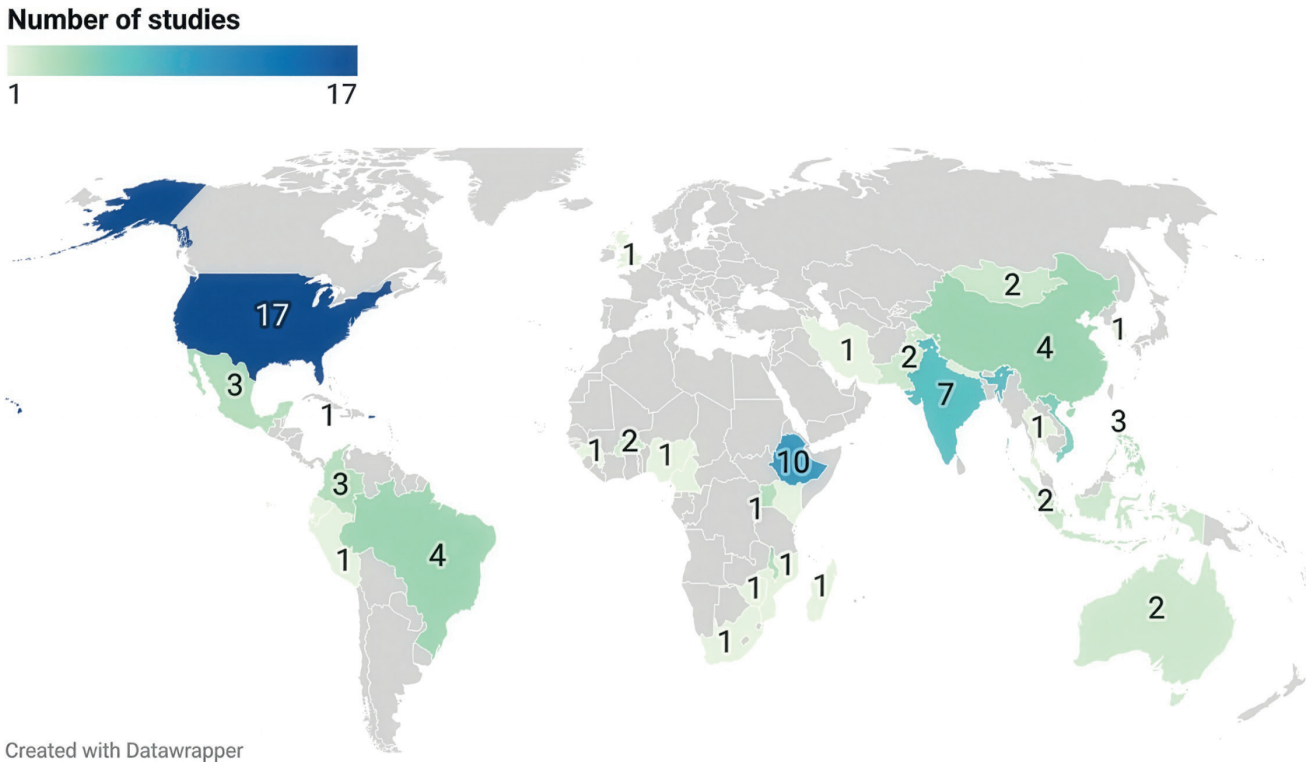
Of the 90 econometric papers included as the core of the systematic review, 83 were papers that assessed the causal impact of climate change on education (climate impact papers) and 17 were intervention studies that examined the impact of interventions on offsetting the impacts of climate change on education (intervention papers). Ten studies covered both impact and intervention.

The main impact findings are derived from 83 econometric papers and are supported by other quantitative studies with weaker methodology, as well as with qualitative and mixed methods studies. See Appendix 4 for details of the econometric studies included in this review.

With regard to sample sizes, all 83 studies had sample sizes greater than 1,000. A number of publications draw on the same data sets, as outlined in Table A2.1 in Appendix 2. This skewed the weight geographically, with 10 studies drawing on data collected by the Young Lives project (Ethiopia, India, Peru and Vietnam) and four studies on ASER data (India) and Progresa data (Mexico). Five studies examined the impacts of a single event – Hurricane Katrina in the US – using different datasets, of which two were econometric.

The geographic distribution of the studies was widespread (see Figure 3), driven by interest in hazard type and data availability. Five studies covered more than 10 countries.

Figure 3 Distribution of econometric impact studies by country



Note: The map excludes five multi-country studies (i.e. those including data from more than 10 countries).

Table 2 Econometric impact studies covering more than 10 countries

Region/countries	Study
West and Central Africa, Southeast Asia, Centra America, the Caribbean (29 countries)	Randell and Gray (2019)
Latin America (15 countries)	Caruso (2017)
Caribbean (13 countries)	Spencer (2016)
Asia, Africa, Central and South America (13 countries)	Jing (2024)
Global (US and 58 countries with PISA data)	Park, Goodman and Behrer (2020)

As Table 3 shows, econometric studies on temperature are the most prominent, followed by studies on rainfall variability. Wildfires are the least studied hazard and there were no econometric studies on windstorms.

Table 3 Distribution of econometric impact studies across hazards

Hazard	Number of studies
Rainfall variability	21
Floods and landslides	14
Droughts	15
Cyclones, hurricanes and typhoons	16
Temperature changes	26
Other hazards (wildfires)	6

Within the impact econometric studies, 43 assessed impacts on access, 56 assessed impacts on learning outcomes, and 23 examined impacts on attainment, as shown in Table 4.

Table 4 Econometric impact studies covering various education outcomes

Impacts	Effects on access	Effects on learning	Effects on attainment
Effects on access	43	24	12
Effects on learning	24	56	11
Effects on attainment	12	11	23

4 Rainfall variability

4.1 Introduction

Key insights

- Findings on access are mixed. Eight papers discuss the effects of rainfall variability on access with one finding positive impacts on attendance and enrolment, one finding negative impacts, four finding mixed results based on the direction of rainfall variability (increase or decrease), gender and age, and two finding no effect on access outcomes.
- Impacts on attainment are mostly negative. Of the seven papers examining impacts on attainment, only one finds positive impacts, while three find negative impacts. Four find mixed impacts based on gender, the direction of rainfall variability, and region.
- Impacts on learning are mostly negative. Of the 11 papers on learning outcomes only two find positive impacts while five find negative impacts. Four studies find mixed impacts based on the timing of exposure.
- The key mediating factors through which rainfall shocks impact education outcomes are household income, labour demand and child health.
- Six studies found heterogenous effects of rainfall shocks based on gender, age and socioeconomic factors. In particular, lower household incomes and exposure from in-utero to age two increased vulnerability.

Twenty-one econometric studies discuss the impact of rainfall shocks[3] on education: these are distributed as outlined in Table 5. Geographically, the studies were concentrated in Africa (10), Central and South America and the Caribbean (seven) and Asia (six). Slightly more studies examined learning outcomes than access or attainment outcomes. Six of these studies investigated the heterogenous effects on different groups of students. This literature is complemented by six studies using other methodologies, mostly undertaken in Asia and Africa.

3 Reflecting the analytical approach of the studies reviewed, this section discusses both increased and reduced rainfall (rainfall shocks). Each paper used different terminology to discuss rainfall shocks (i.e. deviations from average rainfall levels, rainfall variability, positive/negative rainfall shocks). This section uses 'increased rainfall' to refer to levels of rainfall above average, but not qualifying as floods, and 'reduced rainfall' to refer to levels of rainfall below average, but not qualifying as droughts. Many studies did not differentiate between the impact of positive (increased rainfall) and negative (reduced rainfall) shocks, and instead looked at the impact of overall rainfall variability on education outcomes.

Table 5 Distribution of studies on rainfall shocks

Education outcome	Number of studies	Geographical distribution
Access	9	Ethiopia (4), Kenya, Colombia (2), India, Madagascar
Grade attainment	7	Ethiopia, China, Mexico, Vietnam, Colombia, India, 29 countries across the global tropics
Learning outcomes	11	India (3), Colombia (3), Kenya, Madagascar, Brazil, China, Ethiopia

4.2 Effects of rainfall on access to education

Of the 10 studies that examined the effects of rainfall variability on access to education, only three found clear positive or negative outcomes. Two studies found associations with increased school attendance (Randell and Gray, 2016; Colmer, 2021). One found rainfall variability was associated with reduced enrolment (Nübler et al., 2021). A study looking at climate variability in Ethiopia found that increased rainfall increased the likelihood of students attending school. Specifically, children exposed to early life summary rainfall levels 0.5 standard deviations above their village's long-term average were 45% more likely to attend school. The other two studies looked at the overall effect of rainfall variability rather than differentiating between the impacts of increased or decreased rainfall (Randell and Gray, 2016). Colmer (2021) used longitudinal data on 7,142 children aged 4–21 to assess the impact of rainfall variability on human capital accumulation in rural Ethiopia.

The results showed that a one standard deviation increase in rainfall variability led to a 2.41 percentage point increase in school attendance, with particularly pronounced effects among younger children. Time-use analysis indicated greater time spent on schoolwork and home study, and less time on farm work. The authors interpret this reallocation as a response to increased agricultural risk: as rainfall becomes more variable and farming less reliable, households appear to shift children's time away from farm labour and towards education as a way of diversifying future income sources – a strategy known as the portfolio mechanism. Notably, the findings were not explained by changes in household income or wealth, suggesting that this shift reflects a behavioural response to risk rather than increased economic resources. However, the paper did not explore these alternative pathways in detail.

In contrast, Nübler et al. (2021), using baseline survey data from the Adolescent Girls Initiative-Kenya (2,147 girls aged 11–14), found that rainfall variability during early childhood – particularly during infancy (ages 0 and 1) – significantly reduced school enrolment. Rainfall variability at age 0 reduced the probability of ever enrolling by 16.9 percentage points, and enrolment by age 8 by 20.7 points. The study identified early childhood as a critical period during which exposure to climate shocks can have long-term consequences for educational access. Through further empirical analysis, the authors attribute these effects to multiple mediating pathways: rainfall variability is linked to lower and less predictable agricultural yields, which in turn reduces household income and food security. These economic shocks during infancy are associated with impaired cognitive development, poorer early childhood health and lasting constraints on household resources – all of which contribute to lower school enrolment later in life.

Table 6 Variables contributing to mixed or no significant impacts

Reason for mixed results	Number of studies	Study
Mixed results based on direction of rainfall (increase versus decrease)	1	Palacios Rojas-Velásquez (2023)
Mixed results based on gender	1	Falaris (2023)
Mixed results based on age	2	Shah and Steinberg (2017) Brando and Santos (2015)
No effect on access outcomes	2	Colmer (2013) Marchetta et al. (2019a)

Six studies found mixed or no significant effects on attendance and enrolment (Table 6). One study found mixed results based on direction of rainfall variability (increased versus decreased). Using administrative data for 6,327 Colombian students, Palacios Rojas-Velásquez (2023) revealed that increased rainfall increased intra-annual dropout rates by 1.34 percentage points for high school students and 1.12 percentage points for middle school students. On the other hand, decreased rainfall reduced dropout rates for high school students by 0.57 percentage points. After controlling for different mediators, the study found that the effect of increased rainfall on increased dropouts was due to reduced income and health problems.

One study found mixed results by gender. Using data from the Ethiopian Socioeconomic Survey covering 2,256 and 2,158 primary school aged boys and girls respectively in rural Ethiopia, Falaris (2023) found gender-differentiated effects of increased rainfall on school attendance. For girls, increased rainfall was associated with higher overall school attendance with an effect size of 0.127 due to increased household income, but also with greater absences during the harvest season, as daughters were often required to care for younger siblings while mothers worked in the fields. This seasonal pattern – higher absences in the first half of the school year and increased attendance later – highlights that disruptions to learning continuity are dependent on the timing of exposure to rainfall and associated labour demands. This finding underscores the importance of aligning education policies and support services with seasonal labour patterns, such as providing additional childcare support during harvest periods or adjusting school calendars in agricultural regions to reduce absenteeism. In contrast, boys' overall attendance declined following increased rainfall with an effect size of 0.16, which was driven by increased participation in agricultural labour. Boys were more likely to be pulled into agricultural labour during high rainfall because the opportunity cost of them attending school increased due to greater agricultural production and labour demand.

Two studies found mixed results based on age. Using ASER data on 2 million rural children in India to assess the long-term impacts of increased rainfall on human capital, Shah and Steinberg (2017) found that increased rainfall during early childhood (pre-natal to age 2) was associated with increased access to education. These children were more likely to be enrolled and on track in school, and scored 1.3% of a standard deviation higher in tests per year of exposure to increased rainfall. In contrast to positive early childhood findings,

the study showed that increased rainfall during school-age years (ages 5–16) led to declines in educational access. Specifically, enrolment fell by 1 percentage point and attendance by 2 points, and dropout rose by 4 points. Among older children (ages 11–16), exposure to high rainfall at age 12 reduced total schooling by 0.23 years, reflecting increased opportunity costs as children entered the workforce during periods of labour demand.

Brando and Santos (2015) used Colombian household data on 2,887 children's outcomes for 2013 aged between 0 and 5 years, and found that exposure to La Niña (characterised by increased rainfall) during the second year of life was associated with a 7.4% decrease in preschool attendance. Exposure to increased rainfall in the fourth year of life increased attendance. The differences between the impacts of La Niña exposure during the second year of life reducing preschool attendance, and exposure during the fourth year increasing it, illustrates an age-dependent effect of rainfall shocks on access outcomes, with greater vulnerability in early childhood. The paper suggests that this pattern reflects differences in household responses: during the second year, adverse income and health shocks constrained investments in young children, whereas by the fourth year families appear to have partially recovered, increasing educational investments as conditions improved.

Two studies found no effect on access outcomes. Prior to Colmer's study published in 2021, an earlier study (2013) on rainfall variability and schooling using household survey data from 1,477 rural Ethiopian households found no statistically significant overall effect of rainfall variability on attendance or enrolment. It did, however, find that increased child labour on farms was offset by reduced time on household chores, leading to no net impact. Children without siblings were 2.2 percentage points more likely to drop out, indicating that households with more offspring have greater choice about how to fulfil labour demand.

Looking specifically at the impacts of increased rainfall, Marchetta et al. (2019), using data on a cohort of over 1,000 individuals in Madagascar, found that a standard deviation increase in the rainfall rate had no impact on school enrolment.

Overall, the impact of rainfall on access is mixed. Of the nine studies, two reported increased attendance and enrolment, one reported negative impact and four had mixed results depending on factors such as whether rainfall was increasing or decreasing, gender and age. Two studies reported no impact on access outcomes.

4.3 Impacts on educational attainment

Of the eight studies on educational attainment, two found associations between rainfall shocks and increased educational attainment, while three found rainfall shocks to be associated with reduced educational attainment. Colmer (2021), on Ethiopia, looked at the impact of rainfall variability on human capital accumulation. It showed that a one standard deviation in rainfall variability led to a 0.044 gain in grade attainment. The study found no evidence that rainfall variability is associated with income-related factors, specifically income, wealth and agricultural outcomes. Randell and Gray (2016) found that higher summer rainfall was associated with an increased probability of completing between one and four years of schooling.

Across the three studies finding rainfall shocks associated with decreased educational attainment, the nature of the shock varied:

increased rainfall, reduced rainfall and 'adverse rainfall shocks'. In their study on rural China, Leight et al. (2015) found that increased rainfall in early childhood was linked to lower grade levels, later school entry and graduation, and an increased likelihood of grade repetition. These outcomes are consistent with the literature on reduced cognitive development. Adhvaryu et al. (2023) studied the impact of rainfall shocks in Mexico, and found that adverse rainfall shocks[4] during a child's birth year reduced years of schooling by 0.65 years, with statistically significant reductions in grade progression and age-appropriate completion. Their findings echoed those of Thai and Falaris (2014) who showed that in Vietnam's Red River Delta reduced rainfall during early childhood resulted in wider schooling gaps, including delayed progression and higher repetition rates, with impacts twice as large as in other regions.

Four studies found mixed impacts of rainfall shocks on educational attainment, one of which found mixed impacts based on gender. Using census data on more than 15 million individuals in Colombia, Carrillo (2020) found that a standard deviation increase in normal rainfall in Colombia during the first trimester of pregnancy was associated with a 0.035-year increase in schooling for boys – the effect found was three times larger for boys than for girls, with a statistically insignificant effect on girls. These gender differences indicate that male fetuses are more vulnerable to prenatal rainfall shocks than female fetuses. Two studies found mixed impacts based on the direction of the rainfall shock (increase versus decrease). Using census data from rural India, Shah and Steinberg (2017) found that rainfall shocks during early childhood have long-term effects on educational attainment, particularly total years of schooling. Using national labour force data, the study found that increased rainfall during school-age years, especially between ages 11 and 13, was associated with statistically significant reductions in total schooling. Each period of increased rainfall during the transition period from primary to secondary school reduced completed education by approximately 0.2 to 0.23 years compared to normal rainfall years.

Reduced rainfall during the same period increased schooling by a similar magnitude, suggesting that reduced labour demand during dry years encouraged children to remain in school. A key insight from this study was that these effects persisted into adulthood, indicating that changes in educational attainment were not temporary substitutions but rather lasting reductions in human capital investment triggered by climate-related wage fluctuations. Thai and Falaris (2014), using the Vietnam Living Standards Survey data on 4,735 children aged 6–19 living in rural areas, discovered that increased rainfall resulted in faster progression through school and shorter entry delay, while reduced rainfall had the opposite effect.

One study found mixed results by region. Randell and Gray (2019) used census data across 29 countries across different tropical regions with a final sample of 13,831,770 children to explore how prenatal and early childhood rainfall variability affects educational attainment in later life

4 They define a rainfall shock as 'a level of annual rainfall that is one SD above or below the locality-specific mean (calculated over the 10 years prior to the birth year)'. When they look specifically at rainfall below or above average – defined instead as rainfall between the 20th and 80th percentile – there is no significant impact on enrolment, grade progression or age-appropriate completion.

(ages 12 to 16). The study found varying results by region. In West and Central Africa low early-life rainfall is associated with reductions in schooling, with the largest impacts – up to 1.8 fewer years of education – among children from more educated households. While part of this impact could reflect lower baseline attainment among less-educated households as they have less room to fall, the authors interpret the pattern as evidence that even better-off families are not fully buffered from climatic shocks and may face larger disruptions to expected schooling trajectories. In Southeast Asia greater early-life rainfall is linked to increased educational attainment, though this benefit is limited to children from households where the head has at least a primary education; little to no effect is seen among children from the least educated households. In Central America and the Caribbean, the pattern is reversed. Excessive rainfall in early childhood is associated with reduced educational attainment, particularly among children from less educated households, who may lose up to 0.7 years of schooling.

Overall, the literature assessing the impact of rainfall shocks on educational attainment shows that the impacts are mixed, with the majority of papers highlighting decreases in educational attainment as the estimated effect.

4.4 Effects of rainfall on learning

Of the 13 studies on learning, two studies found rainfall shocks to be associated with increased learning outcomes, whereas six studies found associations with reduced learning outcomes. In their study on India, Shah and Steinberg (2017) found that increased rainfall during early life (prenatal to age four) was associated with improved test scores, with gains of 0.012–0.04 points per year of exposure – about 1.3% of a standard deviation annually – attributed to increased household income and investment in human capital. Dasgupta and Karandikar (2021) noted improvements in test scores for boys in India following reduced rainfall periods, with reading and maths scores increasing by 0.06 and 0.14 SD, respectively. Test scores were higher in reduced rainfall years. The studies above show that the positive impacts of rainfall shocks on learning outcomes can be attributed both to increased and decreased rainfall.

Three studies found negative impacts on learning outcomes induced by increased rainfall. A study using longitudinal household survey data from Colombia found that exposure to La Niña-related rainfall shocks – increased rainfall – during the second year of life is consistently associated with adverse developmental outcomes. Brando and Santos (2015) tested for effects on cognitive dimensions of human capital, as well as socio-emotional dimensions. Children exposed to increased rainfall pre-natally and during the second year of life[5] scored 0.10 standard deviations lower on cognitive assessments, such as the Peabody Picture Vocabulary Test, and showed a 7.6% higher probability or 0.19 SD greater of being at risk of socio-emotional difficulties based on the Ages and Stages Questionnaire. These difficulties included problems with following instructions, adapting to daily routines and interacting with peers and caregivers. The cognitive effects appeared to be mediated in part by socio-emotional impairments, suggesting cross-dimensional impacts on human capital development. The study identified the second year of life as a critical developmental window for both cognitive and socio-emotional domains, while prenatal exposure had weaker or statistically insignificant effects.

5 No impacts were associated with exposure in the first year of life.

While prenatal results were weaker in Brando and Santos's study, Carrillo (2020) found the opposite effect. Using census data for more than 15 million individuals in Colombia, the results showed that increased rainfall prenatally was associated with a 1.7% increase in illiteracy rates. The study showed that when prenatal rainfall levels were normal learning outcomes benefited, as male illiteracy rates fell by 2.2%. The effect on female illiteracy rates was approximately half that, around 1%, but still statistically significant.

A study looking at approximately 4,000 children in rural Mexico also found increased rainfall to reduce learning outcomes. Specifically, children exposed to extreme precipitation between the ages of two and six exhibited reduced cognitive development – language, long-term and working memory and visual-spatial thinking – by 0.15 to 0.19 SD (Aguilar and Vicarelli, 2022).

One study found an association between reduced rainfall and reduced learning outcomes. Nübler et al. (2021), in their study on Kenyan children in drought-prone areas, found reduced rainfall in the first year of life significantly reduced literacy, numeracy and cognitive skills, lowering reading accuracy by 13 percentage points and maths and cognitive test scores [Raven test][6] by 0.2 standard deviations or more. Smaller effects were observed from age 1, with little impact from reduced rainfall at later ages except for some negative effects on literacy at age five. Raven scores were only affected by reduced rainfall in early life. The authors suggest that the lack of significant effects at older ages could reflect the critical importance of early life conditions for cognitive development.

The mixed findings from the above three studies – with negative impacts on learning outcomes attributed both to increased rainfall and decreased rainfall – are echoed in a study looking at overall rainfall variability. Marchetta et al. (2019), using data from two surveys in Madagascar on 1,075 individuals from rural communities, showed that rainfall variability affected maths and French test scores among school attendees. Test scores were affected only by immediate rainfall variations (in 2011), but not by rainfall a year prior. A one standard deviation decrease in rainfall immediately lowered combined French and maths scores by 0.326 standard deviations. A one standard deviation increase in rainfall increased test scores by the same amount. The authors attributed these effects to increased school absenteeism rather than psychological stress, as the decline in test scores was observed only among children who attended school, suggesting that reduced attendance and learning time were the primary pathways through which rainfall shocks affected performance.

One study examined the effects of the intensity of rainfall variability on learning. Using data from a standardised nationwide exam in Brazil, with a final sample of approximately 864,000 elementary school students, Ferreira de Lima et al. (2024) found statistically significant results – extreme rainfall shocks reduced maths and language performance by 0.055 and 0.04 standard deviations respectively. When calculated in terms of time spent on learning, the results showed that an extreme precipitation shock corresponds to a loss of approximately 20% of learning time in the school year, equal to two months of the school year.

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6 The Raven Coloured Progressive Matrices test is a non-verbal multiple choice test that measures cognitive skills – the respondent must identify the missing element completing a pattern (Raven et al., 1984).

The study differentiated between low- and high-intensity precipitation shocks using standard deviation thresholds above average rainfall. A low-magnitude shock (1 standard deviation above the mean) had no significant effect on student performance, while a high-magnitude shock (2 standard deviations above the mean) was associated with a statistically significant negative impact. The study found that the adverse effect on performance was influenced by the frequency of extreme shocks; occasional high-intensity rainfall events were insufficient to affect outcomes, but the impact became more pronounced and significant as the number of such shocks increased.

Four studies found mixed or insignificant effects of rainfall shocks on learning outcomes. Studying the effect of rainfall shocks in Colombia on exam scores, Palacios and Rojas-Velásquez (2023) found differing impacts between increased and reduced rainfall. Reduced rainfall had positive impacts on learning outcomes – it was associated with increased reading scores by 1.25 SD and maths scores by 0.29 SD. By contrast, increased rainfall had a negative and greater effect on learning outcomes, leading to a decrease in reading and maths scores by 4.24 SD and 3.95 SD respectively. The results reported contrasting effects of positive versus negative shocks, with increased rainfall reducing scores and reduced rainfall increasing them – highlighting how shock type shapes direction of impact.

Three studies found differing impacts based on the timing of exposure to rainfall shocks – highlighting that prenatal shocks have the most pronounced negative effects on learning outcomes. Using multi-wave survey data on 20,000 children in rural China, Leight et al. (2015) found early-life rainfall variability,[7] particularly during prenatal development and the first year of life, had a significant negative effect on cognitive skills, including numeracy and literacy, as measured in later childhood (ages 9–12). The estimated effect sizes were in the range of 0.1 to 0.2 standard deviations lower on achievement tests, particularly for shocks during the prenatal harvest season and year one planting season. These effects are consistent across multiple survey waves, though appeared to reduce over time, potentially due to biological recovery or compensatory investments.

For example, some households increased educational investments in children who experienced early shocks – particularly in the second survey wave – though these responses were not universal and often modest in magnitude (approximately 0.01–0.05 standard deviation increase in expenditure-to-income ratio per standard deviation of rainfall shock). Exposure in the second year of life showed weaker and less consistent associations with cognitive outcomes. Leight et al. (2015) found no robust evidence of impact on non-cognitive skills (e.g. self-esteem, behavioral indices), with most coefficients statistically insignificant across waves.

Chang et al. (2022) found that prenatal exposure to rainfall shocks in India – defined as at least 1.5 SD away from the historical community and monthly rainfall mean – reduced vocabulary by 5% at age five and maths scores by 2% at age 15. Socio-emotional skills, such as self-esteem and self-efficacy, were also negatively affected. However, the timing of the rainfall shock by trimester was not statistically significant. Shock intensity (mild versus strong) did not affect outcomes – exposure alone mattered. Pazos

7 Defined as unusually high or low level of rainfall relative to the mean rainfall in the village in the same year.

et al. (2024), using data from the Young Lives Study covering 1,728 children from the poorest 95% of households in both rural and urban areas in Ethiopia, found that reduced rainfall during early life reduced Peabody Picture Vocabulary Test (PPVT) scores at ages five and eight, with effects disappearing by age 12, suggesting possible recovery or adaptation. Exposure during the prenatal period appeared to be the most sensitive to these shocks, and the findings were consistent across different durations of reduced rainfall (e.g. four or six months). The study also found that children's working memory declined by 6.6% of a standard deviation when exposed to shocks during the first 1,000 days of life. No significant effects were found on other foundational cognitive skills such as implicit learning and long-term memory.

4.5 Heterogenous effects

Gender

Six studies examined gender-differentiated impacts of rainfall shocks, with mixed results. Three studies found that girls were more negatively affected by rainfall shocks than boys. First, using national survey data on 991,000 individuals from rural households in India, Dasgupta and Karandikar (2021) investigated the gender gap in learning outcomes. They found reduced rainfall was associated with improvements in educational outcomes. For boys, they found that they scored higher in reading and maths (by 0.06 and 0.14 SD, respectively) during periods of reduced rainfall compared to when they were tested during years with increased rainfall. Girls appeared to benefit more than boys under periods of reduced rainfall, with stronger improvements in test scores. Increased rainfall was associated with declines in learning outcomes for girls, especially in regions where rice cultivation dominates agricultural production and gender norms support higher female labour force participation. Under such conditions, girls were more likely to substitute for adult female labour, either by entering paid work or taking on full-time domestic responsibilities, which negatively affected their schooling. Overall, the study showed that girls' test scores are more elastic to rainfall conditions than male children.

Björkman-Nyqvist (2013), using administrative data on 1,667,447 students in Uganda, found no effect of rainfall variation on boys' enrolment, but significant declines for girls, particularly in grades 6 and 7. A one standard deviation drop in rainfall reduced girls' enrolment in grade 7 by approximately 1%. Test scores rose during droughts, likely because lower-performing girls were withdrawn, inflating average outcomes. Ferreira de Lima et al. (2024) showed that girls were more negatively affected than boys by rainfall variability in Brazil.

Three studies found greater impacts on boys from increased rainfall as well as rainfall variability overall. Carrillo (2020) found clear gender differences in the long-term effects of prenatal rainfall exposure on education and labour outcomes. Specifically, boys benefited more from increased rainfall during early gestation in terms of educational attainment, suggesting that male foetuses may be more vulnerable to prenatal shocks. A standard deviation increase in normal rainfall during the first trimester was associated with a 0.035-year increase in schooling for boys, compared to a statistically insignificant 0.011 years for girls. Thai and Falaris (2014) reported that, in rural Vietnam, boys were disadvantaged relative to girls in both height-for-age and educational attainment during periods of increased rainfall. Although no gender differences were observed in school entry age, the authors noted that

increased rainfall had stronger positive effects on schooling outcomes for ethnic majority children and those with more educated parents. Chang et al. (2022) found that negative impacts of rainfall variability on cognitive skills were largely driven by boys, with vocabulary and numeracy scores significantly lower for them. Non-cognitive outcomes were not gender-differentiated.

Age

Eight studies analysed age-specific effects, consistently identifying early childhood (particularly prenatal to age two) as a critical window where rainfall shocks have the most significant and lasting impacts on access, learning and attainment outcomes. One study identified adolescents as also at risk.

Shah and Steinberg (2017) presented one of the most detailed age-differentiated analyses, finding that:

- Early childhood (prenatal to age two): Increased rainfall was associated with increased test scores and enrolment, suggesting this is a critical window for investment in human capital.
- Impacts on ages 5–10 are mixed, but generally smaller. For ages 11–16, increased rainfall was associated with increased child labour and reduced test scores.

Colmer (2021) found that younger children benefited most from positive rainfall variability, with no observable gender differences in time-use outcomes. Nübler et al. (2021) reinforced this finding, showing that rainfall shocks after age five had no consistent or significant effects on enrolment. Access to Kenya's Hunger Safety Net Programme somewhat mitigated the effects, especially for girls, although the non-random rollout limited causal interpretation.

Thai and Falaris (2014)'s analysis of Vietnam Living Standards Survey data found that the third year of life was particularly sensitive. Reduced rainfall during this year was linked to delayed school entry and wider schooling gaps, while increased rainfall was associated with improved health, which may enhance educational outcomes.

Brando and Santos (2015) emphasised the second year of life as a critical window for cognitive and socio-emotional development, while prenatal exposure had weaker effects. Leight et al. (2015) found that prenatal and first-year exposures were strongly linked to cognitive deficits, while second-year exposure showed weaker effects.

Socioeconomic status

Six studies discussed heterogenous effects based on household and socioeconomic factors. Examining household factors, Thai and Falaris (2014) found that parental height, particularly that of the father, was positively associated with both child height and educational attainment, suggesting intergenerational links between health, earning potential, and schooling. Children from the ethnic majority and those with more educated parents experienced more positive effects from rainfall shocks, while those in economically vulnerable areas were more severely affected. Falaris (2023) emphasised the influence of parental education, showing that children of more educated parents had higher school attendance and reduced work hours. Colmer (2013) noted that children without siblings were more likely to stop attending school during climate variability, with a 2.2 percentage point increase in dropout probability, reflecting the unequal distribution of household labour burdens.

Highlighting differences in socioeconomic factors, Chang et al. (2022) found stronger negative effects of rainfall shocks on maths scores and

cognitive test scores among children from less educated households, suggesting that pre-existing disadvantage amplifies vulnerability. Brando and Santos (2015) found that the negative impact of prenatal shocks was greater for children above the poverty line, who suffered 87% greater cognitive and anthropometric losses. Due to floor effects, impacts were only detectable among richer families.

4.6 Impact pathways

The literature reviewed consistently emphasises that rainfall shocks influence education access outcomes through a set of interrelated mediating pathways: particularly household income, labour demand and child health. In agrarian economies, rainfall variability often affects agricultural productivity and household earnings, which can either constrain or enable investment in children's schooling. These income effects frequently lead to children being withdrawn from school to compensate for household shocks or to meet increased demand during harvests. In parallel, health and nutrition outcomes – especially during early childhood – can shape long-term educational trajectories through effects on cognitive development and school readiness.

Income and livelihoods

Three studies identified income and livelihoods as a mediating factor. Using the Uganda National Panel Survey data on 13,263 children to study rainfall variability and school attendance, Agamile and Lawson (2021) found that decreased rainfall reduced school attendance by 9.8%, with rural and poorer children most affected. Parents withdrew children from school in response to income loss, often redirecting them to wage labour. However, land ownership was associated with a 3.1% increase in attendance, underscoring how wealth buffers educational disruption. The authors also found that school meal provision increased attendance by 0.059 SD, offering another mitigating factor against the impacts of income loss.

Nübler et al. (2021) provided longitudinal evidence from Kenya showing that rainfall variability during early childhood reduced household educational spending by one-third even a decade later. While the Hunger Safety Net Programme (HSNP) appeared to partially cushion these long-term effects, particularly for girls, the non-randomised rollout of the programme limited the authors' ability to draw conclusions about its protective effect.

Palacios and Rojas-Velásquez (2023) examined Colombian administrative data and found that excess rainfall increased dropout rates within the same academic year through a 33.8% decline in tax revenue per capita, which weakened municipal capacity to support education. At the household level, reduced income and health problems were the primary mediators of school dropout in high-rainfall municipalities.

Three studies discussed the impact of child labour and opportunity costs. Akresh et al. (2012)'s study using household survey data from Burkina Faso on 2,862 children examined the relationship between rainfall shocks and children's cognitive ability. The study found that reduced rainfall prenatally was correlated with 0.23 standard deviations lower cognitive ability, increased child labour and poorer education outcomes. One standard deviation of higher cognitive ability is correlated with engaging in 0.8 less hours of child labour in comparison to a sibling with lower cognitive ability. These findings were echoed in Falaris (2023), which reported that high rainfall years increased agricultural productivity, resulting

in boys being pulled into farm labour, negatively impacting their schooling. Reduced illness rates during these periods somewhat offset this effect by increasing attendance.

Shah and Steinberg (2017) explicitly tested several mechanisms and found that child labour driven by increased wages was the primary explanation for reduced school participation among older children during positive rainfall years. They found that increased rainfall during school-age years raised local wages and labour demand, pulling children – especially those aged 11–13 – out of school. Drought years reduced labour pressure, allowing more children to stay in school. Other factors (illness, teacher absence and the impact of school meals) were ruled out as explanatory factors.

Together, these findings strongly supported the hypothesis that higher opportunity costs of schooling in good rainfall years led to child labour substitution and educational setbacks.

Nutrition

Three studies discussed nutrition as a pathway mediating the impacts of rainfall on education outcomes; however, they did not empirically establish a causal link. Leight et al. (2015) identified that rainfall variability negatively affected agricultural productivity, particularly when occurring in the harvest season. Rainfall variability lowered household income, which in turn restricted expenditures on child nutrition and education. Children exposed to these adverse shocks in the prenatal period were found to have significantly lower height-for-age Z-scores (–0.15 SD), an anthropometric indicator highly correlated with early malnutrition, especially when rainfall disruptions occurred during the harvest season. Although the study does not empirically establish this causal chain, the authors suggest that nutritional deprivation – both during gestation and infancy – is a key pathway to impaired development.

Brando and Santos (2015)'s study on exposure to La Niña in Colombia investigated impacts on nutritional pathways. The study found that prenatal exposure to La Niña is significantly associated with lower birth weights (–0.19SD) and increased likelihood of low birth weight by 4.6%. These outcomes likely reflect disrupted maternal nutrition and stress during gestation. Children exposed prenatally exhibit lower postnatal weight by –0.15 SD and height by –0.12 SD, which are known to correlate with cognitive development. Although the study did not explicitly test malnutrition as a mediator of educational outcomes, these anthropometric indicators suggest early nutritional deficits may contribute to poorer cognitive outcomes. Pazos et al. (2024) also linked early-life rainfall variability to food insecurity, and hypothesised this as a pathway to learning deficits but did not test causality.

One study carried out a more nuanced investigation of prenatal mediating factors on child health through the role of maternal labour participation during critical developmental periods. Leight et al. (2015) hypothesised that shifts in maternal labour participation could be an alternative mediating pathway. Specifically, a one standard deviation increase in planting season rainfall was associated with a 16% increase in maternal labour participation, likely due to increased demand for agricultural tasks such as weeding. Conversely, harvest season rainfall shocks reduced maternal labour supply by approximately 22%, reflecting lower agricultural demand due to crop damage. The study hypothesised that increased labour during the planting season may reduce time spent on caregiving or result

in physical strain during pregnancy, both of which have been linked to adverse birth and developmental outcomes; however, this is not further investigated in the study.

4.7 Insights from additional studies

Six mixed-methods or qualitative studies illustrated how rainfall shocks disrupt education not just through income loss or child labour as discussed above, but also through compounded effects on infrastructure, health and teaching conditions. Several of these studies (two of which were undertaken with girls only) emphasise girls' greater vulnerability to the impacts of rainfall shocks on education.

Impacts of infrastructural damage. Findings from UNICEF studies[8] in South Asia reveal that heavy rainfall in Bangladesh, Sri Lanka and India led to reported disruptions to school commutes due to climate change-related events. In Bangladesh, some schools reported attendance rates falling below 50% during periods of heavy rain. Damage to educational materials and facilities was also widespread: in Bangladesh, over 18% of schools were unable to recover from structural damage, and more than 10% experienced a complete loss of books and teaching materials. These challenges were further compounded by teacher absenteeism, reductions in instructional time and the absence of effective adaptive measures such as flexible timetabling (Kagawa, 2021; 2022b; 2022c).

A Plan International longitudinal study of girls in three African countries (Uganda, Benin and Togo) reported similar findings. In Benin and Togo, girls reported that attending school became difficult during heavy rainfall, which degraded roads and rendered them impassable. This caused widespread absenteeism, forcing teachers to repeat lessons once students could return, and increasing teacher absences. Girls also noted that rainfall created potholes in school compounds, and children were often removed from class to assist with repair work by filling the holes with sand (Plan International, 2024).

Gendered impacts

The UNICEF studies in Sri Lanka and Nepal found that girls missed school more frequently because they were responsible for water-fetching during periods of low rainfall, particularly droughts. In Nepal, girls also faced difficulties attending school due to inadequate sanitation facilities during menstruation because of lack of water supply. In India and Bangladesh, early marriage and an increase in domestic responsibilities – exacerbated by climate shocks – were identified as leading to school dropout or irregular attendance. In terms of economic stress, 11% of youth in Nepal, 12% in India and 8% in Sri Lanka indicated that their families could no longer afford to send them to school due to climate-related income loss (Kagawa, 2021; 2022b; 2022d).

Mazingi and Muyumbwa (2021) used participatory research methods to collect insights from 160 adolescent girls in Zambia and Zimbabwe. As rainfall patterns shifted and became less predictable, food insecurity increased in communities dependent on rain-fed agriculture, impacting household livelihoods and prompting school dropout – especially among girls. In many

8 These studies combined U-Report data from youth aged 14–24 years with primary data collection, including focus group discussions and participatory methods involving children and teachers.

cases, families prioritised boys' education, and early or forced marriage became more common for girls.

Furthermore, loss of reliable water sources during droughts resulted in communities sharing contaminated water with livestock, impairing menstrual hygiene and contributing to health risks. Heavy rains posed their own dangers, with girls reporting injuries sustained on damaged transport routes. In some cases, displacement due to the destruction of homes led girls to seek temporary shelter, where they faced sexual exploitation by men or older boys. Girls in Plan International's study reported that climate-related agricultural damage – such as destroyed crops and weakened livestock – negatively impacted household income, leading to increased difficulty in paying for school. In several cases, girls were pulled out of school entirely to support household livelihoods (Plan International, 2024).

5 Floods and landslides

Key insights

- There is mixed evidence about the impact of flooding on children's access to education. While four studies found decreases in enrolment and dropout rates, four found no evidence, with three finding contradicting results for the same countries.
- All six studies on the effect of flooding on educational attainment found an association with a decrease in years of schooling or school completion, with the exception of one country.
- While eight of the nine studies on learning outcomes found a link between floods and lower test scores or increased illiteracy rates, seven also reported mixed results, as impact varied depending on type of test, country, age group or flood intensity.
- Flooding may affect educational outcomes via household income, child labour and health, as well as damage to school infrastructure and roads – with the first three being the most discussed in econometric studies.
- Only half of the studies (seven of 14) analyse whether the impact varies across demographic groups, with differences between age groups being the most examined. Prenatal exposure tends to be linked to stronger negative effects than exposure after birth.
- Non-econometric studies highlight floods' mixed impact on access and learning. They add more evidence as to the importance of damage to infrastructure and teachers' well-being as potential impact pathways.

5.1 Introduction

Of the 14 econometric studies that examined the impact of flooding on education, eight examined impacts on access, six on educational attainment and nine on learning outcomes. All studies focused on inland flooding, whether pluvial (river) or fluvial (surface water), rather than storm surges. Also discussed in this section are two econometric studies on the effects of landslides caused by floods on attainment and learning outcomes.

The studies in this section draw mostly on data from Asia and Central and South America and the Caribbean – with six studies covering at least one country in each of these regions – followed by studies that focus on North America (four) and Africa (four).[9] Table 7 shows their distribution. The two studies of the impacts of flood-related landslides were from Latin America. Three studies used large multi-country datasets, one of them covering 15 countries and two using Young Lives data for four countries.[10]

9 Various studies focus on more than one country, explaining why the numbers exceed 14.
10 An additional study also used Young Lives data, but only for Ethiopia (Hyder and Behrman, 2016).

Table 7 Distribution of flooding and landslide studies

Dimension	Number of studies				Geographical distribution
	Total Number	Access	Grade attainment	Learning outcomes	
Floods	14	8	6	9	Pakistan, Vietnam, India, Peru, Ethiopia, Malawi, Colombia, Ecuador, Mexico, Thailand, Latin America and Caribbean[11]
Landslides	2	0	1	1	Latin America and the Caribbean, Colombia[12]

The definition of flooding varied substantially across papers. For example, some papers defined floods as rainfall exceeding the 75th or 80th percentile (Abiona, 2017; Adhvaryu et al., 2020), while other studies used self-reported exposure (Zamand and Hyder, 2016; Nguyen and Nguyet, 2018).

The only three studies that report findings on the impact of floods on educational outcomes in standard deviations find a considerable impact (at or above 0.1 SD) (Brando and Santos, 2015; Caruso, 2017; Rosales-Rueda, 2018). The remainder of the studies report their findings in other units, such as percentage points and years of education.

In addition to these 14 studies, 29 studies using qualitative, mixed methods or less rigorous quantitative studies were examined, mostly from South and Southeast Asia. All also focused on inland flooding; a few mention storm surges as a climate hazard that affects schools in Bangladesh, India and Sri Lanka, but only do so in passing (Kagawa, 2021; 2022b; 2022c).

5.2 Effects of floods on access to education

Of the eight studies investigating the impact of flooding on children's access to education, four found that floods reduced access in Pakistan, Vietnam and Mozambique. Three studies found no impact in Vietnam and Pakistan, as well as other countries. One study found a small increase in school enrolment in India.

Ahmed et al. (2022) and Khan and Hussain (2023) examine the impact of floods on school enrolment in Pakistan, both finding the 2010 floods were associated with lower enrolment rates. Ahmed et al. (2022) examined the impact in both rural and urban communities using six waves of a household survey with more than 1 million children aged 5–16, finding that, in flood-affected districts, there were 51 more children (per 1,000) who remained out of school and 16 more children (per 1,000) who dropped out. The effect on out-of-school children disappeared entirely after the year of the flood, while the effect on dropout became significant again four years later with a very similar effect size. The authors do not explain what might be driving this difference. Khan and

11 The study includes data from Argentina, Bolivia, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Haiti, Jamaica, Mexico, Nicaragua, Panama, Peru, Uruguay and Venezuela.

12 See previous footnote.

Hussain (2023), who used data from three waves of the Social and Living Standards Measurement survey including around 80,500 children, found that the floods were linked to a five percentage point increase in school dropouts.[13] They also report that the floods left around half a million children out of school.[14]

In Mozambique, Baez, Caruso and Niu (2020) found floods to be linked with lower levels of school attendance. Using data from three waves of the Inquérito aos Orçamentos Familiares (IOF) survey for around 16,000 children, they found that children (between the ages of 5–17) who were in flooded areas at the time of the cropping cycle had 8.3 percentage points lower school participation rates relative to their counterparts.

Nguyen and Nguyet (2018) and Zamand and Hyder (2016) focused on school enrolment in Ethiopia, India, Peru and Vietnam.[15] Using Young Lives data, they find mixed, and in the case of Vietnam and India contradictory, results. Using longitudinal data for around 3,700 children aged 12–15 in both rural and urban settings, Nguyen and Nguyet (2018) found that floods were associated with a slightly lower probability of enrolment (by 0.05) in Vietnam – the country that tends to be the most affected by floods among this group. They found no impact on the other three countries. Zamand and Hyder (2016), who used cross-sectional data for around 3,000 children aged 14–16, also found no impact on enrolment in Peru and Ethiopia. In contradiction with the results of Nguyen and Nguyet (2018), they found no impact in Vietnam and a marginal increase of 0.256 on enrolment in India. The contradictory results between the studies might be related to the different age groups represented in the samples.

Hyder and Behrman (2016), who also use Young Lives data (but only two waves and for 979 children only), found floods have no impact on enrolment in Ethiopia. Abiona (2017) and Dasgupta and Karandikar (2021) also found no impact on school access in Malawi and India, respectively. Using three waves of the Integrated Household Survey for more than 10,000 households, Abiona (2017) found that exposure to floods during the prenatal period or early infancy (0 to 2 years old) did not impact children's school enrolment (unlike drought: see Section 6).[16] Dasgupta and Karandikar (2021), using longitudinal data for approximately three million children from the Annual Status of Education Report (ASER) Survey in India, found that floods did not increase dropout rates for children between the ages of five and 16.[17]

5.3 Effects of floods on grade attainment

Across all six studies investigating the impact of flooding on educational attainment, flooding was consistently associated with a decrease in years of schooling or school completion, particularly in cases of prenatal exposure. The only outlier was Peru. While Caruso (2017) reported reduced schooling in this and 14 other Latin American countries (see Box 1), Nguyen and Nguyet (2018) found no such impact in their country-specific

13 This study defined school dropouts as children who had either never attended school or were not enrolled at the time of the survey.
14 There are no available details on the duration of school closures.
15 Both studies used household self-reported exposure to natural disasters.
16 This study defined floods as rainfall exceeding the 75th percentile of the 30-year local historical average.
17 Defined as years with rainfall above the 80th percentile.

analysis. Most studies in this section focused on Latin America, with one study examining impacts in North Africa and South and Southeast Asia.

Caruso (2017)'s finding that prenatal exposure to floods was linked to a decrease in years of schooling (see Box 1) was echoed by two other studies, one in Mexico and one in India. Adhvaryu et al. (2023), who examined the impact of floods in rural Mexico using data from a 2003 survey covering 11,829 children and adolescents (aged 12–18), similarly found that exposure to floods in a child's birth year was also related to a loss in total years of schooling – in this case, of 0.65 years.[18] It was also linked to a lower probability (0.19) of progressing at least five grades and of completing the appropriate number of grades for a child's age, by 0.11 percentage points. These results were echoed by the study of the impact of prenatal exposure to floods in Colombia – a country that is affected by both El Niño and La Niña phenomena (see Sections 4 and 6 for the effects on rainfall and drought). Using census data from birth cohorts between 1942 and 1981 across the country for 15 million individuals, Carrillo (2020) found that a 1 SD increase in prenatal exposure to floods was associated with 0.21% fewer years of schooling.[19] Exposure during the first trimester of pregnancy was the most critical. In India, Dasgupta and Karandikar (2021) found that floods were linked to a reduced probability (by 0.65 percentage points) of being on track in school.[20]

Box 1 Does the impact of flooding vary by its intensity?

Examining the effects of disasters in the last 100 years in 15 Latin American and Caribbean countries, Caruso (2017) studied the long-term impact of exposure from the prenatal period up to the age of 15 on a range of outcomes, including years of schooling. Using available census data for 24 million children, the study found that prenatal exposure to floods was associated with a decrease of 0.472 years of education, equivalent to a 0.1 SD. However, this loss decreased when exposure to floods occurred in later childhood, reaching the lowest level when exposed at the age of eight. It then increased again until it reached a value of around 0.15 years of education when exposed at the age of 14.[21]

18 Floods were defined in this study as rainfall above the 80th percentile.

19 Carrillo (2020) defined floods as a 1 SD increase in the historical monthly rainfall average for each location studied. There is a discrepancy in the paper's results. While it mentions that a 1 SD increase in exposure decreased years of schooling by 0.21%, this is not compatible with the coefficient reported in Table 3 (-0.1197) of the study.

20 The study does not specify if this measure refers to age and grade relation or learning progress.

21 There is a discrepancy in the paper's results. Their explanation of the figure the data is drawn from does not match what the figure shows. The text here is according to the figure, not their explanation.

Box 1 Does the impact of flooding vary by its intensity? (continued)

Caruso (2017) was the only study to analyse the impact of floods of different intensities – of 'big' and 'small' floods, respectively defined as floods above or below the mean number of affected individuals. The study found that big floods were linked to a reduction in schooling when exposure occurred at most ages (except ages 11–12 and 13–14). Impact was highest when exposure occurred in-utero, with a reduction of 0.590 years of schooling, decreasing afterwards and reaching its lowest at age 9–10, after which it picked up again. There was a similar trend in the impact of small floods, though their impact was less. Their negative effect on years of schooling was also highest when exposure occurred during the prenatal period, with an estimated loss of 0.191 years of schooling, decreasing until the age of 5–6 and increasing again at ages 12–13.[22] This could be due to the importance of the prenatal period for cognitive development and the trade-offs that might arise of studying or working during adolescence.

Nguyen and Nguyet (2018), examining the impact of floods in four countries on children between the ages of 12 and 15, found that, while floods were linked to a reduction in the number of completed grades in India, Ethiopia and Vietnam, this was not the case in Peru, probably reflecting a lack of severe floods in Peru during the study period. In India and Ethiopia, floods were linked to a reduction in the average number of completed grades by 3.8% and 3.4%, respectively. The effect was most pronounced in India, a country with a considerably lower proportion of flood-exposed households compared to Ethiopia. They also found a reduction in Vietnam by 1.8% (discussed in Sections 5.2 and Section 9). This contrasts with their findings regarding access (see Section 4.2), where they found negligible to no impact on enrolment, potentially showing that, while parents may prioritise getting children back to school after a flood, floods can still delay children's school progression.

Khan and Hussain (2023) found that floods decreased grade attainment, like enrolment, in South Asia (see Section 5.2). They found that the 2010 floods in Pakistan were linked to lower primary and secondary school completion rates, by 6.5 and 3.7 percentage points respectively, and to a reduction in the total number of grades by 0.138 grades.

For the impact of landslides on grade attainment, see discussion in Box 2.

22 Results for ages 6–12 are not statistically significant.

Box 2 Impact of flood-induced landslides on grade attainment

Caruso (2017) also studied the impact of landslides on educational attainment. Like floods, landslides were associated with a decrease in years of schooling when the individual was exposed between the prenatal period and the age of 15. Prenatal exposure was linked to a reduction of 0.486 years of schooling, reaching its highest negative effect when exposure occurred at age three (when the loss was approximately 0.55 years). Caruso (2017) argues infrastructural damage might be driving this impact, in this case, damage to healthcare and basic services, which presumably damage mothers' health.

When estimating how the impact of landslides varied depending on their intensity – categorised in this case by the number of individuals affected – the study found that, while exposure to 'big' landslides was associated with a decrease in years of schooling when exposed at any age, exposure to 'small' landslides was only associated with a smaller loss and only when exposed at some ages. 'Big' landslides were linked to the greatest loss when exposure occurred between the ages of three and six, while the greatest loss in relation to 'small' landslides occurred with exposure in-utero or in the child's first year.[23]

5.4 Effects of floods on learning outcomes

Nine studies examined the impact of flooding on learning. Eight of those studies found that exposure to floods was associated with a decline in children's learning, by increasing illiteracy rates or by reducing subject or cognitive test scores (such as the PPVT and Cloze test).[24] However, in the six studies that specifically look at test scores, results are mixed. Floods decrease some test scores but not others. Brando and Santos (2015) was the only study to examine impact on socio-emotional skills.

Illiteracy rates. Both Khan and Hussain (2023) and Carrillo (2020) found evidence that floods increased illiteracy. Carrillo (2020) found that a one SD increase in prenatal exposure to floods is associated in Colombia with a 1.7% increase in illiteracy rates. While the impact is significantly smaller (estimate value of 0.0045 compared to 0.0085), floods were also associated with higher illiteracy rates when exposure occurred in the first trimester of pregnancy.[25] Khan and Hussain (2023), who examined the impact of the 2010 floods in Pakistan, also found that illiteracy rates increased – in this case by 4.4 percentage points.

Test scores. All of the studies examining the impact on test scores found evidence that floods reduced scores, but only when exposure was at certain ages, in certain countries or at higher levels of intensity. The exception to this was

23 For big landslides, exposure at age 3–4 was related to a decrease of 1.534 years of schooling, at age 4–5 to a reduction of 1.239 years, and at age 5–6 to a reduction of 1.486 years. For small landslides, exposure at age 0–1 was linked to a reduction of 0.393 years.

24 A cloze test measures reading comprehension and vocabulary. It assesses a person's ability to understand context and fill in missing words in a text.

25 The 1.7% figure is not consistent with the coefficient reported in the study.

Dasgupta and Karandikar (2021), who found that, in rural India, floods were linked to lower reading and maths scores – by 0.0183 SD and 0.0500 SD, respectively – for all children between five and 16.

Rosales-Rueda (2018) examined the effect of prenatal and early infancy (until two years of age) exposure to extreme El Niño floods (1997–1998) in Ecuador. Using three rounds of survey data for more than 3,500 children, the author finds that a one-month exposure to floods was only associated with a decrease in PPVT scores when exposure occurred in the prenatal period (reducing by 0.034 SD). Rosales-Rueda argues that, on average, children exposed in-utero scored 0.1 SDs lower on PPVT tests than their peers who were born either in less affected areas or after the shock. When disaggregating by trimester of pregnancy, however, only exposure during the first trimester was associated with lower PPVT tests (by 0.11 SD). Thamtanajit (2020), who examines the impact of severe flooding in 2011 in Thailand on the country's national examination, the O-net (applied in Grades 6, 9 and 12), also found floods only affected some age groups – in this case, Grade 6 and Grade 9, but not Grade 12. Using more than 30,000 school-level O-net examination scores from the National Institute of Educational Test Service (NIETS), the author found that floods were associated with lower Grade 6 and Grade 9 overall scores (by 0.481 and 0.329 points, respectively). Floods were linked to lower test scores across almost all subjects in Grades 6 and 9,[26] while they were only related to lower Grade 12 Social Studies scores, which decreased by 0.213 points.[27]

Zamand and Hyder (2016) found that floods only decreased test scores in two out of four countries for children aged 14–16. Using Young Lives data, they found that, in Ethiopia, floods were associated with decreases in all three sets of test scores examined – PPVT scores by 5.471, maths scores by 2.909 and Cloze scores by 3.399 – while in Peru, floods were only linked to lower Cloze scores (by 3.215). In India, floods were related to higher PPVT and Cloze scores (by 4.935 and 4.849, respectively); there was no impact on maths tests, while in Vietnam floods did not impact any test score. Nguyen and Nguyet (2018), who also used Young Lives data to examine the impact of flooding on maths and PPVT scores in the same four countries, found floods only had a negative impact on learning in Vietnam. Children between the ages of 12 and 15 who were affected by floods had lower rescaled mathematics and PPVT scores than their counterparts, by 5.491 points (9.3% of the score mean) and 2.295 points (2.9% of the score mean), respectively.

Hyder and Behrman (2016) found that floods had no significant impact on maths scores and contradictory results on PPVT scores depending on whether the shock was reported at the individual household level or the community level, distinguishing between floods of different intensities (localised versus widespread). Less intense floods reported at the individual level decreased scores by 8.7 points, while more intense floods reported at the community level increased scores by 10.7 points.

For the impact of flood-induced landslides on learning, see Box 3.

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26 Except for Grade 6 social studies, which increased (by 0.458 points). The author does not provide a reason for this difference.

27 Thus, the absolute sizes of the impact in test score due to floods ranged from 0.03 to 0.11 SD, depending on the subject and level.

Box 3 Impact of flood-induced landslides on learning outcomes

Brando and Santos (2015), who focused on the impact of exposure to heavy rainfall (from the prenatal period to the age of five) caused by La Niña in 2010–2011 in Colombia, controlled for their results by changing the measure to exposure to floods and landslides as they can be considered La Niña-related disasters during this period (see Section 4 for their results on rainfall).[28] While they did not disaggregate the effects of floods from landslides, using data from the ELCA survey for 2,887 children they found that prenatal exposure to one flood or landslide was associated with a decrease of 6.68 points in PPVT scores and, in the second year after birth, with a reduction of 0.39 points. They also found that one flood or landslide in the second year after birth was associated with a slightly higher risk of socioemotional problems, such as having problems following instructions or performing everyday tasks or reporting less enjoyment from spending time with their families and friends (by 0.0094). Extrapolating the potential effects, they argue that exposure to five additional disasters when a child is one year old would be associated with lower PPVT scores (by 0.10 SD) and higher risk of socioemotional problems (by 3.6pp). They found no impact when exposure occurred in the first year after birth (i.e. before a child turns one).

5.5 Heterogenous effects

Only seven of the 14 studies examined whether the impact of floods and landslides on educational outcome varied by demographic group. Those examining impact on access only analysed differences between rural and urban communities, boys and girls, and socio-economic status. Those focusing on attainment and learning looked instead at difference by age at the time of exposure, with those on learning also looking at socio-economic status.

Location (rural/urban)

When analysing the impact of floods by location, Ahmed et al. (2022) found that the 2010 floods in Pakistan were only associated with children remaining out of school in rural areas, not urban areas. However, the authors do not provide an explanation of why this might be the case.

Gender

Analysing the impacts of floods on the number of children remaining out of school in Pakistan, Ahmed et al. (2022) only found impacts on boys: 50 more boys (per 1,000) remained out of school in flooded districts compared to non-flooded ones. However, a more detailed analysis, disaggregating by age group, revealed a similar increase in out-of-school rates for both boys and girls in the 5–9 and 10–16 age brackets. During the flood year (2010) the reasons for remaining out of school (parental permission, children's preferences and distance) were all significant for both girls and boys. In subsequent years none remained relevant for boys, while two did for girls – school distance and parental permission – suggesting girls could have been more negatively affected in the long term than boys. Dasgupta and Karandikar (2021) found that in rural India the impact of floods varied between boys and girls

28 The study does not specify the working definitions of heavy rainfall and floods.

depending on gender norms about labour force participation, with enrolment/dropout being the outcome most affected.

Socio-economic status

Zamand and Hyder (2016) found that, in Peru, Ethiopia and India, household wealth largely increased the likelihood of a child being enrolled in school and to have higher PPVT and maths scores. While they did not examine the interaction between household wealth, enrolment and flooding, their finding suggests that household wealth might reduce or prevent learning losses because of flooding.[29]

Age

As discussed in Sections 5.3 and 5.4, Caruso (2017) found that in Colombia prenatal exposure was associated with the largest decrease in years of schooling, while Rosales-Rueda (2018) found that in Ecuador only prenatal exposure was associated with lower PPVT scores (not after birth until the age of two). Brando and Santos (2015) also found that in Colombia floods were only linked to lower PPVT scores when exposed in-utero or during the second year after birth. Thamtanajit (2020) also found that in Thailand floods were only associated with lower test scores for children in Grades 6 and Grade 9, but not 12. Dasgupta and Karandikar (2021), when looking at the impacts of floods in rural India on younger and older children (5–11 and 11–16 years old, respectively), found that younger children were more likely to have their test scores affected, while older children were more likely to have dropped out.

5.6 Impact pathways

The mediating factors examined in these studies include household income or expenditure, child labour, health (including cognitive development), damage to school infrastructure and roads, and schools being used as shelters – with the first three being the most discussed.

Household income, expenditure and child labour

Child labour and household expenditure were highlighted by both Ahmed et al. (2022) and Khan and Hussain (2023) as some of the possible impact pathways in Pakistan. Ahmed et al. (2022) found that 29 more children (per 1,000) dropped out of school in the same year of the flood because they had to help with domestic work. Khan and Hussain (2023) found that children exposed to floods were 7.4 pp more likely to become engaged in child labour, and that exposed households reduced their expenditure on education by 47%. Dasgupta and Karandikar (2021) also highlighted in their study in rural India that the opportunity cost of going to school, when compared to the income that could have been earned if the child was working instead – and its interaction with gendered divisions of labour – likely explained why girls were more prone to drop out of school and have lower test scores than boys in years when floods occurred. In Mozambique, Baez et al. (2020) found that floods were linked to an increase in poverty of between 12 and 17.5 percentage points. Rosales-Rueda (2018) found floods affected household income and expenditure in Ecuador.

In their four-country study, Nguyen and Nguyet (2018) found that in Vietnam – the only country where they found an impact on enrolment – per

29 In Peru, they also find that household size had a negative effect on test scores.

capita household expenditure was reduced by 9.6%, adding this as a possible impact pathway. While they found floods were linked to fewer years of schooling in India and Ethiopia (see Section 5.3), they only found an impact on household expenditure in Ethiopia, where flood exposure reduced household per capita expenditure by 15%. Zamand and Hyder (2016) also argued that household income/expenditure may explain their results in Ethiopia and Peru, where the typical negative effects of decreased income – such as reduced education spending or children entering the workforce – could have been offset by floods' negative impact on the local labour market (making work less profitable or viable for children). In Vietnam, instead, better-functioning credit markets might have allowed households to better cope with decreases in income and prevent school dropouts.

Hyder and Behrman (2016) make this argument in Ethiopia in relation to their varying results regarding PPVT scores. They argue that, when shocks were not widespread (i.e. reported at the household level), children might have had less time to study or been more stressed, or the household might have reduced expenses on education; while when the shock was widespread, it might have led to a substitution effect where, for example, flooding reduced child labour opportunities, leading children to spend more time studying.

Health

The studies that found a relation between prenatal exposure and reduced educational outcomes (Caruso, 2017; Rosales-Rueda, 2018) stressed that health was an important impact pathway, with the exception of Carrillo (2020). This is because of the existing literature on the damaging effects of malnutrition when in-utero and during early childhood on a person's development. Caruso (2017) argued that malnutrition was likely driven by the impact of floods on income or while in India – where there was a small increase in enrolment and PPVT and Cloze test scores (see Sections 5.2 and 5.4) – floods might have reduced work opportunities for children and, thus, reduced the trade-off costs between going to school or working in the 15 Latin American countries he analysed. This was also likely in the case of Mozambique, as Baez, Caruso and Niu (2020) found that floods were linked to a decrease in per capita food consumption of 25% to 30% and almost 0.5 fewer meals a day. In Ecuador, Rosales-Rueda (2018) found children exposed to El Niño floods, especially during the third pregnancy trimester, were more likely to be born with low birth weight: for example, each month of prenatal exposure to floods was related to a smaller but higher probability (of 0.008) of low birth weight. She also found that one month of prenatal exposure to floods was associated with a decrease in height-for-age z scores by 0.031 SD – meaning children exposed to floods in-utero were 0.09 SD shorter than their counterparts – as well as 1.8 percentage points more likely to be anaemic.[30] Nguyen and Nguyet (2018) found that in Vietnam – the only country where they found an impact on enrolment – children were 0.08 more likely to develop health problems when exposed to floods, adding this as a possible impact pathway.[31] Carrillo (2020) ruled

30 When examining the effects of flood by pregnancy trimester, however, the effect on anaemia disappears and only exposure during the 3rd trimester maintains a statistically significant impact on height (-0.083 SD, significant at a 0.05 p-value).

31 They measured health by body mass index for age and height for age scores. They only find a negative impact in the case of Peru, where floods are linked to a decrease of 0.24 points in weight for age scores (only statistically significant at a 0.1 p-value). However, as discussed in Section 5.2, their results on access outcomes were not significant for Peru.

out health as a mediating factor as the study did not find floods had a greater impact on educational outcomes in areas with higher malaria risk compared to low-risk areas.[32]

Zamand and Hyder (2016) found no evidence that health mediates the impact of floods on enrolment, while Hyder and Behrman (2016) found that, while less intense floods did not affect body mass or height, more intense floods (i.e. community-reported floods) were associated with a positive increase of 0.22 in height for age z scores. They do not provide any possible explanations for this result, nor do they test whether the impact carries through to education outcomes. Brando and Santos (2015) found no evidence of dengue or malaria being an important pathway in Colombia.

Other pathways discussed were infrastructure damage, parent-related factors and school closures. Caruso (2017) found that, while both maternal and paternal exposure were associated with fewer years of education in Latin America, the effect of parental exposure was almost negligible. As in the case of children's direct exposure, the negative effect of maternal exposure to floods was higher when the mother was exposed pre-natally, when it was associated with a reduction of 0.478 years of schooling for her children. Caruso also found that a mother's prenatal exposure to floods was related to a slightly higher probability of child labour for her children (by 0.012). The study suggested that damage to infrastructure could have played a significant role. This is because, when the intensity of floods was defined by damage to infrastructure (measured in USD rather than the number of affected individuals), the decrease in years of schooling remained statistically significant for exposure from the prenatal period to the age of 15.

Ahmed et al. (2022) found that distance to school was the third most important reason for children dropping out of school in Pakistan in the flood year (2010).[33] While they did not investigate possible mediating factors for their results on children remaining out of school, they hypothesised that this effect might also be related to damage to school infrastructure, and schools being used as shelters.[34] This was echoed by Khan and Hussain (2023), who documented that the 2010 floods destroyed almost 11,000 schools in Pakistan, and by Thamtanajit (2020), who suggested lower test scores in Thailand might have been caused by flood-related school closures and damage to school equipment and learning materials.

For the impact pathways of flood-induced landslides, see Box 4.

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32 They argue that floods can increase the likelihood of infectious diseases by creating optimal conditions for disease transmission (e.g. malaria) and hinder agricultural yield, impacting a household's food supply and/or income. They argue that impact via the mother's health can also occur through reduced nutritional income, but do not test for this.

33 The most frequently mentioned reasons were lack of parental permission (52 more children per 1,000 than pre-flood) or children not wanting to attend (44 more children per 1,000 than pre-flood), compared with 32 per 1,000 for distance. Two years after the flood, school being far away and parental permission were the only significant reasons for not attending; distance was the only significant reason four years post-flood.

34 Ahmed et al. (2022) report that the flood represented a cost of $311.1 million and damaged 10,348 schools; 4,935 schools were used as shelters.

Box 4 Mediating factors for landslides

As with floods, Caruso (2017) argued the loss of educational attainment related to landslide exposure is likely to be linked to damage to infrastructure. However, unlike floods, when controlling the results by damage (measured in USD), the results are relevant for fewer age groups (between in-utero and the age of two, and between the ages of three and four). When examining the effect of parental exposure to floods, impact was almost negligible.[35] The study also found that the mother's exposure to landslides was related to a fractionally higher probability of children being engaged in child labour – with an estimate of 0.021 when exposed between the ages of four and five, and of 0.24 when exposed between the ages of six and seven.

5.7 Insights from additional studies

A total of 29 studies non-econometric studies – two quantitative, 14 mixed methods and 13 qualitative studies – provided additional insights on the impacts of flooding on children's educational outcomes. These reinforce the mixed findings in the econometric literature regarding access and learning, as well as the importance of household income, health and child labour as impact pathways. However, these studies further stress flood-related damage to school infrastructure, learning material or roads, as well as teachers' and students' motivation and concentration – pathways not discussed in depth in the econometric literature. Two studies in this set focus on the impact on socio-emotional skills, three highlight specific impacts on girls, and one highlights the role of IT in alleviating impact.

Reduced access

Okuom et al. (2012), examining the impact of floods on primary school enrolment in Kenya using surveys, interviews and focus groups (among other methods) with a sample of 1,225 students and around 300 teachers, found that the rate of grade repetition and dropout was higher (23.63% and 20.17%, respectively) than in areas not prone to floods. Other studies similarly found that floods were linked with higher rates of absenteeism or dropout, in Zimbabwe (Mudavanhu, 2015), Nigeria (Ofem et al., 2024), Pakistan (International Rescue Committee, 2023; Ashraf et al., 2024), India (Krishna, Ronan and Alisic, 2018; Greeshma and Subudhi, 2020), Bangladesh (Habiba et al., 2021) and the Philippines (Cadag et al., 2017), respectively. In the Philippines, Ardales et al. (2016) found that floods led to the cancellation of classes in public schools and reduced children's attendance, but did not increase dropout rates.

Mixed impact on learning

David et al. (2018) examined the impact of floods on test scores in the Philippines using multi-year data for the National Achievement Test (NAT)

35 For example, maternal exposure was also not significant for all age groups. The highest decrease in years of education was when the mother was exposed between the ages of 0 and 1, when it was associated with a small decrease of 0.203 years of education.

from 33,704 elementary and 6,337 secondary public schools. While they found that, in the 2013–2014 academic year, 21% of schools were affected at least once and 19.3%[36] were used as an evacuation centre at least once, there was no impact on test scores at the national level. However, Habiba et al. (2021) found – using a survey with 80 children across two primary and secondary schools, along with interviews and document analysis – that in Bangladesh 93.8% of students faced academic challenges after floods. Studies in the Philippines (Bicar, Añar and Valdez, 2020) and Nigeria (Mfon, 2024; Ofem et al., 2024) had similar findings.

Health, household income and child labour

Various studies identify health and household income as important impact pathways. International Rescue Committee (2023) found that, besides infrastructure damage, lower household income played a major role in Pakistan in decreasing access to school after floods, contributing to 60% of dropouts and 41% of non-enrolment.[37] This was echoed in Okuom et al. (2012) in Kenya, and Ofem et al. (2024) in Nigeria. In Bangladesh, increased academic challenges, dropout rates and absenteeism might be related, in part, to health as 87.5% of children suffered from waterborne diseases like diarrhoea, skin diseases and dysentery after floods (Habiba et al., 2021). Mudavanhu (2015) found that, in Kenya, increased absences and poor academic performance were partly related to the impact of floods on household income, increasing food insecurity, child labour, child marriage and illness. Krishna, Ronan and Alisic (2018) highlight these as possible mediators in their study in India on the impact of the 2015 floods in Tamil Nadu, as do Chikoko and Chihiya (2023) and Chigwanda, Mutopo and Mutanana (2023) in their studies on Zimbabwe. The importance of household income and its knock-on effect on child labour or child marriage (or child trafficking in the case of India) and subsequently on education was highlighted by UNICEF studies in Sri Lanka, India, Bangladesh, Nepal and Bhutan (Kagawa, 2021; 2022a; 2022b; 2022c; 2022d).[38]

Infrastructure damage

Reduced access to school may result because infrastructure, learning materials or roads have been damaged or schools are being used as shelters. UNICEF carried out a series of studies in South Asia in 2021 and 2022 – specifically in Nepal, Bhutan, Sri Lanka, India and Bangladesh.[39] Looking at the impact of climate change on educational outcomes, they highlight how throughout the

36 There is a discrepancy between the text and the result table presented. The text states this figure as 18%.

37 It finds households experienced a severe negative impact: 63% of households had their houses damaged, with 24% undergoing temporary migration for over a year as a result; 53% reported asset loss, 49% saw declines in their income, and 54% experienced unemployment. Ashraf et al. (2024) highlighted how floods in Pakistan displaced thousands of families, reducing access to schooling. Almost 70% of girls (over the age of 15) surveyed had stopped going to classes.

38 In Sri Lanka, the study finds that girls from lower-income families were at higher risk of dropping out of school (Kagawa, 2021).

39 The studies draw on a desk-based documentary review, 5–8 key stakeholder interviews, two school-level focus groups and U-report surveys with youth (14–24 years old). U-Report, run by UNICEF and its partners, is a messaging tool that enables young people around the world to engage with and speak out on issues that matter to them. The sample size of the survey is unspecified in all studies.

region floods reduced school access by damaging school buildings, learning materials or roads, mountain trails or bridges, or by prompting the use of schools as shelters. In Nepal and Bhutan, floods are among the climate hazards that cause the most damage to school infrastructure (Kagawa, 2022a; 2022d). In 2017, floods in Nepal's Terai region destroyed or damaged 1,945 schools, affecting the education of 238,900 children, with costs estimated at NPR 1,193.8 million.[40] In the same year, at least 383 schools and learning centres were used as temporary shelters (Kagawa, 2022d). The UNICEF reports highlight that, despite this, school construction plans in Nepal, Bhutan and Bangladesh do not incorporate climate change concerns and schools are still being built in areas near rivers or at risk of landslides (Kagawa, 2022a; 2022c; 2022d).[41]

> 'Our school is very near the river, only about 100 meters distance. There is a growing concern that the school might be flooded. The bridge construction is not very stable, but many students go through it. Unexpected and sudden rainfalls cause landslides so we face a higher risk of death. We are ok so far. Those who have to walk a long distance might face landslides. It is difficult to know when to expect landslides' (Class 10 student, Bhutan (Kagawa, 2022a:15)).

> 'Because of soil erosion and heavy rains in hilly areas, we have rock falls and landslides every year. Last September, when I was travelling to my school, I encountered rock falls. I was worried about my education and examination, as I could not go to school for several days until the rocks were removed' (Grade 11 student, Sri Lanka (Kagawa, 2021: 12)) .

Teachers' wellbeing

Various studies found that floods could be decreasing learning outcomes by affecting syllabus coverage, and most of these studies traced this back to teachers' wellbeing (except Okuom et al. (2012) and Plan International (2023)).[42] In the Philippines, Ardales et al. (2016) found low syllabus coverage (in this case related to a decrease in teachers' wellbeing, as they were personally affected by the floods and had to help schools respond and recover). Difficulties in covering the syllabus were found by Mudavanhu (2015) in Zimbabwe, partly related to a high turnover of qualified teachers who are reluctant to work in disaster-prone areas. These findings were echoed in Convery, Carroll and Balogh (2015), which looked at the impact of the 2007 Hull floods in the UK. Using questionnaires with 91 head teachers of primary and secondary schools (including schools for children with different

40 This includes 'damages to school buildings (NPR 538.9 million), classrooms (NPR 189.9 million), drinking water facilities (NPR 162.6 million), walls (NPR 141 million), toilet facilities (NPR 97 million) and textbooks and other teaching materials (NPR 64.4 million)' (citing National Planning Commission, 2017).

41 These findings are echoed in other studies in these same countries (Chaudhary and Timsina, 2017; Krishna, Ronan and Alisic, 2018; Habiba et al., 2021; Plan International, 2023; Kubra, 2024) or others such as Pakistan (International Rescue Committee, 2023), Indonesia (Lassa, Petal and Surjan, 2023), the Philippines (Ardales et al., 2016; Cadag et al., 2017; Bicar, Añar and Valdez, 2020), Zimbabwe (Mudavanhu, 2015), Bangladesh (Habiba et al., 2021), Nigeria (Mfon, 2024), Zimbabwe (Chigwanda, Mutopo and Mutanana, 2023), Kenya (Okuom et al., 2012), Australia (Plan International, 2023) and the UK. Convery, Carroll and Balogh (2015) found that, in the UK, this led to the decision to not teach some students with special needs, as the required resources were unavailable. Damage to school infrastructure, roads or bridges or school materials is also highlighted in the flood-related landslide literature.

42 In their study, Okuom et al. (2021) relate it mostly to damage to school infrastructure.

needs) and follow-up interviews with six, they found that floods created an additional demand on teachers that affected their ability to cover the curriculum and the time they could spend with students. UNICEF's study in India found a negative impact on teachers' wellbeing (Kagawa, 2022b).

Socioemotional skills and mental health

Philip and Vithya (2023) examined the impact of floods on the resilience and mental health of adolescents in India using surveys and interviews with students aged 12 to 18. They found that flood-affected students scored higher for depression, anxiety and stress, whereas their counterparts scored higher for resilience. This was due to how floods had affected their families' livelihood, affected them at school, and how much they worried about future occurrences of floods. Greeshma and Subudhi (2020) echoed these findings. Based on a survey with 100 children aged 12–18 in India, they found that, six months after the 2018 flood in Kerala, 60% of children reported PTSD symptoms – the majority of whom were girls (41% of girls and 19% of boys). This was driven by the losses children experienced during and after the floods (family, friends, pets), damage to school buildings and materials, economic uncertainty and a lack of counselling services. Overall, 26% of affected study participants reported poor concentration and 20% reported decreased attendance.

Krishna, Ronan and Alisic (2018) found that floods affected children's mental health in India, via an increase in problems within households, such as domestic violence and alcoholism. In the UK, students exposed to the 2007 Hull floods experienced more stress than their counterparts, leading to behavioural or concentration problems. This reflected lack of personal space and lack of sleep due to crowded accommodation, loss of possessions, family separation, stress among parents, health impacts of adverse living conditions and school disruption (Convery, Carroll and Balogh, 2015).[43] In Ethiopia and Bangladesh, Devonald, Jones and Workneh (2020) found higher levels of stress and anxiety linked to floods, among other climate hazards – especially among children previously exposed. This could be more acute among boys, when boys are seen as responsible for providing for the household.

> 'If suddenly my home gets damaged then I have to bring bamboo to repair it. If it's raining and the rain gets inside the home and we get a lot of trouble I have to buy some materials for repairing … I have to earn money' (15-year-old Rohingya boy, Bangladesh in Devonald, Jones and Workneh, 2020: 20).

> 'We were there, after the landslide we stayed at my aunt's place, then we came here … I'm worried about the rainy season … because the landslide happened in the rainy season' (12-year-old boy, Bangladesh in Devonald, Jones and Workneh, 2020: 20).

Impacts on girls

Swarup et al. (2011) found that in Bangladesh floods decrease household income, increasing girls' participation in domestic work and child labour and, in turn, reducing school attendance

43 Multiple studies stressed the negative impact of floods on student motivation and concentration in countries like Bhutan (Kagawa, 2022a), the UK (Convery, Carroll and Balogh, 2015), India (Greeshma and Subudhi, 2020), Kenya (Okuom et al., 2012) and the Philippines (Ardales et al., 2016). In most instances this was related to the impact of floods on mental health.

and enrolment. This is echoed by Mazingi and Muyumbwa (2021), based on participatory qualitative research with 80 adolescent girls in Zambia and Zimbabwe. They found that floods – among other climate hazards – have particularly reduced girls' school attendance because of damage to roads and bridges, as girls may find it more difficult to take paths that are flooded when they are menstruating, for example, for fear of soaking their sanitary pads. Climate-induced household income shocks have also increased child marriage, resulting in girls dropping out of school. Studies in Zimbabwe (Chigwanda, Mutopo and Mutanana, 2023) and India (Krishna, Ronan and Alisic, 2018) stress that declining rural household incomes affected girls' school attendance more than boys', as parents tended to prioritise boys' schooling when their income was affected by floods. In Nepal, Kagawa (2022d) stresses that landslides have been one of the factors leading to a deterioration in schools' water supplies, and that this is particularly reducing the attendance of girls of menstruating age.

Limited access to information technology (IT)

Drawing on literacy and numeracy assessment plus additional data collection, International Rescue Committee (2023) found that, in Pakistan, an important factor influencing the different impact that floods had on children's learning outcomes in private and government schools was limited access of the latter to IT. The study found that pre-flood computer and internet access was very low in government schools compared to private schools (1.5% and 25% respectively), hindering the adoption of IT-based learning solutions during the floods.

6 Drought

Key insights

- There is evidence that droughts reduce school access by reducing enrolment or increasing drop-out rates (5/7) studies). Two studies found increased enrolment during droughts, reflecting less demand for agricultural labour.
- Four studies examine the impacts of drought on educational attainment. Three show decreased attainment, and two find no impact on years of schooling.
- Out of nine studies on learning outcomes, four found declines in outcomes including cognitive skills, numeracy and literacy, four found mixed results, and one found no impact on learning.
- Possible mediating factors are children's health (five studies), reduced household income (four studies) and child labour and domestic work (three studies).
- The five studies of gendered impacts find mixed evidence. The three studies analysing impact by age at time of exposure agree that early life exposure is the most damaging.

6.1 Introduction

Fifteen econometric studies discuss the impact of droughts on education, distributed across educational outcomes as shown in Table 8. Geographically, the studies are concentrated in Africa (nine of 15), followed by Asia (five studies) and Central and South America and the Caribbean (five studies). This body of literature is complemented by seven studies using other methodologies, mostly undertaken in Asia and Africa.

Table 8 Distribution of drought studies

Education outcome	Number of studies	Geographical distribution
Access	10	Ethiopia, Iran, Brazil, [Malawi and Indonesia], Malawi, [Ethiopia, India, Peru and Vietnam (2)], India, Brazil, Zimbabwe
Grade attainment	4	Mexico, Ethiopia, Nigeria, Colombia
Learning outcomes	9	Ethiopia (3), Brazil (2), India, [India, Ethiopia, Peru, Vietnam], Zimbabwe, Colombia

6.2 Effects of droughts on access to education

Five studies find a negative impact on various indicators of school access, such as enrolment and drop-out rates (Abiona, 2017; Dessy et al., 2023; Hyder and Behrman, 2016; Khalili et al., 2020; Prenhaca and Melo, 2024). Three studies find no statistically significant impact (Branco and Féres, 2018; Nguyen and Nguyet, 2018; Zamand and Hyder, 2016), while two find a positive relationship between drought and school access (Dessy et al., 2023; Nordstrom and Cotton, 2020). There is mixed evidence on whether droughts impact boys' and girls' access differently, with only two studies finding evidence to this effect (Abiona, 2017; Dessy et al., 2023).

Hyder and Behrman (2016) used Young Lives data from Ethiopia to examine the impact of drought, among other climate hazards, on school enrolment for 979 children. They found that community-level (i.e. more intense) droughts were associated with reduced enrolment, but less intense droughts were not. As discussed below, Khalili et al. (2020) and Prenhaca and Melo (2024), who examine the impact on dropout rates instead of enrolment, also find droughts had a negative impact on school access. Dessy et al. (2023) find mixed evidence.

Khalili et al. (2020) examined the impact of droughts of different intensities in rural Iran, using primary data from a sample of 300 small-scale and subsistence farmers. They found that, in severely drought-affected villages, only 4.8% of school-age children dropped out of school due to drought, with no significant differences between boys and girls. No school-level dropouts were reported in weakly drought-affected villages.

Using school census data from the Ministry of Education on 1,171 municipalities in Brazil, Prenhaca and Melo (2024) found droughts to be associated with increased dropout rates and reduced student progression in the short term, particularly in public schools in the semi-arid north-east region. While the short-term increase in dropout rates was not statistically significant, longer-term impacts revealed a decline in retention rates, with an average negative effect of -1.2 percentage points. These findings suggest that droughts may gradually erode school participation, especially in the later stages of elementary education.

Dessy et al. (2023), who examined the impact of income shocks caused by droughts in Malawi and Indonesia, found that drought reduced school dropouts in matrilocal communities while increasing them in patrilocal communities in Malawi. In contrast, there were no statistically significant drought effects across kinship groups in Indonesia. Using household survey data from Malawi and Indonesia on 9,054 individuals, the study found that drought-induced income shocks intensify gender disparities in secondary education, primarily in patrilocal societies. In patrilocal communities in Malawi, there was a statistically significant difference in girls' and boys' dropout rates: girls' dropout rates by approximately 6.8 percentage points; effects on boys were insignificant. Gender differences were not significant in matrilocal communities, indicating that drought amplifies the gender education gap only in patrilocal communities, particularly when school fees are required. This further explains why disparities were concentrated among students aged 15–18 in Malawi whose education typically requires payment of fees and is no longer compulsory.

Abiona (2017), who also examined the impact of droughts in Malawi, investigated instead the impact on school entry. The author found early life drought shocks increased delayed school entry. Impacts were starker for droughts experienced prenatally than in the second year of life (0.159 and 0.129 standard deviations respectively).

Zamand and Hyder (2016), Nguyen Nguyet (2018) and Joshi (2019) found no impact of droughts on school enrolment (across varied age cohorts). The first two studies used Young Lives data in Ethiopia, India, Peru and Vietnam, while Joshi used administrative school data from rural India. Investigating the impact of drought on student absenteeism rather than enrolment in Brazil using data reported by school principals on 350,838 fifth grade students and 253,946 ninth grade students, Branco and Féres (2018) found no significant impact.

Nordstrom and Cotton (2020) also found a positive impact on school access. Using data from the Improving Girls' Access through Transforming Education project on 85 schools in rural Zimbabwe (374 girls in the participant group and 621 girls in the control group), the study found that more girls in drought-affected areas stayed enrolled in school. Specifically, girls residing in regions impacted by drought are 2.8 percentage points more likely to be enrolled in school following the drought, with endline enrolment rates at 93% in affected areas compared to 91% in areas not affected. The authors hypothesise that this reflects a lowered opportunity cost of education resulting from the negative agricultural impacts of the drought. As discussed in Section 6.4, the study found that the drought led to declines in maths performance, showing that the positive impacts of increased attendance were offset by declines in learning outcomes.

6.3 Effects of droughts on educational attainment

Three of the four studies examining the impact of droughts on educational attainment found a statistically significant negative effect.

Adhvaryu et al.'s (2023) study on rainfall shocks in Mexico (which explores the impact of droughts in their robustness checks), finds that droughts decrease educational attainment. However, the magnitude of the impact was larger for drought or rainfall below the 80th percentile of normal rainfall compared to adverse rainfall shocks which represented less extreme variations below normal rainfall.

Using rural household survey data from Ethiopia on 3,336 children, Randell and Gray (2016) found that exposure to droughts during early childhood significantly reduced the likelihood of completing school. Specifically, each additional summer drought experienced in early childhood was associated with a 16% reduction in the odds of completing at least one grade of schooling.

Efobi (2022), examining the impact of the 1972–1974 drought in Nigeria using Demographic and Health Survey data for 38,948 women, found that early-life drought exposure significantly reduced women's educational attainment. Women exposed to drought were 2.2 percentage points more likely to have no formal education (5.9% of the mean), and 2.3 percentage points less likely to complete primary, secondary or higher education. These effects were most pronounced among individuals exposed to drought in the prenatal and early postnatal periods. One study – Carrillo (2020) – found no statistically significant impacts of droughts (unlike floods) on total years of schooling.

6.4 Effects of droughts on learning

Four studies found a negative impact on a range of learning outcomes, including cognitive skills, numeracy and literacy test scores (Berhane, 2010; Branco and Féres, 2018; Joshi, 2019; Prenhaca and Melo, 2024). Four studies found mixed results (Hyder and Behrman, 2016; Nguyen and Nguyet, 2018; Nordstrom and Cotton, 2020; Zamand and Hyder, 2016) and one found no impact on learning (Carrillo, 2020).

Using Young Lives data from rural Ethiopia tracking two age cohorts of 3,000 children, Berhane (2010) found that exposure to drought during early childhood and preschool years significantly reduced children's cognitive outcomes, as measured by the PPVT. Children who experienced drought in early life scored 0.12 to 0.18 standard deviations lower than their non-affected peers. The negative effects were comparable regardless of whether shocks occurred during early childhood (ages 0–4) or at preschool age.

Branco and Féres (2018) found similar impacts on test scores in Brazil. Using Educational Census data from 3,977 primary and 6,098 elementary rural schools in North-eastern Brazil, they found that drought shocks significantly reduced student performance in both mathematics and language, as measured by Prova Brasil[44] scores. For each standard deviation increase in drought exposure, fifth-grade scores declined by 0.39 points in maths and 0.27 in Portuguese, while ninth-grade scores fell by 0.29 and 0.24 points, respectively. These effects remained robust after controlling for student and school characteristics. Joshi (2019) found a similar impact in rural India. Using data from the Annual Status of Education Report for approximately 226,965 children, the author found that a 2012 drought led to a 2.67% decrease in reading scores and a 4.14% reduction in maths scores. The study finds both an immediate and persistent effect on test scores – in 2012, as well as in 2014 and 2016 – possibly reflecting compounded effects of repeated shocks. Also in Brazil, Prenhaca and Melo (2024) found that droughts have a consistently negative impact on student learning outcomes, particularly in numeracy and literacy across elementary and secondary grades. Exam scores, pass rates and grade transition rates declined, with the effects most pronounced during more intense drought episodes for ninth-grade students.

The following studies found mixed effects or no impact on learning outcomes. Three studies using Young Lives data found mixed results on learning outcomes. Zamand and Hyder (2016) examined the impact of droughts on vocabulary and numeracy skills in Ethiopia, Vietnam, Peru and India. In Ethiopia, drought only decreased PPVT and maths scores. In India and Vietnam, drought had no impact on any score. In Peru, drought was only associated with a decrease in PPVT scores. Hyder and Behrman (2016) found mixed effects in Ethiopia. Droughts were associated with significantly lower PPVT scores, but had no significant impact on numeracy scores. Nguyen and Nguyet (2018) found no significant negative impact on maths test scores in India, Ethiopia, Peru and Vietnam, and only found significant negative effects on cognitive outcomes in India, where exposure to droughts was associated with an average decline of 6.1 points out of 100 on PPVT scores.

Nordstrom and Cotton (2020) find mixed results in rural Zimbabwe. They found that girls from drought-affected households were 7.9 percentage

44 A national-level assessment of student learning.

points less likely to repeat a grade, suggesting some resilience in school progression. However, numeracy performance declined by 4 percentage points (0.15 standard deviations) and literacy scores slightly increased by 1.6 percentage points. The authors suggest that this may be potentially due to the nature of the standardised assessments used, and further hypothesise that literacy skills may be less sensitive to stressors like hunger and psychological strain compared to numeracy (Nordstrom and Cotton, 2020). Carrillo (2020), who uses census data on more than 15 million individuals in Colombia, found prenatal drought shocks, unlike floods (see Section 5.4), have limited and statistically insignificant impacts on illiteracy rates.

6.5 Heterogenous effects

Ten studies examined heterogenous effects of drought – mostly by gender, age and wealth.

Gender

Five studies investigated gender differences, with two studies finding greater impacts on girls (Dessy et al., 2023; Joshi, 2019), one study finding only impacts on boys (Abiona, 2017), and two studies finding similar impacts on both boys and girls (Khalili et al., 2020; Randell and Gray, 2016).

Dessy et al. (2023) find that, in patrilocal communities in Malawi, there was no impact on boys' dropout rates while girls' rates increased, indicating that drought amplified the gender education gap in these communities. Also in Malawi, Abiona (2017) found that droughts only delayed school entry for boys. In Iran, Khalili et al. (2020) found no differences in dropout rates between boys and girls in severely affected rural villages. Joshi (2019), examining the impact on reading and maths scores, found that girls' reading scores declined 1.8% more than boys' following the 2012 drought, indicating a short-term gender disparity. However, this gap did not persist in later years. For maths scores, there were no significant gender differences, with both boys and girls experiencing similar declines from 2013 to 2016. Randell and Gray (2016) found that each additional summer drought experienced in early childhood was associated with a 16% reduction in the odds of completing at least one grade of schooling in Ethiopia. They find that these do not significantly differ between boys and girls.

Age

Three studies investigated different effects by age. Abiona (2017) found that prenatal exposure to drought and at the age of two delays school entry, while exposure at age one does not. Berhane (2010) found that exposure to drought during early childhood and preschool years significantly reduced children's PVVT scores, regardless of whether shocks occurred prenatally or during early childhood (ages 0–4) or at preschool age. As previously discussed, Efobi (2022), who finds that early-life drought exposure significantly reduces women's educational attainment, finds that the negative effect on attainment was most pronounced when exposure occurred in the prenatal and early postnatal periods.

Socio-economic status

Three studies investigate different effects by household wealth and find that drought impacts are greater on children from households with less wealth. Hyder and Behrman (2016) and Zamand and Hyder (2016) both suggest that children in wealthier households experience a smaller decrease in learning outcomes as a result of droughts than their counterparts. Prenhaca and Melo (2024) also find wealth mediates the impact

of drought on teacher presence. While they find that, in public schools, prolonged droughts were linked to a reduction in teachers, there was no similar effect in private schools.

6.6 Impact pathways

The mediating factors examined in these studies include household income, health, child labour or domestic work, child marriage and teacher presence – with the first three being the most discussed.

Household income

Khalili et al. (2020), Dessy et al. (2023), Randell and Gray (2016) and Berhane (2015) examine the possible role of household income/expenditure in mediating the impact of drought on educational outcomes. In Iran, Khalili et al. (2020) found that households experiencing a 1% drop in per capita farm income – often due to drought – were 0.6% more likely to increase their education spending. However, they found that a 1% rise in non-farm income was associated with a 0.8% decline in education expenditures. In Indonesia and Malawi, Dessy et al. (2023) found that income shocks due to drought interact with different kinship systems (matrilocal or patrilocal) to different effects. As previously discussed, they found that in Malawi patrilocal households were more likely to sacrifice daughters' schooling when income decreased, particularly when schooling incurred a cost and when education was no longer compulsory. In Indonesia, they did not find an interaction between household expenditure, kinship systems and education outcomes. Randell and Gray (2016), who found droughts reduce the likelihood of completing years of schooling in rural Ethiopia, argue that droughts were associated with reduced household food consumption and higher likelihood of food insecurity, suggesting that early-life malnutrition linked to drought undermines children's cognitive development and school readiness. Berhane (2015) found that, in Ethiopia, food price inflation, particularly for cereals and meat, was associated with significant declines in cognitive scores – up to 0.98 and 0.47 SD respectively – highlighting the broader impact of economic stressors on household income/expenditure. These results were consistent after controlling for child, household and village-level characteristics – the authors attribute the result to the sample being from a poorer rural area, and as such more likely to be affected by food price rises.

Health

Reduced household income can reduce educational outcomes by affecting children's nutrition, as in the case of Randell and Gray's study in Ethiopia (see above). Branco and Féres (2018) argue health impacts might be mediating the impact of drought on educational outcomes as they found that, in Brazil, one additional drought shock per year was associated with a 5% increase in malnutrition-related hospitalisations and a 2.6% increase in hospitalisations due to infectious diseases, for children aged nine to 11. Hyder and Behrman (2016), Abiona (2017) and Nguyen and Nguyet (2018) highlight the possible role of health as they find that drought was associated with lower height and weight in children or higher likelihood of health problems.

Child labour

Reduced household income can also increase families' need for children to support income-generating activities or household work. Randell and Gray (2016) found that in Ethiopia drier hotter seasons increased children's domestic responsibilities, with girls being more likely to engage in domestic labour and boys more likely to

be involved in farm labour. Nordstrom and Cotton (2020) and Branco and Féres (2018) had similar results for Zimbabwe and Brazil. Nordstrom and Cotton (2020) found significant differences in the time girls spent on agricultural chores and family business chores in drought-affected and unaffected areas in rural Zimbabwe (by -8.64% and -11.18% respectively), which means that the difference between enrolment rates in these areas was likely to be driven by this factor. In Brazil, Branco and Féres (2018) found that each additional drought shock per year was associated with a 4.24 pp increase in the probability of a child being employed.

Child marriage

Efobi (2022) found that in Nigeria drought exposure reduced the average marriage age by approximately 0.58 years (a 3.3% decline relative to the mean), probably motivated by declining household incomes since child marriage can be a way of obtaining extra income (bride price) or reducing household consumption.

Teacher presence

Prenhaca and Melo (2024) found that municipalities in Brazil exposed to prolonged drought experienced an average 8% reduction in public elementary school teachers, with the decline reaching 14% in areas affected by more intense droughts. The loss was most pronounced among lower-skilled teachers – those with only a high school education – and teachers on temporary contracts, though tenured teachers were also affected. These staffing reductions were linked to water supply issues and permanent school closures, particularly in public schools. Branco and Féres (2018) also examined whether droughts increased teacher absenteeism in Brazil, finding no statistically significant impact.

6.7 Insights from additional studies

This body of literature is made up of three quantitative studies (non-econometric), two mixed-methods studies and two qualitative studies. The findings from these studies cover two main themes: labour market participation as a mediating pathway, and gendered vulnerabilities and roles.

Labour market participation as a mediating pathway

Consistent with the econometric analysis, these studies find that a common mechanism through which droughts affect education is children's participation in the labour market. In Ethiopia, 2015/2016 El Niño-driven weather conditions caused one of the worst droughts in decades. Using data for 1,210 grade 8 students in a mixed-methods study, Eshetu and Tessema (2017) showed that El Niño-affected students, on average, performed worse than unaffected students on regional exams, with boys being impacted more than girls. The results are consistent with participation in the labour market for boys being a key mechanism affecting learning outcomes.

Studies from other contexts found similar results. For example, droughts have been linked to school dropouts in the Indian state of Maharashtra, largely for marginal farming households, driven by displacement or the need to enter the labour market (Khetwani et al., 2020). In Nigeria, where droughts impacted livelihoods, students were withdrawn from school (Ofem et al., 2024).

In Iran, labour market dynamics were different. A qualitative study found that, in most cases, women and children of families vulnerable to droughts had to undertake casual or seasonal off-

farm work in order to secure livelihoods. Unlike most research, which highlights boys having to enter the labour market, in Iran drought led to considerable unemployment for men in resource-poor families, forcing women to undertake minimal wage work. Reduced household expenditure led younger members of affected households to discontinue education (Keshavarz et al., 2013).

Gendered vulnerabilities and roles

These studies highlight the impact of gender norms in influencing how drought affects boys' and girls' education. In Ethiopia, climate-related impacts exacerbated adolescents' vulnerabilities to food insecurity, particularly in agriculturally dependent regions. Poor harvests often forced boys to migrate for daily labour, disrupting their education, while girls were more likely to remain at home and take on greater household responsibilities. Water scarcity further intensified girls' workloads, as prevailing gender norms typically assign adolescent girls the task of collecting water for the household (Devonald, Jones and Yadete, 2020). Similar gendered patterns emerged from interviews with adolescents in Australia, Nepal and Indonesia, where girls reported increased household burdens during periods of environmental stress (Plan International, 2023).

In Iran, drought (unusually) forced women and children – rather than boys alone – to undertake casual or seasonal low-wage work, ultimately leading to school dropout among younger family members (Keshavarz et al., 2013).

7 Cyclones, hurricanes and typhoons

Key insights

- The majority of the 16 studies on cyclones, hurricanes and typhoons demonstrate negative impacts on education outcomes. Impacts on learning outcomes are generally significant but small.
- Six studies examined the impacts of cyclones on education access, with five showing a negative impact on access and one showing only a small impact on attendance.
- Seven studies examined the impact on grade attainment and all found negative impacts on grade attainment.
- Nine studies examined the impact on learning outcomes. Of these, eight found negative outcomes, and one found no impact.
- Exposure intensity, particularly in utero, can have greater impacts on learning outcomes. Frequent disasters tend to make communities more resilient. The consequences for learning and subsequent employment outcomes last longest for children impacted in utero by cyclones, hurricanes and typhoons.
- School closures and school infrastructure damage due to cyclones, hurricanes and typhoons lead to decreased learning time, and are the key factors impacting learning outcomes. Student and teacher trauma following the event is an emergent theme in the qualitative and mixed methods studies. Meeting the psychosocial needs of both teachers and students could be crucial to ensure continued learning.
- Disaster preparedness, well-planned post-disaster recovery efforts and parental investment in education are key to ensuring continued learning.

7.1 Introduction

Of the econometric papers analysed, 16 studied cyclones, hurricanes or typhoons (henceforth referred to as cyclones). Of these, one also discussed rainfall and one discussed multiple disasters in addition to cyclones. Two studies focused on Central and South America and the Caribbean, and one each on Jamaica and Madagascar. In addition to one global study covering Asia, Africa, Central and South America and the Caribbean, two studies focused on China, three on the Philippines and six on the US. These studies examine a range of impacts including the long-term effects of early-life exposure to tropical cyclones, hurricane-induced school closures, and the educational impacts of infrastructure damage and destruction.

Table 9 Distribution of studies examining educational impacts of cyclones

Hazard	Access	Grade attainment	Learning outcomes	Countries/ regions covered
Cyclone, hurricanes and typhoons	6	7	8	Asia, Africa, Central and South America and Caribbean (global study); China, Jamaica, Madagascar, Philippines, US

Of the 16 studies examining the impact of cyclones on educational outcomes, six examined access, seven studied attainment and eight examined the impact on learning outcomes, with most finding a negative impact on education. Five out of six studies showed negative impact on access, with one showing a small impact on attendance. All studies examining attainment showed a negative impact and all but one of those that examined learning outcomes showed negative impacts. It is noteworthy that only 50% of the studies demonstrate effect sizes of 0.1 SD for at least one outcome measure.

7.2 Effects of cyclones, hurricanes and typhoons on access to education

Six studies examined the impacts of cyclones on education access, with five showing a negative impact on access and one showing only a small impact on attendance. Using cyclone track data and nationally representative georeferenced survey data for 5.1 million people living in 13 low- and middle-income countries[45] (restricting the data to 10-year-olds) who were exposed to tropical cyclones between 1954 and 2010, Jing et al. (2024) find that exposure to tropical cyclones during preschool age is associated with a 2.7 percentage point decrease in primary school enrolment on average. This equates to a 14.2% decrease, with larger effects (up to 28%) from more intense storms. They also find that the effects are more pronounced among school-age girls than boys and are greater in areas less accustomed to tropical cyclones, probably due to adaptation measures in cyclone-prone areas. While tropical cyclones reduced primary enrolment by 3.3 percentage points in regions that were rarely exposed, such effects are much smaller in regions with more frequent exposure. Unsurprisingly, they find that the impacts decrease with distance from the storm, with effects no longer statistically significant among children beyond 150km from the storm edge. Jing et al. suggest the following factors may explain the impacts on school enrolment: physical conditions of schools and school buildings, physical damage to households leading to increased participation of children in household labour, short-term displacement and long-term economic impacts (Jing et al., 2024).

Raeburn (2023) estimates the effect of destruction caused by Hurricane Ivan in 2004 on educational outcomes in Jamaica, drawing on a sample of over 6,000 students. On average, 29.9% of schools reported requiring repairs post-hurricane. School enrolment was largely unaffected by the hurricane. However, school attendance of girls (12–16 years of age) in rural areas decreased in the short to medium

45 Comoros, Madagascar, Mozambique, Cambodia, Indonesia, Philippines, Dominican Republic, Honduras, Haiti, Colombia, Bangladesh, India and Pakistan.

term after the hurricane, largely as a result of household reallocation of resources from girls' education. Long-term impacts were not studied and it is therefore difficult to predict impact on enrolment in the long term (Raeburn, 2023).

Marchetta et al. (2019) examine the impact of cyclones on schooling and work among a cohort of 1,000 14–16-year-olds in Madagascar. They found that the occurrence of a cyclone decreases the probability of being enrolled in school by 15.2 percentage points and increases the probability of being engaged in a work activity by 10.5 percentage points at mean asset levels. The study hypothesises that adolescents drop out of school as a result of economic hardship, possibly exacerbated by damage to schools and related infrastructure that impede access to schooling. They also find that enrolment rates among young people from wealthier households are less affected (Marchetta, Sahn and Tiberti, 2019).

In a study on typhoons in the Philippines, Deuchert and Felfe (2015), using children's time use data, show that children missed school more often when exposed to typhoons (0.32 days per month in 1991) and that the reduction in schooling is most likely driven by an increase in children's time spent helping at home, but not by an increase in work for pay. In the case of Hurricane Katrina, Imberman et al. (2012) find that attendance was impacted for existing secondary school students but not for elementary school students, although this was not statistically significant where schools faced an influx of students. An increase in evacuee share of 10 percentage points reduced attendance of incumbent students by 0.4 percentage points (not significant).

7.3 Effects of cyclones, hurricanes and typhoons on grade attainment

Seven studies examined the impact of cyclones on grade attainment and all found negative impacts. Caruso (2017) examined the long-term effects of exposure to cyclones prenatally and among young children, drawing on data for 15 Latin American and Caribbean countries. It finds persistent effects on years of education for people exposed to large cyclones in utero, in early childhood and of school-going ages (>0.1 SD across age groups) but very small or statistically insignificant effects for small cyclone-related disasters. However, small tropical cyclones result in small but significant impacts on years of schooling if a child is exposed between age seven and 12 (school-going age). The study proposes that damage to school infrastructure explains this result for these school-going children. However, it must be interpreted with caution as the effect sizes are small (<0.1 SD) and with a sample size greater than 2 million this is not unexpected. With respect to intergenerational effects of exposure to cyclones on years of schooling, Caruso (2017) finds impacts for the next generation are economically relevant and statistically significant if the mother was affected during school age (ages 5–12), but less so for fathers.

Deuchert and Felfe (2015) analyse the short- and long-term consequences of a typhoon on children's education and health on a small island in the Philippines. The authors compare children whose houses were damaged due to the typhoon with children who live in the same area but did not experience household damage. Using a panel survey of over 2,300 children, they observe increased grade retention four years after the typhoon. These effects are more pronounced for children who experienced housing damage.

On average children who experienced damage lagged 0.13 years behind in school four years after impact, and the gap remained significant and even widened as children grew older. The gap in completed grades amounts to 0.27 years eight years on, 0.52 years 12 years on and 0.67 years 15 years later.

Herrera-Almanza and Cas (2021) examined the effects of exposure to super-typhoons in the Philippines at 9–11 years on children's education attainment. On average exposed students had three years lower educational attainment than their older counterparts (aged 18–20 years) who had not been exposed to typhoons. They were also less likely to enter and complete high school and to speak English than the older cohort. These results are consistent with those of Deuchert and Felfe (2025).

Drawing on a sample of nearly 60,000 individuals in the US, Karbownik and Wray (2019) compare individuals exposed to a tropical cyclone in utero, those born before or conceived after a storm, and those born in areas not affected. They find that income in adulthood was 5.7% lower for those exposed to hurricanes while in utero and 4.7% lower for those exposed during infancy before the age of nine months. Further, they find that among individuals from low socioeconomic backgrounds exposed in utero to hurricanes, the probability of high school graduation decreased by 9.9%, while years of completed education fell by 3.8%. The authors' analysis suggests that these results arise through biological and health-related factors such as maternal stress during pregnancy rather than the destruction of physical capital, the spread of disease or other events associated with hurricanes.

A similar study by Lin, Liu and Xu (2021), which examines the long-term effects of typhoon disasters on individuals born in the coastal provinces of East and South China in 1963–1993, found small but significant effects on learning outcomes. They found that prenatal typhoon exposure has a significant negative effect on educational attainment and income in adulthood, but that exposure in infancy had no significant effects, nor did the effects differ by gender. In addition, adverse effects increased with greater typhoon intensity: prenatal exposure to the strongest typhoons (above 75% quantile) reduced education attainment by 1.38 years and income by as much as 40%. Prenatal typhoon exposure also decreases the subsequent birth interval, thereby increasing the probability of having a younger sibling, which in turn could lead to greater competition for resources.

Zhang and Zhang (2023) used census data for over 12,000 people to understand the impact of the Zhumadian typhoon, which caused floods affecting over 10 million people in Henan province in China. They found that the floods slowed the trend of increasing years of schooling for Zhumadian residents, and reduced schooling attained by an average of 0.2 years. This amounted to a 2.5% reduction, given that on average people in this sample attained eight years of schooling.[46] The study identified shocks to grain production, land assets and loss of income as the key pathway affecting educational outcomes.

7.4 Effects of cyclones, hurricanes and typhoons on learning outcomes

Nine studies examined the impact of cyclones on learning outcomes. Of these, eight found negative outcomes, and one found no impact.

46 Comparisons with unaffected 'control' districts suggest that the 2.5% reduction may be an underestimate.

Two studies examined the effects of typhoons on learning outcomes in the Philippines. In the Philippines, Deuchert and Felfe (2015) find that children affected by housing damage scored on average lower on a general IQ test in one and four post-disaster, by 0.12 SD and 0.11 SD respectively. Additional estimates using results from tests in Cebuano (local language), English and maths confirm the negative impact of typhoon-related housing damage. The study identified the main mechanism for these outcomes to be a shift in parental investments away from education: parents spent 9.1 percentage points less on schooling four years post-disaster; 15 years after the typhoon parental expenditure on schooling had decreased by 23.7 percentage points. Short- and medium-term effects were more pronounced for girls, but effects were more significant for boys in the long term.

Using data from the 2019 Trends in International Mathematics and Science Study (TIMSS), school administrative records and area-level typhoon warnings in the Philippines, Abrigo et al. (2024) assess the impact of short school closures on learning outcomes for over 4,000 grade four students. The study shows that one school closure day induced by use of the school as a shelter reduces student achievement by 12% to 14% of a standard deviation, equivalent to roughly half to a full year's worth of learning. These effects are significantly larger than reported comparable per day learning losses identified in the literature,[47] and must be interpreted with caution as the instrumental variable assumptions are not fully satisfied.

A study of the effects of Hurricane Florence in North Carolina sought to quantify the effects of school closure. Using administrative data on over 80,000 students, Morrill and Westall (2023) find that one additional closure day is associated with a significant decrease in mathematics and reading scores, of 0.0034 and 0.0035 standard deviations respectively; there were significant differences by gender or socio-economic group. It must be noted that the effect sizes in this study are very small.

Using learning outcome panel data from 13 Caribbean countries and over 800 schools for the period 1993–2010, Spencer, Polachek and Strobl (2016) examine the impact of hurricanes on students' performance in standardised high school examinations. They found that hurricanes negatively affect performance when they occur during the school year, particularly for more technical and laboratory-oriented subjects such as biology, chemistry and physics. If storms strike when school is not in session, then test scores are not adversely affected for these subjects. In the case of humanities subjects such as French, Spanish and geography there are no impacts of hurricanes regardless of whether the impacts occur during or outside the academic year. Hurricanes do not impact the two compulsory subjects – mathematics and English – in the same way, with mathematics learning impacted more due to school closures. The impacts on mathematics and English are not consistent across countries, and the authors hypothesise this may be due to size of the country, with slower recovery of the education system post the shock in smaller countries.

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47 In the Netherlands, for example, for an eight-week school closure during the Covid-19 pandemic, a 0.08 SD loss of learning was estimated (Engzell, Frey and Verhagen, 2020). In the Netherlands, for example, for an eight-8 week school closure during the Covid-19 pandemic, a 0.08 SD loss of learning was estimated (Engzell, Frey and Verhagen, 2020).

A study of over 85,000 secondary school students in Puerto Rico found that Hurricane María had a statistically significant but moderate adverse effect on academic achievement. The effects were explained by the length of school closures and students' proximity to areas affected by the hurricane. The adverse effects of Hurricane María on academic achievement were accentuated for students with disabilities in both highly and moderately impacted municipalities. The authors hypothesise that the key channels of impact were the emotional impacts of the cyclone, and access to adequate nutrition during school closures. The authors further hypothesise that school interruptions affect access to health and social services, which are crucial in times of increased emotional stress, especially for students with disabilities. The authors find that Hurricane María did not have a significant impact on risk of dropout for students in high-impact areas, but did increase the risk of dropout in medium- impact areas (Segarra-Alméstica et al., 2022). It is unclear how these results should be interpreted.

Examining data for 464 Texas public schools following Hurricane Ike in 2008, Lai et al. (2019) find that schools where academic performance had been improving (as measured by the Texas Assessment of Knowledge and Skills) prior to Hurricane Ike had their growth pathways (growth trajectory slope or predicted rate of learning curve) changed dramatically afterwards. In contrast, schools that were not showing high rates of improvement continued on the same growth pathways pre- and post-hurricane. The authors find that two risk factors significantly affect whether a school's test scores would be affected by Hurricane Ike: those with low attendance rates and higher rates of economically disadvantaged students were more likely to see interruptions in their progress trajectories.

Two studies examined the effect on host communities of accommodating students displaced by cyclones. Imberman et al. (2012) study the impact on the learning achievement and attendance[48] of existing students in schools which accommodated students displaced by hurricanes Katrina and Rita in the south-eastern US in 2005. The study used panel data from 60,000 students in primary, middle and secondary schools. They find no effect of the inflow of evacuees on learning achievement of existing students in Houston and Louisiana in primary or secondary schools, with the exception of effects on primary students in the middle of the distribution of learning achievement. However, they do find a negative impact on attendance (by less than one day). The authors rule out changes in school resources as the reason for these impacts and their analysis suggests the impacts may be due to peer effects, especially increased behavioural infractions (Imberman, Kugler and Sacerdote, 2012).

Examining the effects on host communities of migration from Puerto Rico into Florida public schools following Hurricane Maria in 2017, Özek (2023) examined the effects of 3,991 migrant students joining a school district of over 200,000 students. He found that a five percentage point increase in the share of 'hurricane migrants' reduced average reading and maths scores by roughly 4% of a standard deviation (0.04 SD).[49]

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48 They also studied impacts on student behaviour, which is out of scope of this review.

49 Like Imberman et al. (2012), this study also measured rates of behavioural infractions among host students and found a 50% increase. Like Imberman et al., (2012), this study also measured rates of behavioural infractions among the host students and found a 50% increase.

These effects were significantly more pronounced among high-performing students in middle and high school: a five percentage point increase in the proportion of migrants decreased the test scores of existing students deemed proficient in both English language arts (ELA) and maths (based on their prior-year test scores) in middle school by 0.15 SD. In contrast, the effects on low-performing existing students were not significant (Özek, 2023). These results contrast with those of Imberman et al. (2012), who finds no impact on learning outcomes, but is consistent in the finding on disciplinary infractions.

7.5 Heterogenous effects

Gender and disabilities

Seven studies examined the differentiated impacts of cyclones by gender. It appears that the short-term impacts may be equal between boys and girls, but differences appear in the longer term. Two studies on learning outcomes do not find differences across boys and girls: Abrigo et al. (2024) and Morrill and Westall (2023). Another two studies find some impacts on enrolment. Jing et al. (2024) observe a decrease in girls' enrolment in areas less accustomed to tropical cyclones (probably due to existing adaptation measures), and Raeburn (2023) finds that, for girls, having more siblings in the household significantly lowers the probability of attending school. The gendered impacts of cyclones on grade attainment are mixed. Deuchert and Felfe (2015) find that the short- and medium-term effects on grade completion are more pronounced for girls, but gender differences vanish in the long run, and effects are more significant for boys. They do not identify specific indicators but suggest that having an older sibling may be a protective factor. Lin et al. (2021) and Caruso (2017) do not find impacts on years of schooling, but longer-term impacts on earnings and employment. Lin et al. (2021) propose that preferential household resource allocation to boys may explain their findings. One study examined the impacts of cyclones on students with disabilities and found that they are more severely impacted in the case of hurricanes (Segarra-Alméstica et al., 2022).

Socio-economic status and school performance

Five studies examined how far the effects of cyclones differentially affect students from varied socioeconomic backgrounds. Of these, three found that the attainment and learning outcomes of children from lower socioeconomic backgrounds were more severely affected than their peers, one found that the learning outcomes of students in the middle of the distribution were more affected, and one found that high-performing students were more impacted. Individuals from poorer socioeconomic backgrounds impacted by hurricanes in utero had greater probability of reduced graduation rates (Karbownik and Wray, 2019). Lai et al. (2019) show that students whose growth trajectories demonstrate improvement are more impacted by hurricanes, and that these students tend to be from more economically disadvantaged backgrounds. The two studies with opposite impact show negative effects on learning outcomes are concentrated among high-performing students in middle and high schools (Özek, 2023), while the other found that children in the middle of the learning distribution were most affected (Imberman et al., 2012). One study did not find differences by socio-economic status or gender on maths and reading scores (Morrill and Westall, 2023).

7.6 Impact pathways

Infrastructure damage

Five studies identify school infrastructure damage and resulting school closures as mechanisms impacting learning and enrollment. Three of these identified school and infrastructure damage to households and schools as the main mechanisms affecting learning outcomes following a cyclone. Raeburn (2023) found a negative and significant correlation between the average percentage change in school enrollment and household damage. A further two studies propose the infrastructure route as the impact pathway. Jing et al. (2024) propose that physical damage to households could lead to increased participation of children in household labour, short-term displacement and long-term impacts of tropical cyclones. Caruso (2017) suggests that damage to school infrastructure impacts outcomes for school-going children, though effects are even greater for children exposed prenatally. The role of school closures as a key pathway is further strengthened by studies that show that, if storms strike when school is not in session, then test scores are not as adversely affected (Spencer, Polachek and Strobl, 2016).

Morrill and Westall (2023) and Segarra-Alméstica et al. (2022) find impacts of school closures on academic achievement. Segarra-Alméstica et al. (2022) propose that decreased academic achievement could be mediated by emotional impacts from disaster events and further predict that school closures affect students' access to food, and lack of adequate nutrition could also be a mediating factor in impacting learning outcomes.

Labour force participation

Only two studies examine links to household income, and two to labour market participation. Segarra-Alméstica et al. (2022) find an inverse relationship between students' poverty level and the level of impact from Hurricane Maria. Zhang and Zhang (2023) hypothesise the relationship between income and dropout. Özek (2023) finds that farm households located in cyclone-affected districts with at least one boy in high school were likely to pull out their boys from school to meet the increased labour demand from non-farm activities. Deuchert and Felfe (2015) hypothesise increased child domestic labour as the mechanism of reduction in education achievement.

7.7 Insights from additional studies

In addition to the 16 core econometric studies, this section draws on six studies using other quantitative methods. Eight qualitative and six mixed-methods studies were also examined. The key themes discussed are school closures, mental health and psychosocial wellbeing.

Additional literature supports the significance of school closures as a major reason for students being unable to access education following a cyclone disaster. Correlational studies in the Philippines showed that the direction of the association between scores in achievement in high school varies by province and by type of hazard. The repeated use of school structures as evacuation centres has negative impacts on learning outcomes (David et al., 2018). Non-causal studies suggest that hurricanes in Texas were associated with a decrease in enrolment (Holmes et al., 2022) and a decline in middle school mathematics scores due to school closures, with rural schools most affected (Lamb, Gross and Lewis, 2013). Using the Standardized World

Income Inequality Database, Sen, Nayak and Mohanty (2023) explore the relationship between tropical cyclones and education attainment across eight Asian countries where tropical cyclones have become recurrent. The study finds that an increase in occurrence leads to a decrease in overall educational attainment in the base year, though in the following year it increases slightly. The authors also find a u-shaped relationship between cyclones and schooling, with years of schooling increasing after one incidence of cyclone. This may correlate with previous results where recurring incidence of cyclones tends to make systems more 'accustomed' to them.

Damage to infrastructure and learning materials

A rapid evaluation of the aftermath of Cyclone Idai in Mozambique found that a major barrier for children returning to school was lost uniforms, school books, school materials and identity documents. Loss of homes or displacement leading to loss of these belongings, in particular identification documents, made it more challenging for secondary school students to enroll in new schools. Loss of access to schools due to destruction of infrastructure such as bridges and other safety issues were also reported as barriers to return to schools. The reasons for the decrease in girls and boys going back to school were different: boys' dropouts are linked to entering the labour market, whereas girls' dropouts are linked more to safety concerns, and both are linked to lack of resources (Haneef and Tembe, 2019). Damage to school infrastructure also removes the psychosocial safety of a school. Examining the impact of Cyclone Idai in Zimbabwe, a qualitative study found that damage to schools increased long absences, and that children's need for psychosocial support hindered their return to school. There was also a lack of stationery and textbooks and returning for important exams was a challenge. This study underscored the need for disaster preparedness in expediting return to learning (Gandidzanwa and Togo, 2021).

A qualitative study using focus group discussions with parents and teachers to understand the impacts of Cyclone Aila in Bangladesh in 2009 describes school damage and the use of schools as shelters. The use of schools as shelters has been a recurring theme in the case of cyclones as one of the reasons preventing access to education. Loss of books and unsafe transportation affected attendance, with some children missing school for up to two years, eventually losing interest and falling behind. Witnessing traumatic events such as loss of classmates impacted the psychosocial wellbeing of students, and the study hypothesises these as impeding impacted children's academic progress. While the study did not demonstrate a direct link to health, it did describe impact on food intake, nutrition, the spread of disease and challenges with sanitation, which could also interfere with children's learning (Akhter et al., 2015).

Post-traumatic stress

Another study using a focus group methodology for school employees and a grief framework for analysis in the aftermath of Hurricane Katrina in New Orleans found that faculty and staff are often frontline responders in getting their schools back in order after disasters. In the process they also suffer their own losses and setbacks and need healthy coping skills and interventions to prevent increased work fatigue, job frustration and absenteeism (Burnham and Hooper, 2012). Another large qualitative study on the impact of Hurricanes Harvey and Matthew in Texas and North Carolina found that school emergency

plans often did not sufficiently consider the social-emotional factors of recovery. Through 115 interviews with educators and district and state-level officials, the study assessed teachers' mental health. Both hurricanes resulted in significant disruption in social-emotional wellbeing, with educators reporting post-traumatic stress, an increase in demands from students and the community to maintain a sense of normalcy, and lack of clarity and resources on continuing education in light of increased absenteeism, the influx of displaced students and school closures (Cannon, Davis and Long, 2023). Another correlational study identified PTSD as a possible mechanism of impact on learning outcomes in the case of Hurricane Katrina, although causal inference is yet to be confirmed for this study (Carl et al., 2013). Post-disaster trauma is an underlying factor in impacting return to school and learning. An assessment of Cyclone Idai in Zimbabwe with 20 students and school staff found that witnessing traumatic events such as destruction of school infrastructure or death of classmates, school staff or loved ones was a major factor impacting learning (Gandidzanwa and Togo, 2021).

Pressure on teachers

Analysis of the same data on Hurricanes Harvey and Matthew in another study showed that the period after the storms was characterised by a loss of instructional time due to factors including school closures and student and teacher absences. After educators returned to school and regained class time, they were forced to adapt and condense content for students, which ultimately affected students' ability to learn. Teachers recalled students being late due to challenges in commuting or being absent due to family obligations. Teachers faced pressure to cover lost instructional time. Student and teacher trauma post the event continues to be an underlying theme and meeting the psychosocial needs of both teachers and students may be crucial to ensure learning. The loss of teaching time due to school closures appears to be an emerging factor impacting learning outcomes (Davis, Cannon and Fuller, 2020).

Role of community

Another study involving 25 students in post-hurricane Puerto Rico demonstrated the significance of community (which was absent for migrants), with the school at the core. It also pointed out the stress on teachers and students and the continued memory of the trauma. The study reiterated the varied roles teachers need to play under disaster conditions (Guth et al., 2021). A study of cultural stressors post-Hurricane María in Puerto Rico in 2017 used 38 parent–child pairs displaced to the US. The study showed how language barriers were a significant hurdle for parents in navigating the administrative system and supporting their children with learning, as well as for students in understanding content. Both parents and students faced challenges in building relationships, and learning English as a second language supported the building of these relationships (García et al., 2024).

8 Temperature

Key insights

Heat and educational outcomes (19 studies)

- The two studies on heat and school attendance, both from high-income countries, found a clear negative effect over certain thresholds. Three studies also found raised heat associated with reduced school completion.
- Unusually hot school days have a clear detrimental effect on learning (11 studies). Though impacts are often relatively small, they are cumulative. Temperatures over country-specific thresholds have an additional negative effect on learning. This highlights the importance of deviation from a norm, to which school infrastructure and systems are adapted and students acclimatised, rather than an absolute threshold.
- Cooler regions are typically more affected by unusually hot periods as students are less acclimatised and schools less well adapted. However, because hotter regions are likely to experience more days of unusually high temperatures, the overall impact on these regions is greater. In some cold regions, increased temperatures are associated with learning gains.
- In six of the 11 studies that identified varied impacts by subject, the impact of unusual heat or cold was more detrimental on mathematics than on literacy or language-based subjects.
- Three of the four studies that probed impact pathways found that the physiological effects of heat explained outcomes.
- The detrimental impacts of heat are generally higher for students from marginalised racial and ethnic groups (six out of seven studies) and from lower socio-economic backgrounds (five out of nine studies) whose access to cooling technologies at home or school is often lower. Five out of nine studies also found no significant differences by gender. Only three studies examined varied effects by age of student; two found greater impacts on younger students.

Cold and educational outcomes (14 studies)

- The effects of cold in reducing attendance were mixed (four studies) but higher for more disadvantaged students.
- Two studies found an effect on school completion, while one found no effect and one found that cooler temperatures had a positive effect on school completion in hot climates.
- Two studies found that cold spells were associated with reduced learning outcomes, two found a small positive effect, and four identified no significant effect on learning.
- Two studies from Mongolia identified impacts on household livelihoods as the key impact pathway; those from high-income countries identified effects on student health and transportation as the key factors affecting attendance in unusually harsh weather.

8.1 Introduction

According to UNICEF estimates, heatwaves constituted the single greatest cause of climate-related disruption to education in 2024, affecting 118 million children in April, with substantial further disruptions in May, June and July (UNICEF, 2025). As well as leading to school closures, heat can affect children's health and thus educational performance directly, as well as through interaction with other hazards, such as air pollution (Hyndman and Vanos, 2023). In this context, understanding the educational impacts to date and potential future impacts of rising temperatures is pressing.

This section draws on 26 econometric studies that discussed the impacts of raised and lowered temperature change on education. These studies were concentrated in North America (10 studies), Asia (nine studies) and Africa (six studies) (see Table 10). Two studies used large multi-country datasets, covering respectively 29 and 58 countries, and one, based on Young Lives data, drew on data from three world regions. Findings are consistent with those of three key systematic reviews (Wargocki, Porras-Salazar and Contreras-Espinoza, 2019; Haßler et al., 2024; Prentice et al., 2025; Box 5).[50]

The measures of both hot and cold weather used varied considerably, with some studies considering the impacts of raised or lower temperatures on a specific test day, while others examined the effects of unusually hot or cold temperatures over a longer period of time. As Wargocki et al. (2019) also found, the metrics of attendance, attainment and especially learning varied considerably across the sample, including national exams, psychological tests and typical schoolwork tasks. Despite this diversity, where possible this section identifies patterns in findings. Table 10 summarises the distribution of econometric studies included in this section.[51]

Box 5 Insights from a meta-analysis of studies on temperature and educational outcomes

Of the 34 studies in Prentice et al.'s review, 26 (76%) reported a link between heat and reduced education outcomes.

- 6/7 experimental studies found a negative effect of raised temperature on academic performance.
- 21/27 observational studies found an association with reduced education outcomes.
- for each 1°C increase in temperature, exam scores decrease by approximately 0.025 of a standard deviation.

Source: Prentice et al. (2025)

50 Studies typically examined the effects of temperatures one or more standard deviations more or less than the seasonal average, though there was some variation in measures and three studies measured the impacts of specific weather events (typically snowfalls and frosts).

51 Some studies reported on more than one outcome.

Table 10 Distribution of temperature-focused studies

Dimension	Number of studies				Geographical distribution
	Total Number	Access	Grade attainment	Learning outcomes	
Heat	20	5	5	12	Brazil, China, England, Ethiopia, India, Mexico, South Africa, South Korea, Vietnam, US, multi-country
Cold	15	5	4	7	Australia, England, Ethiopia, India, Mongolia, Peru, South Africa, US, Vietnam, multi-country

8.2 Effects of heat on education outcomes

Effects of heat on access to education

Only three studies (from England, South Africa and the US) examined the relationship between temperature and school attendance. All found that increased heat reduced attendance. Using administrative data from 22,000 schools in England, Conte Keibavu (2024) found that warm days and in particular hot days (>18°C) were associated with an increase in children's school absences, in particular illness-related absences and authorised holidays. These increased absences were higher in schools with a higher percentage of male students, pupils eligible for free meals at school and days with heavy rain (precipitation at the 99th percentile). Overall, effects were small with an extra day with temperatures >18 °C relative associated with an increase in absences of 0.01 percentage points.

Using administrative data records for 80,000 students from kindergarten to grade 12 in an anonymised large urban school district in the US, McCormack (2023) found a similar relationship. Absenteeism rose as temperatures increased,[52] though at warmer temperature thresholds than in England, reflecting higher average summer temperatures in the US. In the 70–80°F (21–26°C) range absences were more likely to reflect students taking time off in response to pleasant weather, and those above 80°F (26.6°C) reflected changes in student comfort or health. This relationship was similar in both air-conditioned and non-air-conditioned schools. Hot weather was approximately twice as likely to affect the absence of Black and Hispanic students as white students[53] (McCormack, 2023). In South Africa, Pule et al. (2021) found an association between classroom temperatures above 25°C and increasing rates of absenteeism. By contrast, in the US, Alberto et al. (2021) found that high school students' time spent in class or on homework did not decrease in unusually hot weather.

One study – Costa and Goldemberg (2024) – examined the effect of cumulative heat exposure on dropout rates. They drew on administrative

52 Students were respectively 8%, 10% and 16% more likely to be absent on days where the temperature was in the 70s°F (21–26°C), 80s (26.6°–32°C), and over 90°F (32°C).

53 The study also sought to explore the relationship between income, race and access to air conditioning to assess their role in explaining findings on absenteeism, but the data were too heterogenous to enable analysis.

data from over 30,000 schools and 80 million enrolments between 2007 and 2016 for grade 10–12 students across Brazil. They found that a one-standard-deviation increase in the share of days above 34°C raised dropout rates by 0.36 percentage points, representing a 5.1% increase in the average dropout rate. Effects were concentrated in public schools, particularly in urban areas, where poor infrastructure amplified the impact of heat, and no significant effects were found in private schools. The authors hypothesise that this reflects better resources, such as the provision of air conditioning.

Effects of heat on grade attainment

Five studies examined the effects of raised temperatures on grade attainment; three studies found evidence that increased temperatures contributed to reduced school completion, though one found that the effect was seasonal (Randell and Grey, 2016). The remaining two studies focused on the impact of prenatal exposure to heat found contradictory results (see Box 6).

Park's (2017a; 2017b) studies of the impact of raised average temperatures on the probability of graduating from high school on time also found a detrimental effect of heat. Park studied administrative data from high-stakes exams taken by final year high school students attending public schools in New York City between 1999 and 2011, examining 4.5 million exam records for 999,582 students. He found that a 1°F (0.56°C) increase in average exam-time temperatures was associated with a 0.71 to 0.76 percentage point decline in the likelihood of graduating on time. Focusing on more substantial increase in heat, a one standard deviation (+4.4°F, 2.66°C) average exam-time temperature increase was associated with a 3.12–3.34 percentage point decline in the likelihood of on-time graduation, or a 4.59%–4.91% decline relative to a mean on-time graduation rate of 68%.

In Ethiopia, based on a sample of 3,336 households who participated in the Ethiopian Rural Household Survey, Randell and Gray (2016) found that hotter spring and summer were associated with reduced likelihood of completing at least one grade of schooling. Experiencing an average spring temperature 0.5 SD above the village's long-term was linked to 21% lower odds of completing at least one grade of school. This rose to a 28% lower likelihood of completing any schooling with a similar temperature increase in summer. However, a similar rise in winter was associated with a 43% higher likelihood of having participated in any schooling and a greater effect for girls than boys. Randell and Grey hypothesise that these findings are explained by two mechanisms: the effects of food shortages on cognitive development and grade completion, and the effects of temperature changes on agricultural productivity, and demand for child labour. (See Box 6 for more detail.)

Box 6 Impact of exposure to higher temperatures prenatally and in early childhood

Two studies examined the impact of prenatal exposure to higher-than-average temperatures, with contradictory findings.

Examining data from population censuses from 29 countries in sub-Saharan Africa, Latin America and the Caribbean and Southeast Asia, Randell and Gray (2019) probed the effects of periods of raised temperatures in utero and during early childhood on educational attainment at ages 12 to 16.

They found that in Southeast Asia a student experiencing temperatures of two standard deviations above average prenatally or in early life was predicted to attain 1.5 fewer years of schooling than one who experienced average temperatures. Impacts were starkest for children from households where the head had a secondary or greater education – who were predicted to lose on average 2.9 years of education as compared with 0.7 years for those where the household head had only primary education. This difference may reflect the fact that poorer children's educational attainment was already low and thus less affected by change. Patterns were similar across regions, though the effects were starkest in Southeast Asia. The study does not discuss these impacts in relation to average or expected years of education in each region. The authors suggest that these changes are likely to result from increased prevalence of infectious diseases at higher temperatures and from impacts on agricultural production and food availability.

By contrast, a study of census and DHS data from Burkina Faso, Cameroon, Guinea, Malawi, Rwanda and Uganda found that people conceived during high temperatures, on average, have slightly higher educational attainment and literacy (Wilde, Apouey and Jung, 2017). For example, a one standard deviation increase in average monthly temperature[54] nine months before birth was associated with a mean increase of 0.024 years of schooling (a 0.46% increase from the mean). Similarly, the probability of being literate increased by 0.37%. These results, though statistically significant, indicate relatively small effects. Impacts were greatest at eight months before birth, but there were also significant effects at conception, and at six and seven months pre-birth. Wilde et al. hypothesise that these patterns reflect increased food availability as a result of higher temperatures and better agricultural yields.

Effects of heat on learning outcomes

Sixteen econometric studies examined the effects of heat on learning outcomes. The measures of learning examined varied considerably, including test scores in specific subjects, and aggregated scores for standardised exams from primary school to high school exit or college entrance exams. Studies also varied in whether they examined the effect of a single period of heat

54 In this case, 1 SD increase was equivalent to a one-degree increase.

(e.g. on an exam day) or prolonged hot spells, and in the length of effect (ranging from immediate effects to those up to 16 years afterwards). These studies span age groups from primary school students through middle and junior secondary students to high school students taking college entrance tests.

In seven out of these 16 studies, the size of the effect on learning from a single day above specific temperature thresholds was small (below 0.1 SD). However, a measure on a single day gives an inaccurate picture of the impact of raised temperatures, as cumulative impacts are often both more substantial and long-lasting. Various studies therefore estimate the potential effects of exposure to a multi-day heatwave, and find more concerning evidence of the impact on learning.

Twelve studies found that periods of raised temperatures were associated with worse learning outcomes, with two also finding increased test scores in some circumstances. The single most represented country was the US with six studies, likely reflecting the availability of relevant large-scale data. One US study also involved a comparison with global (PISA) data for 58 countries, findings of which are outlined in Box 7.

Box 7 What do PISA data show about the relationship between heat and learning?

Park, Behrer and Goodman (2020) used aggregated mathematics, reading and science test score data from 15-year-olds in 58 low-, middle- and high-income countries participating in the Programme for International Student Assessment (PISA) between 2000 and 2015. They found that:

- Students in school during hotter periods (above 26.7°C) scored worse than their peers in the same country who were not exposed to these raised temperatures.
- Each additional day above 26.7°C (80°F) during the three years preceding an exam lowered scores by 0.18% of a standard deviation, indicating a cumulative effect of heat during a student's education.
- The effects of heat reflect their impacts on learning before the exam (heat on non-school days, on weekends and during summer vacation had little effect).
- The impacts of heat on learning outcomes are greater in poorer countries than richer ones, consistent with lower levels of adaptation.[55]

55 This is based on comparing countries above and below mean per capita income in 1995. Impacts were greater in poorer countries ($\beta = -0.14$; $P = 0.001$; 95% CI = −0.22 to −0.07) than richer countries ($\beta = -0.024$; $P = 0.733$; 95% CI = −0.17 to 0.12).

The key insights from this set of 12 studies are as follows:

Heat across the school year has a consistently detrimental effect on learning. For example, studying data for 3rd to 8th grade students in the US, Park, Behrer and Goodman (2020) found that each additional school day with a temperature of 26.7°C or hotter reduced achievement by approximately 0.04% of a standard deviation. This means that a school year with 30 additional days above 26.7°C would reduce learning by approximately 2.1% of a standard deviation, enough to offset the gains of reducing class sizes by approximately 3–4%. Impacts were starkest for children from low-income backgrounds, and in particular for Black and Hispanic children, who are disproportionately likely to be poor. In Ethiopia, Srivastava, Tafere and Behrer (2024) found that high temperatures during the school year leading up to a university entrance exam reduced scores: 10 or more hot days (over 33°C) were associated with a 2.28% decline in exam scores.

Very high temperatures lead to additional learning losses. For example, studies of high school students in New York found that a year with five additional days at 80°F (26.7°C) or above was associated with a 2.1% (-0.05 standard deviation) reduction in learning on average (Park, 2017a; 2017b). Roach and Whitney (2020)'s study of US 3rd–8th graders found that days over 100°F (37.8°C) led to an additional 2.3% decrease in test scores. Also studying US 3rd–8th graders, Park et al. (2020) found that each additional school day with temperatures in the 90s°F reduced achievement by 0.17% of a year's worth of learning. The effects of days above 100°F (37°C) were up to 50% greater.

Cumulative effects can last several years. Hot school days two, three, and four years prior to the test also lower scores. For the average student taking PSAT exams assessing cumulative high school learning in the US, a sustained increase in temperature of 3.6°F (2°C) lowered achievement gains by 2% of a standard deviation, or approximately 7% of an average year's worth of learning (Park et al., 2020). Other studies with similar findings on long-lasting effects include Cho (2017) and Park, Goodman and Behrer (2020). Studying test data from 3rd–8th graders, one study from the US found that these effects nonetheless did not ultimately affect learning outcomes in the long term (Graff Zivin, Hsiang and Neidell, 2018).

Which areas of a country are most affected depends on how sustained or unusual heatwaves are. Two studies suggest learning losses are greater in cooler areas where they represent a greater degree of change (Cho, 2017; Roach and Whitney, 2022; Srivastava, Tafere and Behrer, 2024). However, this may be outweighed by the persistence of heatwaves in areas prone to warmer temperatures (Park et al., 2020).

Heatwaves can increase the risk of students failing high stakes exams or obtaining lower grades. For example, a study of high school exam-takers in New York found that hot days (90°F, 32°C) increase the likelihood of failing an exam subject by 12.7% (10.9% for the median student). This reflects reduced exam performance by up to 15% of a standard deviation (4.5%) compared to a day at 72°F (22°C) (Park, 2017a; 2017b). In China, drawing on data for 14 million students taking the National College Entrance Exam, Graff Zivin, Song et al. (2018) found that a one-standard-deviation increase in temperature (3.29°C) decreased the probability of getting into a first tier (top 100)

university by 1.97% (4.38% of a standard deviation). This reflected a reduction in total test scores by 1.12% (9.62% of a standard deviation).

Two studies found that warmer temperatures were associated with increased learning outcomes in some contexts. In Wilde et al. (2017)'s six-country study, details of which were outlined earlier, a one standard deviation[56] increase in average monthly temperature nine months before birth was associated with a 0.37% increased probability of being literate (Wilde, Apouey and Jung, 2017). As noted earlier, the hypothesised mechanism for this small effect was through increased food availability on foetal nutrition. Arceo-Gomez and López-Feldman (2024) found that increased heat had a small positive impact on students' learning outcomes in colder municipalities (average temperatures not specified), but that this was only statistically significant for outcomes of Spanish assessments. (See Box 8 for further discussion of different effects on specific subjects.)

Box 8 Do unusually hot or cold temperatures affect some subjects more than others?

Learning in different subjects may be differently affected by heat, but findings are mixed.

Ten studies examined the differential effects of unusually hot or cold temperatures on students' performance in different subjects. Typically, these studies compared impacts on learning in mathematics, literacy skills in the national language, and in a few cases skills in a foreign language or additional subjects (e.g. natural or social sciences).

Six studies found a greater negative impact of heat (four studies) or cold (two studies) on mathematics learning.[57] In Garg et al.'s study in India the differential impact on maths was only evident for more complex skills (e.g. division compared to reading comprehension) and not for basic skills (e.g. number and word recognition). For both subjects there was a statistically significant decline in story reading and division (2% and 3%) if students had been exposed to 10 or more days at over 29°C the previous year (Garg, Jagnani and Taraz, 2020). Thresholds varied: in India a 1°C increase in the average day-of-test temperature above 23°C reduces maths test performance by 0.17 standard deviations (Garg, Jagnani and Taraz, 2020); in the US maths scores declined by a statistically significant margin over 26°C (Graff Zivin, Hsiang and Neidell, 2018).

56 In this study, a one standard deviation increase was equivalent to a one degree C temperature increase.

57 For heat these were Graff Zivin, Hsiang and Neidell (2018); Garg, Jagnani and Taraz (2020); Dang, Do and Nguyen (2024) and Park et al. (2020). The studies finding a greater negative impact of cold on maths learning were Goodman (2014) and Nguyen and Nguyet (2018).

Box 8 Do unusually hot or cold temperatures affect some subjects more than others? (continued)

Two studies from China and Australia found a greater impact on arts and literacy-related subjects (Graff Zivin et al., 2018; Johnston et al., 2021), Cho (2017) found that effects differed regionally, and Srivastava, Tafere and Behrer (2024) found the greatest impacts to be on subjects other than maths and English.[58] Arceo-Gomez and López-Feldman (2024)'s study in Mexico found similar negative effects of heat on maths and Spanish scores, but that additional cold days gave an additional boost to maths learning.

Possible explanations for the greater impacts of unusually hot temperatures on maths learning (and the added gain from colder weather), where this occurs, include neuroscience and the specific nature of maths learning. Graff Zivin, Hsiang and Neidell, (2018) – drawing on neuroscientific literature – suggest that the greater impacts of heat on maths learning may result from the regions of the brain responsible for mathematical tasks being more sensitive to heat. An alternative explanation suggests that, because maths learning is typically more linear, missed lessons – in this case due to weather-related disruption – may mean that students struggle more, and/or that teachers need to spend more time helping students to catch up, at the cost of other teaching and learning (Goodman, 2014).

Srivastava et al. (2024) suggest that their diverging findings – the limited impacts of heat on English and maths – may reflect students putting in extra effort on subjects they find more challenging, which in turn may outweigh the detrimental effect of heat. For subjects perceived as easier, such as civics and general aptitude tests, unusually hot weather in the year preceding the exam is associated with reduced scores.

8.3 Effects of cold on educational outcomes

While raised temperatures are a more widespread effect of climate change, in parts of the world cold weather poses a threat to education.

Effects of cold on access

Four studies investigated the impact of cold temperatures on school attendance, with divergent findings, likely reflecting differences in the intensity of cold spells. Conte Keibavu's (2024) study in England, described above, found that, for most students, cold weather (below 0°C) had no significant effects on attendance. However, for students from neighbourhoods with higher levels

58 In this study English was a foreign language for the students examined.

of fuel poverty, cold exposure was associated with increased absences. Alberto et al. (2021)'s study of 2,561 US high school students found that a cold day reduces a high school student's time use on in-class activities and homework by 13.58% and 22.93% of the mean.

McCormack (2023), studying administrative data from a large urban school district in the US, found that relative to school days with temperatures between 60°F and 70°F (15.6°C to 21°C), students were 34% more likely to be absent on days with temperatures below 30°F (-1°C). She further found that absences of Black and Hispanic students were three times more sensitive to cold weather than those of white students, without drawing clear conclusions on potential mechanisms. Also pointing to a negative effect of cold on student attendance, Pule et al. (2021)'s study in Eastern Cape, South Africa, found that absenteeism was highest where classroom air temperatures were below 15°C.

Finally, Nguyen and Nguyet (2018) found no significant effects of frosts or hailstorms on school enrolment in any of the four countries studied. Explanations varied from greater preparedness in Peru to a more common hazard, and the rarity of frosts and hailstorms in Vietnam and Ethiopia.

Effects of cold on grade attainment

Four studies examined the impact of cold temperatures on grade attainment. Three studies found negative effects on grade attainment in certain circumstances or for particular social groups, and no effects for others. One study found a positive effect.

Of the studies finding negative effects, two studies from Mongolia examined the effects of *dzuds*[59] (unusually harsh winters) on completion of nine years of mandatory basic education. Using panel survey data for 1,768 households, the authors found that children in herding households from severely affected districts who experienced *dzuds* while of school age were significantly less likely (between 20.1 and 26.1 percentage points) to complete mandatory education. As children from non-herding households were unaffected, the authors hypothesise that the key mechanism by which *dzuds* affected grade attainment was through effects on household livelihoods, rather than school closures. Children who were of primary school age during the *dzuds* were more severely affected, reflecting their greater sensitivity to impacts of nutritional stress at a younger age (Kraehnert and Groppo, 2018; Groppo and Kraehnert, 2017).

The study that found positive effects of cooler temperatures on grade attainment – Randell and Grey (2019) – examined data on average temperatures in early childhood (up to age five), and subsequent grade attainment at age 12–16, for 29 countries, as described above. The study found that, in East and Southern Africa, cooler temperatures were associated with the highest educational attainment in the region. Specifically, exposure to temperatures two standard deviations below average during

59 *Dzuds* are 'triggered by the interplay of several unfavorable climatic conditions, including excessive snowfall which prevents animals from grazing; extremely low temperatures which sharply increase the calories required by animals; strong temperature fluctuations above and below zero, leading to snow thawing and then freezing, making grazing more difficult; and insufficient precipitation either in the preceding summer or during the winter which limits vegetation growth' (Kraehnert and Groppo, 2018: 4).

a child's early years (up to age five) increased predicted educational attainment by 2.6 years among households with the least educated heads. Patterns were similar, though not as pronounced, in other regions. It must be noted that – unlike those that follow – this study examined cooler than average temperatures, rather than cold spells, associated with snow and frosts. Its findings therefore should be considered separately to those examining the effects of snow and frosts.

Effects of cold on learning

Seven econometric studies examined the effects of cold on learning outcomes. Three of these found reduced learning outcomes, two found a small positive effect on learning outcomes, and three identified no significant effect on learning.[60]

Studies from Australia, Vietnam and India reported some negative effects of cold spells on learning, with two studies finding notable impacts. Johnston et al. (2021), analysing test scores from a national assessment of Australian children aged between eight and 15,[61] found that additional cold days significantly reduced test scores. Ten additional cold school days (<60°F) in the year prior to the test, instead of 10 warm school days (70–75°F), were estimated to reduce scores by 1.5% of a standard deviation.

The effects were larger for boys than girls, for English than maths test scores and for high school than primary school students, and similar for high and low socio-economic status schools. The authors attribute these findings about the impact of cold weather to people living in generally warmer climates being less prepared to cope with cold weather, and older children making their own clothing choices which may be weather-inappropriate. They do not offer explanations for the differential effects on English and maths, or by gender. Nguyen and Nguyet (2018)'s study of Young Lives data outlined above also found that, in India (but not the other countries in their study), frosts and hailstorms were associated with reduced mathematics scores, with no effect on other learning outcomes. Though the authors do not offer an explanation, this finding may reflect the unexpected effect of cold spells in a normally warm climate.

Even where cold weather is a regular winter occurrence, there is evidence of a negative effect on learning. Investigating administrative data on attendance and learning outcomes in Massachusetts, for 1.5 million students, Goodman (2014) found that snow-related absences, rather than school closures, had a negative effect on learning outcomes in mathematics; impacts on students' English language outcomes were much smaller, for reasons discussed in Box 8.

Three studies identified no significant effects of cold weather on students' learning outcomes. These included Park et al.'s study of PISA data outlined in Box 6. Nguyen and Nguyet (2018), using Young Lives data as described above, found no significant effects of frosts or hailstorms on learning outcomes in Peru, despite 9% and 11% of households respectively being exposed to these hazards.

Two studies found positive effects of cold on learning outcomes. In Vietnam Dang, Do and

60 One study – Nguyen and Nugyet (2018) – found impacts in some countries and none in others; hence numbers add up to seven total studies.

61 The study analysed 2.2 million national standardised tests taken by almost 400,000 grade 3, 5, 7 and 9 students in over 1,500 schools between 2009 and 2018 in New South Wales.

Nguyen (2024) measured the effects of cold weather on maths and literature scores using data for 39,333 students from grades 2 to 7, collected by the Vietnam Escuela Nueva and Research on Improving Systems of Education (RISE) projects. They found that an additional day with temperatures below the 5th percentile resulted in a small increase of 0.015 and 0.010 standard deviations in maths and literature scores, respectively. The authors do not offer an explanation for this finding. Arceo-Gomez and Feldman's study in Mexico, mentioned above, found that experiencing an additional day below 17°C was associated with small increases in test scores in both Spanish and maths (0.0013 and 0.0016 SD respectively) (Arceo-Gomez and López-Feldman, 2024).

8.4 Heterogenous effects

Sixteen econometric studies probed the varied effects of unusual temperatures by social group. Key insights are outlined below.

Socio-economic status

Ten studies examined the effects on different socio-economic groups, with six finding greater adverse effects on poorer students. Costa and Goldemberg (2024) found that the negative effects of heat on dropout rates in Brazil were largely confined to urban public schools, typically attended by poorer socio-economic groups. Four studies from the US examined effects by socio-economic status: three found that the learning and attendance outcomes of poorer students were significantly more adversely affected. Park, Behrer and Goodman (2020) and Park et al. (2020) found that each additional hot school day (26.7°C or above) lowered achievement in lower-income districts by 0.12% of a standard deviation but had little discernible effect on achievement in higher-income districts. Goodman (2014) found the impacts of snowfall on poor students, who are more likely to depend on public transport or less reliable private transport to get to school, to be twice as large as for better-off students. He estimates that these snow-related absences contributed to a quarter of the learning gap between poor and non-poor students in mathematics. McCormack (2023) found that absences of students in lower-income neighbourhoods were more sensitive to temperature than those in higher-income neighbourhoods, as were students in England from households in fuel poverty (Conte Keibavu, 2024).

Three studies found no significant differences: Park (2017a) found no differences between the impacts on students who qualify for publicly funded lunches and those who do not, and also found that test scores of students in the lowest income quintile were less sensitive to heat stress than those in upper quintiles.[62] Vu (2022) found no that students from economically disadvantaged regions were no worse affected than their better-off peers taking on college entrance exams. candidates from economically disadvantaged regions. Arceo-Gomez and López-Feldman (2024) also found no differences by level of marginalisation, which they suggest reflects the fact that the study was undertaken among recipients of a cash transfer, meaning that all were from poor backgrounds, and differences within the sample were less relevant. Randell and Gray (2019) found that the negative effects of raised temperatures in utero on subsequent learning

62 He suggests this may reflect teachers' adjustments to test scores to compensate for challenging circumstances, a topic discussed in more detail in his study.

outcomes affected children from better-off households more, but do not hypothesise the channels through which these impacts arise.

Race/ethnicity

Seven studies examined the varied effects of raised or lowered temperatures by race or ethnicity. In Vietnam Dang et al. (2024) found no differences in the impacts of raised temperatures on student achievement between the Kinh majority and ethnic minorities. By contrast, all six US studies found more detrimental effects of unusually hot or cold weather on marginalised racial and ethnic groups. McCormack (2023) found that Black and Hispanic students are about twice as likely as white students to be absent on hot days and over three times as likely to be absent in cold and snow. This translates into a disparity of over 2.5 days' instructional time over a typical school year. Goodman (2014) found the impact of snowfall on absence among Black and Hispanic students was double that for white and Asian students.

Turning to learning outcomes, Park, Goodman and Behrer (2020) found that each hot school day (over 26.7°C) lowers the achievement of Black and Hispanic students by 0.10–0.12% of a standard deviation but has no statistically significant impact on white students, who are typically wealthier and whose access to air conditioning at home and school is greater. Differences in the temperature environment experienced by students of ethnicity may explain 3–7% of the gap in PSAT scores between white students and Black and Hispanic students (Park et al., 2020). With extremely high temperatures (90°F, 32°C or higher) differences became more pronounced, explaining roughly a quarter of the gap between Black and white students taking high school exams in New York (Park, 2017b; 2017a).

Age

Only three studies compared the impacts of temperature on learning outcomes by age. In Australia Johnston et al. (2021) found that adolescents' learning outcomes were more adversely affected by cold weather than those of younger children, which they attribute to adolescents having more agency over their clothing choices and potentially failing to protect themselves adequately from cold. By contrast, Park, Behrer and Goodman (2020)'s analysis of US data finds third to fifth graders to be more adversely affected by heat than students in grades six to eight. Specifically, each extra day above 26.7°C (80°F) during the school year preceding an exam reduced 3rd–5th graders' test scores by 0.08–0.13% of a standard deviation, but those of 6th–8th graders by a statistically insignificant amount. Park et al. suggest that this is consistent with the greater likelihood of younger children being adversely affected by thermal stress, though acknowledge other possible explanations, such as the lower prevalence of school air conditioning in elementary schools than middle schools.

In their study of the impacts of *dzuds* in Mongolia, which attributes impacts to the impacts of harsh weather on herders' incomes, Groppo and Kraehnert (2017) found weak evidence that the subsequent educational attainment of younger children was most affected. They argue that this is consistent with evidence of the particularly harmful effects of nutritional stress in early life, and with specific studies of *dzuds* and young children's nutrition in Mongolia.

Gender

Eight studies examined whether impacts differed by students' gender, of which four found no gender differences. This is consistent with the key mechanism of impact being physiological

rather than via livelihoods. Two studies found that boys' test scores were more affected than girls' (Johnston et al., 2021; Srivastava, Tafere and Behrer, 2024), and two found that girls' test scores were more affected than boys' (Park, 2017a; Vu, 2022). Srivastava, Tafere and Behrer hypothesise that the greater impact on male students may mask greater efforts to succeed in college entrance exams by girls, one indicator of which is their higher levels of attendance. They suggest that, in the context of pervasive social inequalities experienced by girls and women, girls may have a particularly strong incentive to pass exams governing access to higher education.

Rural/urban differences were largely discussed in relation to economic gaps. No other social differences were probed by these studies.

8.5 Impact pathways

A subset of these studies probed the mechanisms by which the effects of unusually hot or cold weather on children's educational outcomes arose, identifying two mechanisms: physiological and via household livelihoods.

Physiological effects of thermal discomfort

The strongest body of evidence, spanning high-, middle- and low-income contexts, points to unusually high temperatures affecting students directly physiologically (Haßler et al., 2024; Venegas Marin, Schwarz and Sabarwal, 2024; Wargocki et al., 2019).[63]

Two US studies tested this relationship directly. Park, Behrer and Goodman (2020) and Park et al. (2020) found that heat on school days entirely explained their findings.[64] Park et al. (2020a)'s analysis of PISA data from 59 countries corroborates a lack of evidence that income shocks associated with agricultural yields have a significant mediating effect.

Supporting this conclusion, Cho (2017), Srivastava et al. (2024) and Goodman (2014) report that their findings are consistent with disruption to learning being the primary pathway through which impacts on education arise. A study by Alberto, Jiao and Zhang (2021) in the US supports this conclusion. They found that high school students do not reduce study time on hot days, indicating that lower exam results arise from challenges in concentrating. On unusually cold days, students' average study time was reduced, which the authors attribute to snow-related school closures.

Livelihood route

Four studies, all from low- and middle-income countries, highlight the significance of the effects of particularly hot or cold temperatures for household incomes. These indirectly affect learning through their effects on children's access to education, or to inputs that enable them to thrive educationally.

Garg et al. (2020)'s study in rural India demonstrated that the effects of hot days on test score performance were related to impacts

63 These reviews draw on a wider medical and psychological literature, only some of which is based on studies with children who may be more affected by heat than adults, though studies are inconclusive (Graff Zivin and Shrader, 2016). For example, some widely cited studies on heat and cognition – such as Tian et al. (2021) and Yin et al. (2024) – were undertaken with adults. The impact on children may therefore be underestimated.

64 They tested the effects of other potentially relevant factors, such as hot weather at weekends and school holidays, and factors such as snowfall, rainfall and environmental pollution.

on agriculture: they were confined to those that occurred during the agricultural growing season, and were concentrated in warmer regions that grow below-median levels of heat-resistant crops. In addition, the two studies from Mongolia that examined the effects of *dzuds* on completion of basic education found that household income was the main route by which educational completion was affected. Wilde et al. (2017) highlight the significance of food availability in early life for subsequent attainment and learning.

8.6 Insights from additional studies

A total of eight mixed methods and qualitative studies from South and Southeast Asia and southern Africa provided additional insights on the impacts of temperature changes on children's learning. These provide qualitative insights on students' and teachers' experiences, and in particular emphasise the impact of thermal discomfort.

Students' and teachers' perspectives on the impacts of raised or lower temperatures (nine studies). Consistent with the studies discussed above that identified the effects of heat on instruction as the key reason for reduced academic performance, these studies emphasised difficulties concentrating, and the discomfort and health impacts of attending school in hot or cold weather.

For example, Chigwanda et al. (2023)'s study of adolescent girls' experiences of climate change in Zimbabwe highlighted specific challenges with managing menstruation in particularly hot weather.[65] Many of the mixed methods studies – such as UNICEF's *The Heat is On* series[66] – highlighted the impacts of walking long journeys to school in the heat.

> 'The summer season is getting much hotter. I cannot walk more than 10 minutes consecutively as I feel too dizzy … While studying at school, I don't feel good' (Boy, interviewed in Peshawar, Pakistan in Kagawa (2022e: 17).

> 'Both students and teachers are so exhausted because of the heat. Afternoon shift is too hot. 70 students in one classroom. It becomes too tough for both students and teachers to continue the lesson. We have fans but it is not enough as outside temperatures are rising too high now. In winter, it is tough for the morning shift as it is too cold' (Teacher, Bangladesh, in Kagawa (2022c: 19).

Qualitative and mixed methods studies also reported teachers' perceptions of the impacts of unusually hot and cold weather, both for themselves and for students. Drawing on interviews with 335 primary school teachers in seven Indian cities, Lala and Hagishima (2023) also report students struggling to concentrate during heatwaves, and suffering heat stroke symptoms such as dehydration and tiredness. Teachers in UNICEF's *The Heat is On* studies emphasised the lack of classroom ventilation, overcrowding and in one case the smell of sweat, all of which can lead students and teachers to feel unwell (Kagawa, 2022a; 2022b; 2022c; 2022d; 2022e). A principal

65 This study drew on in-depth interviews with 21 school-going adolescent girls, plus 16 Key Informant Interviews and eight focus group discussions, and observations, photography and students' drawings. All the primary research took place in one district.

66 As noted in previous sections, this involved a U-Report survey with 14–24-year-olds, 5–8 key stakeholder interviews and two school focus groups in each country.

interviewed in Nepal directly linked the challenges of additional heat with students not achieving the learning goals mandated by the curriculum (Kagawa, 2022d).

Studies highlighting the effect of cold as well as heat emphasised the challenges students face in cold weather. These often mirror those experienced in hot weather including challenges walking long distances to school, and difficulties concentrating (Kagawa, 2022d; 2022e; Chigwanda, Mutopo and Mutanana, 2023), particularly for poorer students whose families cannot afford additional warmer clothing (Kagawa, 2022f; 2022e).

One study in UNICEF's *The Heat is On* series discussed how heat was affecting pedagogies. Teachers in Sri Lanka reported introducing more games to maintain children's engagement in uncomfortable conditions. One science teacher interviewed highlighted that a combination of hotter temperatures and associated effects of climate change, including increased exposure to animals that could pose a risk to children (e.g. snakes, elephants), meant they were no longer taking their students outside to study natural environments (Kagawa, 2021).

9 Other climate hazards: wildfires and windstorms

Key Insights

- There is no quantitative analysis of the effect of windstorms. All six econometric studies examine the impact on education of wildfires.
- There is little evidence that wildfires reduce school access, with only one study finding delays in school enrolment.
- The two studies examining impact on educational attainment find wildfires are linked to a decrease in total years of schooling, likelihood of completing school, or grade repetition.
- Four studies find wildfires are linked to decreasing English and maths test scores in primary and middle school, a decrease exacerbated by increased wildfire intensity. In two of these studies this is, however, a very small decrease. There is no evidence of impact on PPVT scores.
- Wildfires may affect educational outcomes by impacting children's health (including cognitive development), household expenditure and school closures. However, more evidence is needed.
- There are mixed results on whether children of different genders, race, ethnicity or caste are impacted differently by wildfires, while there is more consistent evidence that age and wealth influence the extent to which children are affected by wildfires.
- Non-econometric studies mostly highlight the impact of wildfires on students' mental health and socio-emotional skills. One study highlights impacts on children with disabilities and discusses the effects of windstorms.

9.1 Introduction

Of the econometric studies included in the review, six discussed the impact of climate hazards other than those discussed in previous sections on educational outcomes: three discussed impact on access, two on grade attainment and five on learning outcomes. All of these studies focused exclusively on wildfires, with the impact of windstorms remaining unexamined. Of these, two focus specifically on the impact of wildfire smoke (Wen and Burke, 2022; Wu, 2022).

The majority of these studies use data from high-income countries – namely, the US (3) and Australia (2). The remaining two studies focus on Nepal and Indonesia. As such, there is little evidence for middle- and low-income countries and no evidence from Latin America, Africa or Europe.

The two studies that report their findings on the impact of wildfires on educational outcomes in SD only find a very small impact (below 0.1 SD) (Wen and Burke, 2022; Wu, 2022). The other studies report their findings in other units, such as percentage points and years of education. Table 11 summarises the distribution of econometric studies included in this section.

Table 11 Distribution of studies on wildfires

Dimension	Number of studies				Geographical distribution
	Total Number	Access	Grade attainment	Learning outcomes	
Wildfires	6	3	2	5	US, Australia, Nepal and Indonesia

In addition to the six econometric studies, seven studies using other methodologies were examined. While most of these studies also focus on wildfires, this set includes the only study covering windstorms.

9.2 Effects of wildfires on access to education

Of the three studies that examine the impact of wildfires on school access, only one – Lo Bue (2019) – found a statistically significant relationship.

Using 10-year panel data from the Indonesian Family Life Survey for 936 individuals, Lo Bue (2019) examined the impact of exposure between the ages of one and three to the 1997 wildfires in Indonesia on delayed school enrolment. The author first tested the effect of wildfires on children's health, using measures of nutritional wellbeing, and then examined the relationship between health and school enrolment. She found that: 1) exposure to wildfires is associated with a decline of about 90% of a SD in height-for-age and 70% of a SD in weight-for-age; and 2) that a 1 SD increase in height-for-age is associated with earlier school enrolment by 0.26 years. This suggests that children whose health was impacted by the 1997 wildfires enrolled later than their healthier counterparts. As the relationship between enrolment and weight-for-age scores was weaker, this suggests long-term health impacts were more significant than short-term ones.

There is no evidence, however, that wildfires affect access to school in other ways. Wu (2022) – discussed in more detail in Section 9.4 – found that a 10-day increase in exposure to wildfire smoke does not affect student enrolment in primary and middle schools in the United States, while Paudel (2023) – further discussed in Section 9.3 – found that a 1 SD increase in wildfire intensity does not affect self-reported school absences for children exposed to wildfires at any point between the past year to over a decade ago.[67]

9.3 Effects of wildfires on grade attainment

The two studies examining the impact of wildfires on total years of schooling find wildfires decrease either total years of schooling (Lo Bue, 2019) or the likelihood of completing school and repeating grades (Paudel, 2023).

Lo Bue (2019) found that exposure to the 1997 wildfires in Indonesia was associated with a decrease in height and weight-for-age scores (see Section 9.2) and that a 1 SD decrease in height-for-age was associated with a decrease in years of schooling of 0.51 years. Paudel (2023) also found wildfires were linked to reduced school

67 Both absences in the last month and illness-related absences.

attainment, though only in some circumstances. Using data from Nepal's Household Risk and Vulnerability Survey for 10,135 individuals, Paudel (2023) examined the impact of wildfires on school completion in Nepal. While the study found that wildfires did not affect the likelihood of completing high school, they did affect the likelihood of completing middle school. A 1 SD increase in fire radiative power (a measure of fire intensity) in wildfires in the previous year and in the previous two to five years was associated with a 1.06 pp and a 2.89 pp decrease, respectively, in the likelihood of completing middle school. When exposed in both the last six to 10 years and more than 10 years ago, they found the decrease to be higher: 6.34 pp and 3.6 pp, respectively. Paudel (2023) also found that wildfires occurring more than 10 years previously were linked to an increased likelihood of grade repetition, with a 1 SD increase in fire radiative power in wildfires leading to a higher probability of grade repetition of 10.10 pp.

9.4 Effects of wildfires on learning outcomes

All five studies investigating the impact of wildfires on learning outcomes focused on test scores: four examined English and maths scores (sometimes including other subjects), and one used the PPVT to measure cognition. Though impact varied, all of the four using English and maths scores – Gibbs et al (2019); Miller and Hui (2022); Wen and Burke (2022); and Wu (2022) – found wildfires were linked to slight decreases in these scores for both primary and middle school students, with increased wildfire intensity exacerbating this decline.

Focusing on the US, Wu (2022) examined the impact of exposure to wildfire smoke on English and maths scores (Grades 3–8) using multi-year standardised test scores from across 6,740 school districts. The study found that a 10-day increase in exposure to smoke plumes in the 12 months before the test was associated with lower English and maths scores – however, this was a small decrease of 0.003 and 0.004 SD, respectively. Exposure two and three years prior to the test did not have an impact. Analysis of wildfire intensity (proxied by PM2.5 ≥ 35.5 μg/m^3)[68] revealed a stronger decrease in test scores. An additional 10-day exposure to PM2.5 one year before the test was linked to much lower English scores (by 0.026 SD) and maths scores (by 0.030 SD). While exposure to wildfires two years prior continued to be insignificant, exposure three years prior to higher PM2.5 levels was associated with reductions in English scores by 0.032 SD and maths scores by 0.040 SD.

These findings are echoed by Wen and Burke (2022), who also examined the impact of exposure to wildfire-attributable PM2.5 smoke on English and maths scores (Grade 3–8) in the US. Using multi-year standardised test scores data for nearly 11,700 school districts, they found that an additional 10 μg of cumulative smoke in the 12 months before a test was linked to slightly lower average test scores (by 0.029% SD), English scores (by 0.035% SD) and maths scores (by 0.024% SD). This means that exposure to PM2.5 ~35 μg/m^3 reduced average test scores by around 0.15% SD – a slightly lower decrease than that found by Wu (2022). They found the decrease in scores carried over into students'

68 PM2.5 are small particles that are a major component of air pollution. They pose an important health risk as they can be inhaled and penetrate into the bloodstream. Wildfire-related PM2.5 can be riskier than PM2.5 from other sources, as exposure to wildfires often means being exposed to very high concentrations of PM2.5 (Venegas et al., 2024).

test performance in subsequent years.[69] While they found a difference between the impact on test scores when comparing school-day and non-school-day exposure, it was not statistically significant and thus the study is unable to conclude that school-day exposure is in fact more detrimental than non-school-day exposure.[70] When analysing the differentiated effect of less severe versus more severe average smoke exposure[71] per year across districts, the study estimates that future exposure to less severe smoke years can reduce average test scores by 0.031% SD while exposure to more severe smoke years would do so by 0.207% SD (relative to a counterfactual of no smoke).

The findings of both Wen and Burke (2022) and Wu (2022) echo the findings in the wider literature on the effect of ambient pollution[72] on children's educational outcomes, as, for the most part, studies in eight countries found ambient pollution was also related to small decreases in English or maths test scores or entrance exams (Venegas Marin, Schwarz and Sabarwal, 2024).[73]

Miller and Hui (2022) also examined the impacts of wildfires in the US on English and maths scores. They focused on the impact of wildfire-related school closures rather than smoke and included high-school students in their analysis alongside primary and middle schoolers. Using standardised test scores for the California Assessment of Student Performance and Progress (also known as CAASPP) and college preparatory exams,[74] they found that school closures were linked to a higher percentage of students that did not meet the standard for the CAASPP exam scores, especially in elementary school.[75] Scores were worse in 3rd, 4th, 5th and 13th grade maths, and in 3rd, 4th and 13th grade English. However, the effect varied depending on the length of the closure, with the 3rd, 4th and 13th grade remaining among the most impacted by extended closures (6–10 days). They also found AP exam scores declined following a wildfire-related closure. Extended closures were linked to improved SAT English, writing and overall scores. The paper does not offer possible explanations for these positive results.

Gibbs et al. (2019) is unique among these studies for examining the impact on test scores in a country other than the US. To investigate the impact of the 2009 Australian wildfires on Grade 3–5 test scores in rural schools two to four years after exposure, they used data from the Victorian Department of Education and Training – the School Entrant Health Questionnaire and the Standardized National Assessment Program

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69 Value unspecified in the article's main text and supplementary materials where the value should be specified were not available.

70 The authors argue the negative effect of school day exposure is mostly driven by the effect on primary school children as an additional 10µg of cumulative smoke on school days decreased their scores by 0.122% SD, while it did not have the same effect on secondary school students (6th–8th grade). This suggests it is younger children who could be the most affected by school day exposure.

71 They compare the 2011 versus 2016 school years, as the former was the least smoky year on average across districts in their sample and the latter was the smokiest year.

72 Mostly measured by PM2.5 levels, but one study also looks at PM10, CO (carbon monoxide) and NOx (nitrogen oxide) and O3 (ozone) levels.

73

74 The college preparatory exams are the Scholastic Assessment Test (SAT), Advanced Placement (AP) and the American College Testing (ACT). The study does not specify sample size.

75 Exact numerical values are unavailable as they are not reported in the text or tables of the study.

Literacy and Numeracy (NAPLAN) for 24,642 students. They compared children attending schools that had high, medium and low exposure to wildfires and found that, in schools with higher levels of wildfire exposure, the expected gains from Year 3 to Year 5 in reading and numeracy scores reduced (by 0.038 and 0.051, respectively, when wildfire exposure increased by one level). They found no impact on writing, spelling and grammar scores.[76]

Concerning PPVT scores, Lo Bue (2019) found wildfires did not impact children's cognitive test scores in Indonesia. However, the study did not assess the direct impact of wildfire exposure on learning. Rather, its methodology involved investigating the correlation between wildfires and children's height (as a proxy for health) and then of height and cognitive scores.

9.5 Heterogenous effects

All six studies examined whether the impact of wildfires on educational outcomes varied across demographic groups. There are mixed results on whether children of different ages, genders and race, ethnicity or caste are impacted differently by wildfires, while there is more consistent evidence that wealth influences the extent to which children are affected by wildfires. This is consistent with health being a key mediator outlined in the literature, followed by household expenditure. Most of the evidence pertains to the impact on learning outcomes, followed by educational attainment. Key insights are outlined below:

Gender

Four studies examined gendered impacts. There was no differentiated impact on school enrolment or total years of schooling in Indonesia (Lo Bue, 2019). This was also the case for English and maths test scores in Australia (Gibbs et al., 2019). Wu (2022) and Paudel (2023) find a differentiated impact. In the US, increased exposure to wildfire smoke plumes or PM2.5 one year before the test was linked to a decrease in girls' scores in both maths and English, while for boys it only affected maths scores (Wu, 2022). Thus, in the US, girls' academic performance might be more susceptible than boys, especially to short-term exposure. In Nepal, the long-term impact of wildfires on the likelihood of completing school was mostly driven by its impact on girls. The strongest effect of a 1 SD increase in fire radiative power was when exposed to fires in the last six to 10 years, which was associated with a reduction of 8.05 pp in girls' likelihood of completing high school (when compared to the no wildfire counterfactual). Impact on girls also drove the impact of wildfires on grade repetition (Paudel, 2023). Neither study elaborates on what might be behind these differentiated effects.

Age

Two studies presented findings differentiated by age. Wildfires in Nepal only affected the school completion of children who were exposed to wildfires between the ages of 0–5 (Paudel, 2023). The impact on the likelihood of grade repetition was similarly mostly driven by primary and middle school students, rather than high school students (ibid.). In the US, recent exposure to wildfire-

76 An important limitation, however, is that the study does not incorporate students who permanently relocated as a result of the wildfires and who were most likely to have been more severely affected and at higher risk of poor academic outcomes.

related PM2.5 affected the test scores of older students (Grades 6–8) more, while long-term exposure affected younger students (Grades 3–5) more. For example, being exposed to a wildfire one year prior to the test reduced English test scores for middle school students (by 0.032 SD) but did not affect those of primary school students. Being exposed to a wildfire three years prior to the test did not affect middle school students, but reduced the scores of primary school students (by 0.047 SD) (Wu, 2022).

Caste, race or ethnic groups

Three studies examined impacts by caste, race or ethnicity. Wildfires in Nepal also impacted children differently according to their caste. The effect was strongest for a 1 SD increase in fire radiative power when exposed to fires in the last six to 10 years, in which case non-Brahmin and non-Chhetri children (more disadvantaged castes) were 5.83 percentage points less likely to complete high school (compared to a counterfactual of no wildfire). This was also the case for the impact of wildfires on grade repetition (Paudel, 2023). In the US, Wu (2022) and Miller and Hui (2022) found more varied results. Wu (2022) found that, while Asian, Hispanic, Black and white students were all affected by exposure to smoke plumes, exposure to wildfire-related PM2.5 led to more varied impact: Asian and Black students were more impacted when exposed in the year before the test, white students were affected by both recent and earlier exposure, and Hispanic students were only marginally affected – with Black primary school students being the most affected overall.[77] Miller and Hui (2022) found wildfire-related closures were related to both positive and negative outcomes for different tests and groups.[78]

Socio-economic status

Three studies examined how socio-economic differences impact the effect of wildfires on children's education. Wildfires in Nepal impacted children differently by type of school (government and private school students).[79] The effect was strongest for a 1 SD increase in fire radiative power when exposed to fires in the last six to 10 years, where students in government schools were 7.19 percentage points less likely to complete high school (compared to a counterfactual of no wildfire) (Paudel, 2023). Wu (2022) and Wen and Burke (2022) also found that, in the US, wildfires harm economically disadvantaged students more. Wu (2022) found that poorer students experienced larger drops in their test scores when exposed to PM2.5 less recently – especially students in primary school (English and maths tests reduced by 0.062 SD and 0.077 SD, respectively). Similarly, Wen and Burke (2022) found that districts with high economic disadvantage (and high proportion of non-white student population) were more affected by wildfires: an additional 10μg of cumulative smoke exposure on school days was linked to a decrease in test scores of 0.085% SD, compared to a decrease of 0.063% SD in districts with low

77 They also found that schools with higher concentrations of white students experienced more wildfire-related school closures than schools with higher concentrations of Hispanic/Latino, African-American or Asian students, or with students receiving FRPMs (Free or Reduced-Price Meals).

78 For example, Asian students' English scores were only affected by exposure to smoke plumes one year prior and by exposure to PM2.5 two years prior to the test – both only relevant at middle school level. Black students' English test scores were also affected by exposure to smoke plumes one year prior, but affected by PM 2.5 only when exposed three years before the test (and mostly concerning primary students).

79 For a 1 SD increase in radiative power when exposed to fires in the previous 12 months up to 10 years.

economic disadvantage (and low proportion of non-white students). However, the impact in districts with low economic disadvantage was also high. The authors argued that, while lower test scores in economically disadvantaged districts may have been driven by structural inequalities and multiple stressors, in wealthier suburbs it may be explained by lower baseline exposure to pollution and fewer adaptive behaviours.

9.6 Impact pathways

The available econometric studies focused on the impact of wildfires on children's educational outcomes primarily via school closures (Miller and Hui, 2022), household expenditure (Paudel, 2023) and health (including cognitive development) (Gibbs et al., 2019; Miller and Hui, 2022; Wen and Burke, 2022; Wu, 2022).

School closures

As discussed in Section 9.4, Miller and Hui (2022) examined the impact of wildfire-related school closures in the US on test scores. They find that the 2002–2003 and 2018–2019 academic years, 63.4% of school closure days occurred as a result of wildfires (21,442 days across 6,644 schools). The average length of wildfire-related school closures was 3.28 days, almost one day more than the average length of closures in general. Of closures lasting more than five days and 10 days, 80.5% and 86.5%, respectively, were wildfire-caused.[80]

Household expenditure

On household expenditure, Paudel (2023) found that wildfire exposure (2 to >10 years prior) in Nepal affected some forms of school-related expenditure. It decreased school supply expenditure, increased self-reported scholarship needs, and decreased self-reported food security. For example, a 1 SD rise in fire radiative power from wildfires in the preceding 2–5 years increased the probability of reporting needing scholarships by 8.82 pp and an increase in worry about food insecurity by 29.08 pp. However, the study found wildfires did not affect expenditure on tuition, uniforms, transportation, lunch or other expenses, or on self-reported work at home and illness. Lo Bue (2019) found, in turn, that in Indonesia household income or household expenditure on education did not play a role in delaying school enrolment in the context of wildfires.

Health

Lo Bue (2019) found that exposure to the 1997 wildfires in Indonesia likely delayed children's enrolment because of malnutrition. This was possibly related to children's exposure to PAHs through air and food or a lack of appropriate care resulting from ill adult family members – both of which can have a negative impact on children's cognitive skills development and long-term health.

While Lo Bue (2019) was the only study that tested for the impact of wildfires on children's health, the studies that examined the impact of wildfires on English and maths test scores (Gibbs et al., 2019; Miller and Hui, 2022; Wen and Burke, 2022; Wu, 2022) also underscored this pathway to impact as potentially relevant. Gibbs et al. (2019) argued that wildfires can decrease cognitive development and focus, explaining why they found the 2009 Australian wildfire had a different impact across subjects, with the greatest decrease in test scores for subjects requiring a higher degree of concentration or cognitive skills. Wen and Burke (2022) and Wu (2022) also argued

80 They included closures because of direct threats of a wildfire and because of smoke's impact on air quality.

that their results in the US might have been driven by a decrease in cognitive development. Wen and Burke (2022) also emphasise the role of illness, as wildfire smoke can increase respiratory conditions in children. Gibbs et al. (2019) also hypothesise for their Australian case study that the decrease in educational outcomes might also be influenced by the impact of wildfires on parents' mental health, appropriate child support and infrastructure.

9.7 Insights from additional studies

Seven non-econometric studies – three quantitative, two mixed methods and two qualitative studies – provided additional insights on the impacts of other climate hazards on children's educational outcomes. Most of these studies also focused on wildfires, and one discussed windstorms. These studies focused distinctively on the impact of wildfires on mental health and socio-emotional skills, with one focusing on the impact of children with disabilities – topics not explored in the econometric literature discussed above. They also emphasise the impact of wildfires on educational outcomes because of school closures highlighted in the econometric literature (Ducy and Stough, 2021; Plan International, 2023).

> 'Climate change really impacted my education in 2019 with the fires, which my family was directly impacted by, putting stresses on my life and education. My school was shut down continually for most of December. I was not able to partake in any exams, which impacted my HSC years later on (combined with COVID, I had no examination prep). Floods followed the next year, closing access to school and my community, placing stress on my family and I again' (Student, Australia, in Plan International, 2023).

Windstorms

The only study to discuss windstorms was from Bhutan, identifying windstorms as a significant risk to school infrastructure. It found that, in 2011–2015, more than 100 schools and early childhood care centres in the country reported windstorm-related damage (Kagawa, 2022d).[81]

Mental health and socio-emotional skills

Three studies examined the impact of the Fort McMurray wildfire in 2016 in Canada on the mental health and selected socio-emotional skills (self-esteem and resilience) of Grade 7–12 students, 1.5 to 3.5 years after the fire. Using primary data for around 3,000 students, Brown et al. (2019a; 2019b) found that students exposed to wildfires exhibited lower self-esteem and resilience, as well as scoring higher on measures of PTSD, depression, anxiety and alcohol/substance use and quality of life compared to those not exposed or only slightly exposed.

When analysing impact over time, Brown et al. (2021) found that mental health conditions increased over time, self-esteem recovered and resilience did not significantly vary. They also found reduced mental health and self-esteem among girls more than boys (no difference in resilience). This was also the case for transgender and gender-non-conforming children when compared to male students; they also scored lower in resilience. Hamideh, Sen and Fischer (2022), who also examined the impact of wildfires in the US, found that escaping the fire, and the displacement, loss and disruption it caused, was linked with the deterioration of students' mental health, affecting their ability to focus and their skills, and thus their performance.

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81 The study uses desk-based documentary review, key stakeholder interviews, school-level focus groups and U-report data from young people (14 to 24 years old). See Section 5 for further methodological detail.

Children with disabilities

Ducy and Stough (2021) investigated the impact of the 2017 Northern California wildfires on children and youth (aged 3–20) with disabilities using in-depth interviews with a small sample of 14 parents. They found that all children missed between a week and over a month of school time because of wildfires, experienced disruptions in school-based services (such as specialised academic instruction and speech occupational therapy), lost previously acquired skills (such as reading), and experienced emotional difficulties or behavioural problems because of the loss of previous routines and social connections.

The study also highlighted that, due to wildfire-related infrastructural damage to some schools in the area, once schooling resumed class sizes were increased beyond ideal levels and in some cases transportation and special needs support continued to be unavailable, reducing children's access to school as well as learning quality.

> 'He had academic regression with missing four months. The intensive reading program had brought him from kindergarten up to fourth grade level, but he lost that, his reading is hanging on by a thread' (Teacher, United States, in Ducy and Stough 2021: 284).

Part 3
Insights from multi-hazard studies

10 Insights from multi-hazard studies

This section outlines highlights from studies that compared impacts from more than one hazard. These studies enable a direct comparison of the impacts of different climate hazards on education outcomes.

Key Findings

- Four out of six studies comparing floods and droughts found that droughts had stronger negative effects on access, grade attainment or learning; two studies found the reverse. One study found impact was comparable for some outcomes.
- The three studies that compared the effects of floods with rainfall shocks, cyclones and hailstorms/frosts found that floods had a greater impact on grade attainment and learning outcomes.
- Three of the four studies found that rainfall variability shocks had less effect on education outcomes (learning and grade attainment) than other hazards: floods, droughts, landslides and cyclones.
- Two studies compared other outcomes, finding a greater impact of temperature increases in spring and summer months (but not other seasons) than droughts on school years attained, and that hailstorms and frosts had a greater impact on learning outcomes than floods and equal impacts to droughts.
- Ten of the studies in this review discuss multiple hazards, providing an opportunity to draw comparative insights across impacts of different hazards on educational outcomes. See Table A3.1 in Appendix 3 for a summary.

10.1 Droughts and floods

Of the six studies comparing floods to drought, four find droughts are associated with a higher loss on all types of education outcomes: access, attainment and learning – even though in some cases this is a small difference. This evidence arises from Malawi, Mexico, India and Ethiopia (Hyder and Behrman, 2016; Abiona, 2017; Nguyen and Nguyet, 2018; Adhvaryu et al., 2023). Interestingly, other evidence from these same countries contradicts these findings, with floods having a greater impact than droughts in India and Ethiopia (Zamand and Hyder, 2016; Dasgupta and Karandikar, 2021) or comparable impact in Mexico (as well as Peru). In Vietnam, evidence suggests floods have a small but greater negative impact on educational outcomes than droughts (Nguyen and Nguyet, 2018). These differences might be related to drought's long-term impact on household livelihoods and nutrition and flooding's more immediate impact on household finances, and on infrastructure. Table 12 summarises the findings.

Table 12 Comparative negative impact between droughts and floods

Country	Comparative impact of hazards	Findings	Authors
Malawi	Droughts > floods	Only drought was related to delay in the school entry of boys (small effect size). When exposed in-utero and during the second year of life, it decreased by 0.159 and 0.129 years, respectively.[82]	Abiona (2017)
Mexico	Droughts > floods	Floods were linked to a decrease in total years of schooling of 0.65 years, while droughts were linked to a reduction of 1.03 years.	(Adhvaryu et al., 2023)
	Droughts = floods	Little difference, between floods, droughts and rainfall shocks on the probability of completing at least 5 grades (of 0.19 and 0.22), and of age-appropriate completion (of 0.11 and 0.18).	
Ethiopia	Droughts > floods	Droughts, unlike floods, were linked to a decrease in enrolment (by 0.22). However, this was only the case for more intense droughts. Droughts of all intensities were linked to significantly lower PPVT scores (ranging from a reduction of 6.82 points to 35.4). Floods had contradicting results on PPVT scores depending on whether the shock was less or more intense.[83]	(Hyder and Behrman, 2016)
	Floods > drought	Floods were associated with decreases in PPVT scores, maths scores and Cloze scores, while drought only decreased PPVT and maths scores – with floods having a stronger impact.[88]	(Zamand and Hyder, 2016)
	Floods > drought	Only floods were linked to a reduction in the average number of completed grades, by 3.4%.	(Nguyen and Nguyet, 2018)
Vietnam	Floods > drought	Only floods were associated with a lower probability of enrolment – by 0.05 – however, this was very small. Only floods were also linked to lower rescaled mathematics and PPVT scores, by 5.491 points (9.3% of the score mean) and 2.295 points (2.9% of the score mean) respectively. Only floods were linked to a reduction in the average number of completed grades, by 1.8%.	(Nguyen and Nguyet, 2018)
Peru	Floods =! droughts	Drought was related to a decrease in PPVT scores, and floods to a decrease in Cloze scores.	(Zamand and Hyder, 2016)

82 Droughts also had no impact when exposure was in Year 1.

83 There was no relation between floods or droughts and maths scores. The study used individual and community-reported floods as proxy measures for hazard intensity (see Section 5).

Table 12 Comparative negative impact between droughts and floods (continued)

Country	Comparative impact of hazards	Findings	Authors
India	Droughts > floods	While floods did not affect PPVT scores, droughts were linked to lower PPVT scores by 6.1 points.	(Nguyen and Nguyet, 2018)
	Floods > droughts	Only floods were linked to a reduction in the average number of completed grades, by 3.8%.	(Nguyen and Nguyet, 2018)
	Floods > droughts	The reading and maths scores of boys tested in a drought year were marginally higher, by 0.06 and 0.14 SD respectively, than those of boys tested in a flood year. Droughts were linked to a higher likelihood of remaining in school (by 0.32 percentage points) and of being on track (by 0.9 percentage points) than that of boys in a flood year.[84]	(Dasgupta and Karandikar, 2021)

In the three studies that examine the impact of floods and other hazards, floods had a higher negative impact on educational outcomes. These studies compared floods to rainfall shocks, hailstorms/frosts and cyclones. This is likely related to the more intense nature of flooding compared to hazards like rainfall variability or frosts and the possibility of preparing for tropical cyclones. Table 13 summarises the findings.

Table 13 Comparison of negative impact across floods and other hazards

Country/ region	Comparative impact of hazards	Findings	Authors
Colombia	Floods and landslides > rainfall shocks (positive)	Individuals exposed in-utero to floods or landslides had much lower PPVT scores than those exposed to heavy rainfall (a decrease of 6.68 points in children exposed to floods or landslides compared to 0.692 points for heavy rainfall). This was also the case when exposed aged 1–2 years (a decrease of 0.39 points compared to 0.096 points). Exposure to floods or landslides aged 1–2 years was also associated with a slightly higher risk of worse socioemotional outcomes, but the effect sizes of both were very small (0.0094 rather than 0.003).[85]	Brando and Santos (2015)
Ethiopia	Floods > hailstorms/ frosts	Only floods were linked to a reduction in the average number of completed grades.	Nguyen and Nguyet (2018)

84 The study does not specify if 'being on track' refers to age and grade relation or learning progress.

85 In both cases they found no relation when exposure occurred in Year 1. Brando and Santos (2015) also examine the impact of rainfall on school attendance; however, they do not run the controls for this variable. Thus, comparative data is not available.

Table 13 Comparison of negative impact across floods and other hazards (continued)

Country/ region	Comparative impact of hazards	Findings	Authors
Vietnam	Floods > hailstorms/ frosts	Only floods were associated with a lower probability of enrolment (even if small), lower rescaled maths and PPVT scores and a lower average number of completed grades.	Nguyen and Nguyet (2018)
India	Floods > hailstorms/ frosts	Only floods were linked to a reduction in the average number of completed grades.	Nguyen and Nguyet (2018)
Latin America (15 countries)	Floods and landslides > cyclones	In-utero exposure to landslides and floods had a very similar impact on years of schooling (reducing it by 0.1SD or 0.486 years and 0.099 SD or 0.472 years, respectively), while in-utero exposure to cyclones had no impact. Exposure to cyclones while of school age[86] had a small impact, much lower than landslides and floods.[87]	Caruso (2017)

In three of the four studies that compare rainfall shocks (increase or decrease) to other hazards, floods, landslides, droughts and cyclones had a higher negative impact than rainfall shocks (Brando and Santos, 2015; Marchetta, Sahn and Tiberti, 2019; Adhvaryu et al., 2023). This is to be expected as rainfall shocks refer to less extreme rainfall variations than floods or droughts.

The exception was the regional study by Randell and Gray (2019), who found that decreases in rainfall were related to a higher reduction in years of schooling compared to that associated with higher or lower temperatures; however, for West and Central Africa this was a small difference of 0.02 years. Table 14 summarises the findings.

86 The authors explain that one factor in this difference is that, unlike floods and landslides, cyclones are predictable, giving people enough time to prepare or evacuate. As damage to infrastructure cannot be entirely avoided, this may explain why cyclones do reduce years of schooling.

87 Exposure to 'big' floods was higher than to 'big' landslides, but marginally, and the impact of both at their peak (in-utero and early infancy, respectively) was around 0.5 years. When looking at 'small' hazards, these did not have impacts when exposed at any age. In general, landslides were linked with the highest reduction in years of schooling (when exposed between 0–1, reducing years of schooling by 0.39 years). However, this was a small difference and for some age brackets floods had higher impact (though also only slightly).

Table 14 Comparative negative educational impacts of rainfall shocks and other hazards

Country/ region	Comparative impact of hazards	Findings	Authors
Colombia	Floods and landslides > rainfall shocks (positive)	See Table 10	Brando and Santos (2015)
Mexico	Droughts and floods > rainfall shocks (positive and negative)	Below average or above average rainfall – defined as rainfall between the 20th and 80th percentile – had no impact on educational attainment, while floods and droughts did decrease all these outcomes.	Adhvaryu et al. (2023)
Madagascar	Cyclones > rainfall shocks (positive or negative)	A 1 SD increase or decrease in rainfall did not have an impact on children's enrolment rates; however, cyclones were related to a decrease in the probability of being enrolled in school, by 15.2 percentage points.	Marchetta, Sahn and Tiberti (2019)
West and Central Africa	Rainfall shocks (negative) > higher temperatures	Low early-life rainfall was associated with reductions in schooling, with the largest impacts – up to 1.8 fewer years of education – seen among children from more educated households. Hotter temperatures led to a slightly smaller decrease (1.6 years) in the same demographic group.	Randell and Gray (2019)
Central America and the Caribbean	Rainfall shocks (negative) > higher or lower temperatures	Excessive rainfall in early childhood was associated with reduced years of schooling, particularly among children from less educated households who lost up to 0.7 years of schooling, while higher and lower temperatures were linked to an increase in years of schooling among children of less educated households.	Randell and Gray (2019)

In Ethiopia, high temperatures were linked to a lower probability of completing at least one grade of schooling than droughts, although only in some months (Randell and Gray, 2016). This highlights the potent effect of thermal stress on learning.

In India, hailstorms/frosts were associated with lower maths scores, while floods had no impact. Hailstorms/frosts also had similar impacts as droughts on learning outcomes (Nguyen and Nguyet, 2018). Table 15 summarises findings.

Table 15 Comparative negative educational impacts of other hazards

Country/ region	Comparative impact of hazards	Findings	Authors
Ethiopia	High temperatures > droughts (in spring and summer only)	Experiencing warmer springs and summers (by 0.5 SD) was linked to a lower likelihood of completing at least one grade of schooling, by 21% and 28% respectively, compared with a 16% reduction among children exposed to an additional drought in early life. Experiencing warmer winters (by 0.5 SD) were associated with a 48% higher likelihood of completion.	Randell and Gray (2016)
India	Hailstorms/frosts > floods	Only hailstorms were linked to lower maths scores (by 16.29 points).[88]	Nguyen and Nguyet (2018)
	Hailstorms/frosts ~ drought	Droughts were linked to lower PPVT scores (by 6.1 points), while frosts/hailstorms were linked instead to lower maths scores.	

88 Neither had an impact on PPVT scores.

11 Impact pathways and heterogenous effects

This section synthesises insights on the most commonly identified direct and indirect pathways by which climate affects education: school closures and impacts on infrastructure; health and nutrition including mental health and concentration; and household income, livelihoods and participation in the labour market. Few of the studies reviewed compared the relative importance of different pathways. This section therefore discusses the evidence for each pathway separately.

11.1 Infrastructure damage and school closures

Infrastructure damage

The review found that evidence of damage to school buildings, school water and sanitation, roads and students' homes was an important pathway leading to educational losses (seven out of eight studies examined).[89] For example, flood damage to school equipment and learning materials in Thailand contributed to reduced test scores (Thamtanajit, 2020). A study of 15 Latin American and Caribbean countries found that destruction of infrastructure by cyclones, floods and landslides reduced the educational attainment of children exposed prenatally by 0.486 years – showing the long-term impacts of climate-induced damage to infrastructure on education. This study also found that, as the age at the time of exposure increases, the size of the impact on education decreases, with the greatest impact on children exposed under the age of seven (Caruso, 2017). Consistent with evidence of the role of infrastructure destruction in more extreme events, a study of the impacts of rainfall shocks in Colombia found that education outcomes are still affected even when controlling for infrastructural damage. This indicates that other factors may play a more important role, such as disruption to markets (Brando and Santos, 2015).

Damage to homes also affects children's education. Hurricane damage in the US and related disruption in children's homes was associated with reduced learning outcomes, highlighting that school closures were not the only reason children's maths and reading scores declined (Morrill and Westall, 2023). Housing damage from typhoons in the Philippines led to shifts in parental investments and household expenditures (spending on education reduced by 9.1 percentage points in the short term, and by 23.7 percentage points in the long run). This contributed to typhoon-related damage disproportionately affecting the educational outcomes of poorer households, which were less able to afford such investment (Deuchert and Felfe, 2015). By contrast, Raeburn (2023) found that cyclone-related damage to schools had a much greater effect on students' enrolment than damage to their homes.

89 Goodman, 2014; Caruso, 2017; Branco and Féres, 2018; Ahmed et al., 2022; Morrill and Westall, 2023; Raeburn, 2023 (for school but not housing damage); Prenhaca and Melo, 2024. Brando and Santos (2015) was the only study that tested an infrastructure pathway, and found it to be less significant than health or income pathways.

School closure

When schools are destroyed by a disaster, their reconstruction and the return of children to school can be one of the most effective ways to demonstrate a return to normalcy to the local population and to help the government rebuild the social contract (UNDP, 2007; Baez et al., 2010). Climate-related disasters – especially floods, droughts, cyclones and wildfires – cause significant disruptions to education primarily through school closures, which in turn lead to long-term negative effects on children's learning, enrolment and wellbeing (Venegas Marin, Schwarz and Sabarwal, 2024b). These closures are driven by infrastructure damage or inaccessibility, teacher absence and schools being used as shelters (Pal et al., 2023).

Schools may be closed because they are too damaged to reopen, are inaccessible (to students or teachers) or because they are used as shelters. In the Pakistan floods of 2010, 11,000 schools were destroyed and others were used as shelters (Khan and Hussain, 2023). The International Rescue Committee (2023) found that government schools suffered significant infrastructural damage in the floods, leading to a surge in government school dropouts from 20% to 50%. During these closures, 69% of children reported no contact from their schools, with the majority relying on family, neighbours or paid tutoring for learning support.

Four of the seven econometric studies that investigated their impacts found that school closures were a key mechanism by which climate-related events affect educational outcomes, a finding corroborated by the qualitative and mixed methods studies.

For example, examining droughts in Brazil, Prenhaca and Melo (2024) found that municipalities exposed to prolonged drought experienced a decrease in the number of public elementary school teachers due to water supply issues and permanent school closures. These staffing losses were more pronounced among lesser skilled teachers and those on temporary contracts. A correlational study in the Philippines showed that the repeated use of schools as shelters or evacuation centres also had negative impacts on school performance (David et al., 2018). In Puerto Rico, the negative effects of Hurricane Maria on learning outcomes were attributed to school closures, which also meant a reduction in the access of students with disabilities to specialised health services (Segarra-Alméstica et al., 2022).

A study of the impact of wildfire-related closures in the US found that they increased the percentage of students who performed poorly in standardised tests, with effects varying by length of school closure (Miller and Hui, 2022).[90,91] By contrast, evidence from Mongolia and the US suggests that snow-related closures do not have a significant impact on educational outcomes (Goodman, 2014; Groppo and Kraehnert, 2017). Where cold weather shocks affect individual students' ability to attend (through illness, transport difficulties or financial pressures),

90 By contrast, extended closures due to wildfires were followed by improved SAT English, writing and overall scores (Miller and Hui, 2022). While the paper does not explain these positive results, extended scores might reflect home learning by students already preparing for standardised tests.

91 They find that between the 2002–2003 and 2018–2019 academic years, 63.4% of school closure days occurred as a result of wildfires (21,442 days across 6,644 schools).

snowstorms are associated with reduced learning outcomes and grade attainment (Groppo and Kraehnert, 2017). No studies were found measuring the impact of heatwave-related closures on learning, despite their periodic implementation in LMICs (Haßler et al., 2024).

11.2 Health

The literature reviewed discusses four health-related pathways by which climate change may affect children's education outcomes: through illness, nutrition, mental health and thermal discomfort.

Illness

Seven of the 12 econometric studies that examined the role of climate-related illness – for example as a result of a rise in infectious diseases (water- or insect-borne) or wildfire smoke – found that it was an important impact pathway. Two studies from Colombia identified the increased incidence of malaria and dengue fever following unusually high rainfall as an important factor contributing to, respectively, school drop-out and reduced grade attainment (Carillo, 2020). In Brazil, one additional drought shock per year was associated with a 5% increase in malnutrition-related hospitalisations and a 2.6% increase in hospitalisations due to infectious diseases, for children aged nine to 11, and thus to reduced school attendance (Branco and Féres, 2018). One US study linked wildfire smoke, children's susceptibility to respiratory illness and reduced test scores (Wen and Burke, 2022). Six studies did not find a link between climate-related health impacts and educational outcomes. These ruled out hot weather and high rainfall as factors affecting attendance (Dang et al., 2024), illness arising from wildfire pollution as a pathway affecting middle school completion (Paudel, 2023), and high rainfall, droughts, floods and cold weather as factors explaining cognitive test outcomes (Brando and Santos, 2015; Nguyen and Nguyet, 2018; Shah and Steinberg, 2017).

Nutrition

Climate-related disasters can be particularly damaging for nutritional outcomes if they directly affect food availability or increase the price of food (Baez et al., 2010). They may also increase the incidence of malnutrition and disease through their impacts on household assets and income, maternal health, or through exacerbating related environmental challenges, such as air pollution. All of these processes can affect children's cognitive development, and thereby educational outcomes.

Four econometric studies demonstrated a relationship between climate change, nutrition and children's educational outcomes. An additional 12 studies demonstrated poorer nutritional outcomes among young children (usually measured in terms of weight or height for age) as a result of climate shocks. They then examined the relationship between nutritional status and access to education (five studies), attainment (seven studies) and learning outcomes (eight studies), and suggested that impacts on nutrition may help explain these educational outcomes. Given the known relationship between nutrition and cognitive development, nutrition is then hypothesised as a likely pathway through which climate shocks affect learning outcomes. Some of this evidence is discussed further in Section 11.4.1, which examines how climate events experienced at key sensitive periods such as early childhood are associated with worse nutritional and educational outcomes, and so is not repeated here. One study also related nutritional deficits and cognitive damage to increased likelihood of child labour and reduced school enrolment

(Akresh et al., 2012). One study related exposure to PAHs as a result of wildfires to malnutrition and delayed school enrolment (Lo Bue, 2019).

Two studies explicitly ruled out nutritional impacts as a pathway to specific education outcomes. In contrast to findings on school enrolment in Indonesia, Lo Bue (2019) found no significant impact of health conditions experienced during the first year of life and in utero related to wildfires on subsequent school performance. Studying the impact of heat on high school students' performance in college entrance exams in Ethiopia, Srivastava et al. (2024) tested for and found no evidence of a nutritional pathway to the impacts observed.

Mental health

Climate-related disasters disrupt the mental health and psychosocial wellbeing of children, teachers and school communities. The impacts are often acute and enduring, particularly for those experiencing displacement, bereavement or the destruction of homes and schools. Children exposed to such events frequently exhibit symptoms of PTSD, depression, anxiety and behavioural difficulties, all of which compromise their capacity to learn and thrive in school environments. Nineteen non-econometric studies mention the impacts of climate disasters or hazards on mental health. We present this evidence to surface some of the hidden impacts of climate disasters that may in turn affect children's learning outcomes.

In India, for example, students affected by the Kerala floods in 2018 reported heightened post-traumatic symptoms six months later (Greeshma and Subudhi, 2020). Studying the same floods, Philip and Vithya (2023) found that this increased stress was due to how floods had affected students' family livelihoods, and their continued worries regarding the future (Philip and Vithya, 2023), with similar findings in Tamil Nadu (Krishna, Ronan and Alisic, 2018). Witnessing traumatic events such as loss of classmates also contributes to greater anxiety among students, as found in Pakistan and Zimbabwe (Akhter et al., 2015; Gandidzanwa and Togo, 2021). Displacement also compounds students' stress after a climate-related disaster, as found in a study of Puerto Rican students displaced to the US by Hurricane Maria, who faced additional stresses related to migration and associated language barriers (Guth et al., 2021).

Fears of safety or the future are also common sources of stress for students who have witnessed disasters such as floods or hurricanes or as a result of knowledge regarding climate change (Kagawa, 2022b). Exposure to wildfires has also been shown to impact mental health (Gibbs et al., 2019), causing lower self-esteem and resilience, as well as higher scores on measures of PTSD, depression, anxiety and alcohol/substance use (Brown, Agyapong, Greenshaw et al., 2019; Brown et al., 2021). It can also lead to behavioural problems related to the loss of previous routines and social connections (Ducy and Stough, 2021; Hamideh, Sen and Fischer, 2022).

Climate-related stress is not limited to acute disasters. Rising temperatures and heatwaves are chronic stressors and increase irritability, fatigue and discomfort among both students and staff, impede attention spans, exacerbate stress and reduce learning outcomes (Kagawa, 2021). Teachers, too, bear significant psychological burdens. Educators must manage their own trauma while being expected to restore routine and support distressed students – often without training in trauma-informed care (Guth et al., 2021; Cannon, Davis and Long, 2023). This dual responsibility could lead to burnout and absenteeism among teachers, further affecting school functioning.

Mental health and psychosocial support (MHPSS) services in schools remain limited and there is a need for education systems to integrate mental health into climate resilience planning. Studies undertaken after Hurricanes Harvey and Matthew in Texas and North Carolina found that school emergency plans often did not sufficiently consider the social-emotional factors of recovery (Cannon, Davis and Long, 2023). This includes training teachers in psychosocial support, strengthening referral systems and designing climate-adaptive, safe learning spaces. Without such investment, the cumulative psychological toll of climate disasters will continue to compromise both wellbeing and educational equity across vulnerable contexts.

Thermal discomfort, concentration and cognitive functioning

As discussed in Section 7, an extensive literature probes the effect of raised temperatures on cognitive functioning, though it is important to note that many of these studies were not conducted with children and may not be fully generalisable to younger people.

Two studies of heatwaves identified their impacts on children's ability to concentrate, and/or to undertake cognitive processes. One study from the US attributed a statistically significant short-term reduction in maths test scores to cognitive challenges in warmer temperatures (despite high prevalence of air conditioning (Graff Zivin et al., 2018)). One multi-country study ruled out a livelihood-related pathway, concluding that the physiological effects of heat drove reduced learning (Park, Behrer and Goodman, 2020).

Eleven further studies (eight of temperature change, three of wildfires) provide supporting evidence for disrupted concentration and cognitive processes as pathways affecting educational outcomes. These highlighted the potential effects of hot or cold classroom conditions and thermal discomfort or wildfire smoke on absenteeism (five studies) and learning outcomes (eight studies). For example, studies of the positive effect of air conditioning on test scores during heat waves, or of the association of heat waves falling on school days rather than at weekends or holidays, provide indirect evidence of a thermal-comfort and cognition-based pathway (Park, Behrer and Goodman, 2020; Park et al., 2020; Park, 2017a; 2017b).

Studies indicating the differential impact of raised temperatures or wildfire smoke on test scores in subjects requiring a higher degree of cognitive effort are consistent with this pathway (Gibbs et al., 2019; Park et al., 2020), though evidence is mixed. The US-based studies also highlight the greater vulnerability to thermal discomfort and its effects on cognitive processes of more disadvantaged students, who are more likely to live in crowded conditions with less effective cooling and attend schools without adequate cooling (see Park, 2017a; 2017b; McCormack, 2023).

One study from India found no evidence for a pathway based on thermal discomfort affecting cognitive processes, demonstrating that the impact of high temperatures on farm-based livelihoods explained the reduced test scores observed.

11.3 Livelihoods

The impact of climate change on livelihoods indirectly impacts children's education outcomes through two main channels: household expenditures on education and child labour. Empirical studies have shown that households that are seriously affected by a shock, when left with tighter budgets, tend to cut back on basic

investments in education, health and productive physical capita (Dillon, 2013). Disasters change the opportunity cost of sending children to school; parental disinvestments in children that appear to be temporary adjustments to difficult times can become permanent shifts.

Household assets, income and expenditure

Across all hazards, 25 econometric papers identified impacts on household livelihoods as a pathway of impact on educational outcomes. Just over half these papers discussed the effects of rainfall variability on crop yields or agricultural wages, which affect households' capacities to invest in children's education and nutrition. The others discuss the effect of more extreme shocks, such as cyclones, floods, droughts and cold waves.

Damage to assets and agricultural yields from variations in rainfall can lead to reduced household expenditures on education and health – as found, for example, in Colombia (Brando and Santos, 2015; Palacios and Rojas-Velásquez, 2023), China (Leight, Glewwe and Park, 2015) and Uganda (Agamile and Lawson, 2021). Studies of decreased rainfall also highlight reduced agricultural wages as affecting household investments in education, as found in Mexico (Adhvaryu et al., 2023) and Uganda (Agamile and Lawson, 2021). Impacts may be particularly severe if the rainfall shock occurs during harvest season, as found in China (Leight, Glewwe and Park, 2015).

Studies of more intense or extreme events identified similar mechanisms. For example, a study of floods in Ethiopia, India, Vietnam and Peru found household expenditure reduced by almost 15% (Nguyen and Nguyet, 2018). In China, the Zhumadian flood led to a decline in grain holdings, cotton and oil seeds from farming households, with the fall in income increasing children's risk of dropping out of school (Zhang and Zhang, 2023). A study in drought-affected rural Iran showed that a 1% decrease in farm income led to a 0.86% increase in education expenditures. Households used adaptation strategies such as taking off-farm jobs, borrowing money, cutting savings and selling crops before they were harvested to cover their children's education fees by any means possible (Khalili et al., 2020). These impacts can differ based on gender, age and other factors (see Sections 11.4.1–11.4.3).

Although most studies of changes in temperature emphasise that effects primarily arise through thermal discomfort discouraging attendance and affecting concentration, two studies identified impacts resulting from the effects on rural livelihoods. Higher temperatures in India affected test scores via their effects on agricultural yields and household incomes, with a pronounced impact in regions with lower levels of heat-resistant crops (Garg, Jagnani and Taraz, 2020). For herding households in rural Mongolia, the effect of *dzud* (extreme winter) on children's educational attainment was largely attributed to losses in income and household assets (Groppo and Kraehnert, 2017). A study on wildfires in rural Nepal found that the lasting economic damage they caused resulted in lower investment in school supplies (Paudel, 2023).

Impacts on household income may also have long-term effects. One study from Kenya found that the effects of rainfall shocks on educational expenditures persisted even after a decade due to reduced land and livestock ownership after such a shock (Nübler et al., 2021). Similarly, reduced investment in education following Typhoon Mike in the Philippines contributed to poorer young people affected by the typhoon having one year's less completed education at age 22 than

unaffected young people, and six months' less than their better-off counterparts exposed to the typhoon (Deuchert and Felfe, 2015).

Child labour

Fourteen econometric studies identified children working (including domestic labour) as a pathway through which climate change impacts education outcomes. These pathways are gendered (see Section 11.4.2) and consistent with findings from wider literature that has found an association between environmental shocks, including climate variability, and child labour (Eze et al., 2024).

Eight studies examined the impact of rainfall variability on child labour as a pathway to education outcomes, and found several different patterns. Where a rainfall shock increases agricultural yields, it may increase demand for child labour and reduce attendance or enrolment, as found for boys in rural Ethiopia (Falaris, 2023). In rural India higher wages resulting from increased rainfall led to 5–16-year-olds being 1 percentage point more likely to report working as their primary activity and 2 percentage points less likely to report attending school as their primary activity relative to a drought year (Shah and Steinberg, 2017). Increased rainfall can also lead to less pressure on children to work as a result of greater household income, as found for example in Ethiopia by Colmer (2021) and by Falaris (2023), for girls only.

Where rainfall variability reduces yields this could lead to children working to contribute to household income, or taking on more domestic work. For example, a study in rural Uganda found reduced rainfall increased children's engagement in wage work by approximately 1% – while school attendance during periods of reduced rainfall decreased by 12.5% (Agamile and Lawson, 2021).

Reflecting long-term impacts of exposure to reduced rainfall, one study in Burkina Faso related reduced rainfall before birth to lower cognitive abilities and increased participation in domestic labour (Akresh et al., 2012).

Theoretically, reduced rainfall could also lead to increased attendance at school in the absence of work opportunities. None of the studies of rainfall variability reported this pattern, but one study of drought, discussed below (Nordstrom and Cotton, 2020), did so. Several studies also found considerable variation in the extent to which child labour contributed to impacts on education outcomes, by children's gender, by the direction of rainfall shock (reduced or increased rainfall) and by agro-ecological zone, and the labour intensity of key farming activities (e.g. Dasgupta and Karandikar, 2021).

Fourteen studies examined the effect of more extreme shocks: floods, droughts and cyclones. All but one of these found that these shocks increased child labour, which in turn affected educational outcomes. For example, flood exposure in Pakistan increased the likelihood of children engaging in child labour by 7.4 percentage points (Khan and Hussain, 2023). Examining prolonged water shortages in Brazil, Branco and Féres (2018) found that every additional drought shock that a child is exposed to per year increased their likelihood of working by 4.24%, contributing to reduced student achievement. In the Philippines, children missed school more often after exposure to a typhoon, probably as a result of increased time spent helping at home (Deuchert and Felfe, 2015). A study of 15 Latin American and Caribbean countries also found intergenerational effects: if a child's mother was exposed to a cyclone when of school age, there was an increased likelihood of a child working (Caruso, 2017).

Two studies of temperature change examined child labour as a possible pathway to education outcomes – in this case, grade attainment. One (of extreme cold) found no impact (Kraehnert and Groppo, 2018), while the other (of raised temperatures and rainfall variability) in rural Ethiopia found a marginal increase in girls' domestic labour and reduced likelihood of attending school associated with hotter, drier summers and springs (Randell and Gray, 2016). The only study that examined child labour as a possible reason for reduced middle school completion in Nepal following a wildfire found it was not a significant factor (Paudel, 2023).

Six studies found that climate-related shocks and stresses could reduce children's workloads. For example, a drought in Zimbabwe reduced demand for children's labour, leading to increased school participation (Nordstrom and Cotton, 2020), while increased rainfall could increase farm yields and household incomes, resulting in greater school enrolment and attendance in India (Shah and Steinberg, 2017).[92]

Five studies – covering drought, rainfall shocks, wildfires and extended severe snow and cold waves – did not find a link between climate shocks, paid or unpaid work and educational outcomes In these contexts, impacts on health or household expenditure on education played a greater role.

11.4 Other pathways

Beyond the pathways identified through this review, the broader literature also highlights other climate-linked mechanisms that could potentially impact education and learning outcomes.

Droughts increase water insecurity, which in turn has particularly important implications for infant growth and development. For example, lactation intensifies the need for water to maintain hygiene and breast milk production, which could be associated with dehydration. In a study of children aged five to 18, relative wealth, gender, age, distance from water source and children's involvement in household water collection were associated with increased school absence (Dreibelbis et al., 2013).

Climate-related disasters triggered more than half of new reported displacements in 2022, and disasters triggered a record 32.6 million internal displacements, of which 98% were caused by weather-related hazards such as floods, storms, wildfires and droughts, according to the International Displacement Monitoring Centre (IDMC, 2023; Siegfried, 2023). Displacement is one of numerous consequences of disasters that force people to leave their homes and take up temporary or permanent residence elsewhere. Children, in particular, experience a range of reactions and difficulties coping with evacuation, displacement and relocation including post-migration stressors and PTSD, as well as social and cultural loss (Pfefferbaum et al., 2016). Moreover, children affected by climate change-related displacement and migration experience systemic and administrative, geographical, economic, sociocultural and legal barriers (Nielsen and Allen, 2021) that could hinder their ability to learn and access schooling. However, no econometric study examined the impact of this pathway, with only three studies (Imberman, Kugler and Sacerdote,

92 Other studies finding enhanced educational outcomes in the context of climate shocks and stresses include: Colmer (2021), Dasgupta and Karandikar (2021), Falaris (2023) and Randell and Grey (2016). These positive impacts on education sometimes varied by agro-ecological zone, season or gender of child.

2012; Efobi, 2022; Jing et al., 2024) mentioning in passing the potential role of displacement in affecting educational outcomes.

From a financial perspective, longer winters can put substantial stress on public spending. According to the World Bank, in 2004 18% of Mongolia's national education budget was spent on heating schools and dormitories (World Bank, 2006). During the exceptional winter of 2009/2010, school authorities report a large proportion of their school budget on fuel for heating, severely restricting funding for other essential education needs like school textbooks and updating infrastructure (Lawrie and Dandii, 2010). More frequent harsh winters and longer cold seasons (as reported by communities and suggested by some climate models) will likely place an additional burden on financial resources (UNICEF, 2019b).

11.5 Heterogenous effects

Social inequalities exacerbate vulnerability to the effect of climate change (Otto et al., 2017; IPCC, 2022). This section synthesises insights on the heterogenous effects of climate hazards on educational outcomes, focusing on differences by age, gender and socioeconomic status.

Age

Twenty-three econometric studies examined age-related impacts of exposure to climate hazards on children's educational outcomes, with some studies covering more than one hazard. Evidence is clustered around the prenatal period, early childhood and adolescence.

These studies were skewed towards rainfall shocks (12 studies) and floods (six studies), followed by temperature (five studies), droughts (five studies), cyclones (two studies) and wildfires (one study).[93]

Exposure in early childhood: Six studies compared the effects of exposure to climate shocks pre- and post-natally, while two compared impacts on young children (0–5-year-olds) and older children. A further 11 studies examined the effects of exposure to climate shocks prenatally or in infancy (without necessarily comparing between different age groups).

Exposure to climate shocks prenatally and in early childhood can significantly affect nutrition and cognitive development. Two studies on rainfall shocks found that increased rainfall during early life improved test scores and enrolment (Shah and Steinberg, 2017; Colmer, 2021), while two others found that decreased rainfall during this period was associated with delayed school entry and lasting learning deficits (Brando and Santos, 2015; Leight, Glewwe and Park, 2015). Nübler et al. (2021) found that, after age five, rainfall shocks generally had minimal or inconsistent effects on enrolment and cognitive scores, suggesting that early-life shocks carry the most persistent consequences.

Similar patterns were found for floods and droughts, where impacts on cognitive outcomes and schooling are largely concentrated in the prenatal period and the first two years of life (Brando and Santos, 2015; Abiona, 2017; Rosales-Rueda, 2018). For instance, floods only affected PPVT scores when children were exposed in- utero or at age two, while droughts during these early years delayed school entry and reduced cognitive development (Berhane, 2015; Efobi, 2022).

93 They add up to more than 23 because some studies reported multiple findings.

A study in Mongolia, Groppo and Kraehnert (2017), also found that *dzuds* (harsh winter shocks) disproportionately reduced the educational attainment of younger children, likely through nutritional stress in early life. For more detail on the ways that early exposure to climate shocks affect educational outcomes (see Bapna et al., forthcoming).

The six studies that compared impacts in early childhood found varied patterns by country, period of time after birth and educational outcome observed. However, all were consistent with the key finding that exposure to climate shocks prenatally and in infancy can detrimentally affect education outcomes.

Exposure during school years: Ten studies compared the impacts of climate shocks on different school-going- age groups, with considerable variation in the age groups studied. Of these, four studies examined impacts of cyclones and rainfall shocks on attendance or attainment. These studies found that older adolescents were at greater risk of drop-out and/or lower grade attainment (Caruso, 2017; Shah and Steinberg, 2017; Dessy, Tiberti and Zoundi, 2023), and that primary school students were at greater risk of reduced attendance (Agamile and Lawson, 2021).

Six studies examined impacts on learning outcomes in different age groups. In the US, younger students' test scores (grades 3–5) were more affected by heat stress than middle schoolers, likely due to physiological vulnerability and differences in school infrastructure (Park, Goodman and Behrer, 2020). Conversely, in Australia cold weather more strongly impacted adolescents' learning outcomes, potentially due to behavioural factors like wearing less protective clothing (Johnston et al., 2021). In the US, Morrill and Westall (2023) found that the test scores of middle school students were slightly more affected by hurricanes than those of elementary students, but that the effect was small. In Thailand, Thamtanajit (2020) found that floods impacted test scores most in grades 6 and 9, suggesting that transitions between school levels may also heighten vulnerability to shocks. This study also concluded that grade 12 students may have studied harder to mitigate the effects of shocks given the importance of their upcoming exams (Thamtanajit, 2020).

Two studies – both from India – also identified different types of impacts on different age groups. Dasgupta and Karandikar (2021) found that adolescents were more likely to drop out if affected by rainfall shocks (both floods and droughts), while primary school students remained in school but their test scores suffered. Shah and Steinberg (2021) found that younger students' cognitive skills were affected by rainfall shocks, whereas adolescents' school retention was particularly affected as they took up work opportunities.

Gender

A total of 35 papers investigated gender-based impacts of climate hazards on education outcomes. Of these, it should be noted that one was a study that solely looked at the impact on women. Efobi (2022) found droughts to be associated with reductions in educational attainment for women, but did not compare women's and men's attainment outcomes. The remaining 32 papers are accounted for in the tables below, with Table 16 distinguishing the number of studies that found girls were more impacted, boys were more impacted and where no difference was found within each education outcome, and within each hazard for Table 17.

Table 16 Distribution of studies examining gender differences

Who is affected?	Number of studies			
	Access[94]	Attainment	Learning	Totals
Girls more affected	7	3	4	14
Boys more affected	3	2	5	10
No difference	5	5	5	15

Table 17 Distribution of studies by gender impact and hazard

Hazard	Girls more affected	Boys more affected	No difference
Rainfall shocks	Falaris (2023) Dasgupta and Karandikar (2021) Björkman-Nyqvist (2013) Ferreira et al. (2024)	Colmer (2013) Chang et al. (2022)	Thai and Falaris (2014) Chang et al. (2022) Shah and Steinberg (2017)
Floods	Ahmed et al. (2022)	Ahmed et al. (2022) Carrillo (2020)	Ahmed et al. (2022) Caruso (2017)
Droughts	Abiona (2017) Dessy et al. (2023) Joshi (2019)		Dessy et al. (2023) Khalili et al. (2020) Joshi (2019) Randell and Gray (2016)
Cyclones	Deuchert and Felfe (2015) Jing et al. (2024) Raeburn (2023) Marchetta et al. (2019)		Abrigo et al. (2024) Deuchert and Felfe (2015) Lin et al. (2021) Morrill and Westall (2023)
Temperature	Park (2017) Vu (2022)	Johnston et al. (2021) Srivastava et al. (2024)	Arceo-Gomez and López-Feldman (2024) Dang et al. (2024) Groppo (2017) Randell and Gray (2016)
Wildfires	Paudel (2023)	Wu (2022) Lo Bue (2019)	Gibbs et al. (2019)

94 One of the studies that looked at the impacts of floods in Pakistan on school dropout rates found varied results based on different analyses of gender impacts overall, gender impacts within age groups, and gender impacts over time. As such it has been placed under all three categories of who is affected (Ahmed et al., 2022).

Access to education: Seven studies on access found that girls are more affected. In Malawi, drought shocks lead to greater school entry delays for girls than boys (Abiona, 2017). Another study looking at the impact of drought in Malawi and Indonesia found that, in patrilocal groups, drought increases the probability of school dropouts for girls, while in matrilocal groups there was no gender gap in dropout rates (Dessy et al., 2023). In terms of rainfall, in Ethiopia increased rainfall was associated with decreased attendance during harvest season, having a greater impact on girls having to support the household during the rainfall shocks (Falaris, 2023). In India, female dropout rates increased more than for males as a result of rainfall shocks in districts where girls participated more in paid labour or domestic work (Dasgupta and Karandikar, 2021). When investigating the impact of hurricanes in Jamaica, the results showed that, for girls, having more children in the household lowers the probability of attending school (Raeburn, 2023). Tropical cyclones in 13 countries[95] were associated with greater decreases in enrolment for girls (Jing et al., 2024).

One of the studies that looked at the impacts of floods in Pakistan on school dropout rates found varied results based on different analyses, with greater impacts on boys overall, no difference in impacts by gender within the age groups of 5–9 and 10–16, and greater impacts on girls in the long run due to factors such as school distance and parental permission (Ahmed et al., 2022).

Three studies on access found that boys are more affected. In addition to Ahmed et al., a study investigating rainfall variability in Ethiopia, the results showed that hours working on the farm increase for boys more than girls, leading to greater disruption in education access (Colmer, 2013). In Bangladesh, male labour was required for construction and repair after a cyclone, resulting in decreased education expenditures on boys (Mottaleb et al., 2015).

In addition to the findings from Ahmed et al. (2022) and Dessy et al. (2023), three other studies on access outcomes found no gender differences. A study on the Philippines showed that school closures caused by cyclones had similar impacts for boys and girls (Abrigo et al., 2024). Drought in Iran was found to have no significant gender differences in attendance rates (Khalili et al., 2020). Looking at the impacts of rainfall shocks in Vietnam, there was no difference in the years of entry delay between boys and girls (Thai and Falaris, 2014).

Educational attainment: Three studies on educational attainment found girls were more affected. In Brazil, girls' educational attainment was found to be more negatively impacted by extreme precipitation shocks (Ferreira de Lima et al., 2024). In Nepal, the reduction in middle school completion rate after exposure to a wildfire was greater among girls (Paudel, 2023). Lastly, when looking at the impacts of cyclones in the Philippines, the negative effects on educational attainment were more pronounced for girls in the short and medium term, with gender differences disappearing in the long term (Deuchert and Felfe, 2015).

Only one study on educational attainment found that boys were more affected. In Colombia, the impact of rainfall variability on years of schooling was three times greater for boys than for girls (Carrillo, 2020).

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95 Comoros, Madagascar, Mozambique, Cambodia, India, Indonesia, Pakistan, Philippines, Dominican Republic, Honduras.

In addition to Deuchert and Felfe (2015), four other studies on educational attainment found no difference in impacts on girls and boys. A study on multiple countries in Latin America[96] found the effect of disasters such as floods, landslides and cyclones to have the same impact on years of education for girls and boys (Caruso, 2017). Typhoons in China also showed no significant difference in the years of schooling between boys and girls (Lin, Liu and Xu, 2021). Looking at temperature in Mongolia, there was no gender difference on the impact of *dzud* (extreme winter) on educational attainment (Groppo and Kraehnert, 2017). In Ethiopia, the effects of climate variability (temperature, drought) on school completion did not differ by gender (Randell and Gray, 2016).

Learning outcomes: Four studies on learning outcomes found that girls were more affected. Looking at rainfall shocks in Uganda, results showed that girls' test scores decreased more than boys' from reduced rainfall, with older girls being impacted the most (Björkman-Nyqvist, 2013). Drought in India was associated with greater declines in reading scores for girls than boys; however, in the long term there were no gender-based differences (Joshi, 2019). In terms of temperature, in the US girls responded worse than boys to heat stress on exam days (Park, 2017a). In Vietnam, girls' maths scores declined more than boys when exposed to heat (Vu, 2022).

Five studies on learning outcomes found that boys were more affected. Increased rain in Colombia affected boys more positively than girls, leading to declines in illiteracy rates for boys, two times greater than the effect that was seen on girls (Carrillo, 2020). While rainfall shocks in India reduced cognitive scores for boys more than girls, there were no gender differences found for non-cognitive scores (Chang, Favara and Novella, 2022). On temperature in Australia, there was a greater decline in boys' test scores on cold days than girls' (Johnston et al., 2021). In Ethiopia, heat affected the test scores of boys more than girls (Srivastava, Tafere and Behrer, 2024). Wildfires in the United States showed greater declines in boys' ELA and maths scores, with greater long-term impacts on boys as well (Wu, 2022).

In addition to Chang, Favara and Novella (2022) and Joshi (2019), three studies on learning outcomes found no gendered differences. A study on extreme temperatures in Mexico found the same impact on test scores of boys and girls (Arceo-Gomez and López-Feldman, 2024). In the US, cyclone impacts had no gender difference in maths and reading scores (Morrill and Westall, 2023). Wildfires in Australia led to no gender differences in test scores (Gibbs et al., 2019).

Socio-economic status

Twenty-one studies examined heterogenous effects by socio-economic group. Tables 18 and 19 show the distribution by climate hazard and learning outcome. These indicate that, in approximately three-quarters of studies (16/21), poor students' educational outcomes were more severely affected than those of better-off students.

96 Argentina, Bolivia, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Haiti, Jamaica, Mexico, Nicaragua, Panama, Peru, Uruguay and Venezuela.

Table 18 Distribution of studies by students' socioeconomic background

	Number of studies			
Who is affected?	**Access**	**Attainment**	**Learning**	**Totals**
Poor more affected	9	2	10	16
Non-poor more affected	0	1	4	5
No difference	0	0	1	1

Table 19 Distribution of studies on learning outcomes by students' socioeconomic background and hazard[97]

Hazard	Poor more affected	Non-poor more affected	No difference
Rainfall shocks	3	2	0
Cyclone	5	0	1
Temperature	6	3	0
Wildfire	3	1	0

The studies reviewed identify or hypothesise the following impact pathways for greater educational impacts on more disadvantaged students.

Household investment in children: Four studies suggest that poorer households' lesser capacity to offset the effects of climate-related shocks may help explain heterogenous effects. Examining the long-term effects of a super typhoon (Mike) in the Philippines, Deuchert and Felfe (2015) found that, by age 22, young people from poor households who had been exposed to Typhoon Mike as children had almost a year's less educational attainment than their peers, double the impact on richer children. The authors attribute this gap to poorer households' lesser abilities to invest in children's education. Paudel (2023) suggests that poorer households' decreased ability to invest in school supplies contributed to their children's lower middle school completion rates following wildfires in Nepal. Studies of the effects of prenatal exposure to hurricanes in the US on high school graduation rates (Karbownik and Wray, 2019) and to rainfall shocks in India on cognitive skills draw similar conclusions.

Early workforce entry: Only two studies identified school drop-out to enter the workforce as a key factor explaining lower school enrolment (Agamile and Lawson, 2021) or attainment and learning (Marchetta, Sahn and Tiberti, 2019) among poorer students following, respectively, rainfall shocks in Uganda and flooding and cyclones in Madagascar. In the latter case, the authors identify earlier transition to the workforce as a factor explaining lower grade attainment following rainfall and cyclone shocks, and reduced attendance (itself also potentially work-related) as explaining reduced learning outcomes.

97 Numbers add up to more than 20 because one study reported on the effects of two hazards, and because one study reported effects on both the poorest and the best-off children.

Thermal comfort: Two studies from the US that identified socio-economic differentials in learning outcomes associated with high temperatures identify access to air conditioning as a key factor. Lower prevalence of air conditioning/ adequate ventilation in poorer students' homes and in schools, which reduces students' ability to concentrate on schoolwork, may explain the additional negative impacts of heat on poorer students (Park, Goodman and Behrer, 2020; McCormack, 2023). Examining the effects of extreme heat on grade attainment outcomes in Brazil, Costa and Goldemberg (2024) attribute lower levels of school completion among urban public than private school students to differences in resourcing, including for ventilation and air conditioning. One other study from the US found no differences in how far heat affected poorer students' test scores (Park, 2017a).

Other explanations: Two studies identify other explanations: poorer students' increased difficulties in accessing school during snowy weather (compared to better-off students whose families are more likely to own cars) (Goodman, 2014). Two studies suggested greater exposure to hazards as an explanation for heterogenous effects. Studying the impact of heavy rains, flooding and landslides in Colombia in 2010, Valencia Amaya (2020) looked at outcomes of the *Pruebo Saber 11* end of high school assessment test. He found that differential damage to schools in better-off and poorer areas was an important factor explaining these differences in outcomes. Greater proximity to wildfires among more disadvantaged households may also help explain their greater effects on poorer children's test scores in the US (Wen and Burke, 2022).

Greater impacts on better-off students: The two studies that found better-off children's educational outcomes to be more severely affected both examined the long-term impacts of exposure to climate hazards prenatally and in early childhood (Brando and Santos, 2015; Randell and Gray, 2019). In Colombia, Brando and Santos found that cognitive outcomes of children of better-off households exposed to unusually heavy rainfall in their second year of life were negatively affected, unlike those of poorer counterparts. Similarly, Randell and Gray's 29-country studies identified greater potential reductions in completed years of schooling for children with more educated parents (a proxy for income), exposed to raised temperatures and drier conditions in early childhood. In both cases, the authors hypothesised that parents were unable to make expected investments in their children, leading to expected educational gains not materialising.

12 Interventions

Key points

- The 17 econometric and four additional quantitative studies that examined the impacts of measures to promote learning resilience are skewed towards livelihood initiatives (10 studies) and infrastructure (six studies). This may reflect the greater availability of quantitative data in these areas.
- Social protection measures such as cash transfers and employment guarantees help protect children's access to education and learning outcomes in the context of droughts and floods. For cash transfers, the evidence is variable across contexts, and gains are relatively small though statistically significant (four out of six studies). All five studies of employment programmes found that they helped protect learning outcomes.
- Reducing temperatures – by various methods – to a comfortable range is associated with learning gains (two studies). Using resilient building materials, school water storage and enhancing overall access also help protect learning resilience in drought-, flood- and cyclone-affected contexts (one study each).
- Only one quantitative study of remote education after a climate-related disaster was found. This found that weekly phone calls helped protect student learning, but that SMS nudges were ineffective.
- Schools and education systems are making a range of adjustments to cope with climate-related impacts. These include scheduling changes to avoid particularly hot or cold periods, implementing passive solar reduction measures (e.g. blinds, shading), enhancing ventilation, nature-based solutions such as water conservation and increasing vegetation in school environments, and deploying remote learning following a disaster.
- There is little evidence of MHPSS provision after disasters – the few examples found were all from high-income or upper middle-income countries in the aftermath of a cyclone or wildfire. No rigorous quantitative studies (and few qualitative studies) were found for any of these approaches.

12.1 Overview of intervention studies

Effective action to protect learning resilience is a fundamental part of strengthening societies' overall resilience to climate change: higher levels of education are associated with reduced vulnerability. Adapting education systems for greater resilience requires policy-makers to act on four fronts: (i) education management for resilience; (ii) school infrastructure for resilience; (iii) ensuring learning continuity in the face of climate shocks; and (iv) leveraging students and teachers as change agents (Venegas Marin, Schwarz and Sabarwal, 2024b). This section draws on systematic or comprehensive reviews of approaches to protecting learning in the context of climate change, such as Haßler et al. (2024), Nusche, Fuster Rabella and Lauterbach

(2024) and Venegas Marin, Schwarz and Sabarwal (2024a). For each of the intervention areas identified, there is a large wider literature beyond the scope of this study with insights of potential relevance. For example, there is an extensive literature on school ventilation and cooling strategies, which may contain pointers for education systems in low- and middle-income countries. Some of this is summarised by Haßler et al. (2024). Cumulative learning from the education in emergencies (EiE) literature likewise helps extend and nuance some of the insights presented here, particularly on alternative education programming. Where possible, this section draws on insights from this literature. However, a full review of relevant EiE literature was outside the scope of this study.

The body of literature examining the impact of policies, programmes and initiatives on mediating pathways (e.g. classroom temperature, teacher or student wellbeing) is larger than that considering impacts on education outcomes. The studies of impacts on learning outcomes found for this review focus largely on infrastructure (four studies) and a range of measures to promote continuity of learning, including poverty reduction (11 studies) and remote learning programmes (one study). This distribution may reflect the availability of existing quantitative data in these areas. Tables 20 and 21 outline the distribution of the 17 quantitative impact studies and four additional studies found. It is notable that no studies of initiatives to protect learning resilience in the context of wildfires or windstorms were found.

Table 20 Distribution of econometric intervention studies[98]

Intervention area	Intervention type	Number of studies	Distribution
Poverty reduction	Cash transfers	6	Colombia, Jamaica, Mexico, Peru, Vietnam,
	Employment guarantee	4	Ethiopia, India
	Food support	2	Malawi, India
	Multi-component	1	Bangladesh
Infrastructure	Air conditioning and ventilation	1	US
	Resilient buildings, school construction and water storage	3	Philippines, Indonesia, Brazil
Teaching and learning	Curriculum	1	China
	Remote learning	1	Philippines

98 Some studies covered multiple interventions.

Table 21 Distribution of intervention studies by climate hazard

Hazard	Number of intervention studies	Distribution[99]
Temperature	6	Costa Rica, China, England, India, US
Cyclone	4	Jamaica, Philippines, Taiwan
Rainfall shocks, including floods and droughts	12	Bangladesh, Brazil, Colombia, Ethiopia, India, Indonesia, Malawi, Mexico, Peru, Vietnam

12.2 Poverty reduction initiatives[100]

Cash transfers

Six studies examined the effects of conditional cash transfers on protecting educational resilience. All but one focused on protecting children's education from the effects of excessive rainfall or droughts. One examined their education impact after a cyclone.

Four of the six studies of cash assistance found that it had a positive effect on protecting educational outcomes but that the strength of this effect varied. Adhvaryu et al. (2023) examined the effects of the PROGRESA cash transfer on children and young people aged 12–18 whose year of birth was affected by rainfall shocks[101] in rural Mexico. They found that receipt of the PROGRESA transfer was associated with smaller reductions in grade attainment, post-secondary enrolment and employment outcomes than for matched students of similar socio-economic background and geographic locations. The impacts of PROGRESA transfers on alleviating the impacts of droughts were slightly greater than for floods. However, Aguilar and Vicarelli (2022), studying participants in an earlier phase of PROGRESA, found no significant effect of the cash transfer in protecting children's cognitive outcomes in the context of rainfall shocks.

Studying the interactions between the effects of conditional cash transfers and floods and droughts in Colombia, Duque, Rosales-Rueda and Sanchez (2018) found that transfers received in early childhood had a greater protective effective on school enrolment and retention than those received in adolescence. Though the effects of these transfers on children not affected by weather shocks were greater, the *Familias en Acción* transfers offered effective protection, particularly for young children. Pazos et al. (2024), examining the effects of Peru's *Juntos* conditional cash transfer, similarly found protective effects on the foundational skills[102] of children aged under five when their households received the transfer. The evidence was suggestive, rather than

99 For some countries (e.g. Ethiopia, India, Mexico, the Philippines, Peru and the US) there were multiple studies.

100 One other study found that assistance to flood-affected households had no impact on children's learning in Ethiopia (Hyder and Behrman, 2016). This is not included in the discussion in this section as the type of assistance is not specified.

101 Defined as one standard deviation above or below the mean rainfall for that area. The study used data from a survey undertaken in 2003.

102 These were measured by studying evidence on four aspects of executive function.

conclusive, and like the other transfers, there was some protective effect on learning losses related to both an excess and a deficit of rainfall. Transfers received later in childhood did not have the same protective effect, which the authors hypothesise reflects their additional value in the sensitive period of early childhood.

A study from Jamaica found that the PATH cash transfer did not appear to protect children's school enrolment or attendance following Hurricane Ivan in 2004, as there were no significant differences in the responses of recipients and non-recipients (Raeburn, 2023). Finally, one study – Zamand and Hyder (2016) – examined the contribution of cash transfers in Vietnam to protecting children's educational enrolment against drought and floods. Because these hazards had little impact on school enrolment, the protective role of cash transfers was negligible. The protective nature of cash transfers against climate shocks thus appears to be context- and age- dependent, and likely to vary with the scale of the transfers, and the impacts of the shock on livelihoods.

Employment guarantee programmes

Four studies examined the potential effects of household participation in employment guarantee programmes on protecting children's educational outcomes from the effects of droughts or excess rainfall. Three focused on Ethiopia's Productive Safety Net Programme (PSNP).[103] One examined the effects of India's National Rural Employment Guarantee Act (NREGA). All four found that employment programmes protected learning outcomes.

The three studies of the potential protective effect of Ethiopia's PSNP, spanning a period of 14 years, all drew on Young Lives data and all assessed the impacts on cognitive skills. The earliest – Berhane (2010) – which drew on the first three rounds of data collection, found that household participation in the PSNP alleviated the negative impact on cognitive skills associated with droughts by 0.18 standard deviations. The second, Zamand and Hyder (2016), which drew on data for children who were 14–16 in 2009, found that, in the context of droughts and floods, PSNP participation only had a protective effect on cognitive skills as measured by the PPVT test. Freund et al. (2024), whose study drew on data collected in 2013/4 (Round 4), found that PSNP participation was associated with enhanced long-term memory among children who experienced at least one rainfall shock (drought or flood) in their first year of life.

Garg, Jagnani and Taraz (2020) examined how far households' participation in NREGA attenuated the effect of hot temperatures on children's maths and literacy outcomes in India. They found that household members' NREGA participation attenuates the effect of an extra hot day above 21°C in the prior calendar year on maths and reading scores by more than 50%.

Additionally, one combination study examined the impacts of a multi-component programme aiming to build resilience to floods in Bangladesh – the Saemauel Zero Hunger Communities (SZHC) project implemented in 19 villages particularly vulnerable to flooding and river erosion. The project combined employment on public works, training, cash grants and community infrastructure-building, aiming both to boost

103 The primary safety net mechanism offered by PSNP is participation in public works programmes with a small proportion (unspecified) of households receiving support via cash and food transfers (Freund et al., 2024).

household livelihoods and strengthen community infrastructure to better withstand floods. Following the project, absence levels for primary school students were a statistically significant 5.4 times lower in participant households than in control households (Park and Ochieng, 2024).

Food support

Two studies examined the potential effects of food support on reducing the negative impacts of climate-related shocks. In Malawi Staffieri et al. (2023) found some evidence that access to a school feeding programme was associated with moderate increased enrolment among older children (aged 12–17) whose households experience anomalously low rainfall, as compared to those without access to a school feeding programme. The authors hypothesise that the school feeding programme may have helped both boys and girls remain in school rather than dropping out to participate in the labour market. By contrast, in India, Zamand and Hyder (2016) found that access to the Public Distribution System had no impact in protecting children's learning (as measured by two cognitive tests) from rainfall and drought shocks. They attribute this lack of effect to problems of programme implementation and coverage. These findings are consistent with those of Agamile and Lawson (2021), who found in Uganda that school meals helped protect children's attendance in the context of rainfall variability.

12.3 Infrastructure initiatives

Rigorous quantitative evaluations examining impacts of infrastructure initiatives on learning outcomes were available for air conditioning, building with resilient materials and building more schools (to protect against distance-related drop-out). The discussion in this section focuses on this sub-set of studies. Most of the studies examined for this review only examine the effect of an initiative on improved school conditions, such as reduced temperatures in hot weather, and so their potential impacts on learning outcomes are hypothesised, rather than demonstrated.

Temperature regulation

As discussed in Section 8, most studies agree that the negative effects of raised temperatures on learning outcomes largely arise through effects on students' comfort and ability to concentrate.

In this context, two of the additional studies – from Costa Rica and the US – investigated the impact of increased classroom ventilation and air cooling. Porras-Salazar et al. (2018) tested the impact of air conditioning in an elementary school in Costa Rica, studying the impacts on performance of mathematical, language-based and logical thinking tasks for 11-year-olds. They found that lowering the classroom temperature to 25–27°C from 30°C enabled all children to perform language and logical-thinking tasks significantly more quickly, while the less able pupils performed better on all tasks at the lower temperature. There were no significant effects on accuracy, nor were impacts on maths outcomes statistically significant.

Examining elementary schools in the south-western US, Haverinen-Shaughnessy and Shaughnessy (2015) found that increased ventilation[104] was associated with an increase in students' mean mathematics scores of 0.5%, and a similar, but slightly smaller, effect associated with each 1°C decrease in temperature within the 20–

104 The study examined the effects of increasing ventilation within the range of 0.9–7.1 l/s per person.

25°C range. The study also found effects of similar magnitude but higher variability for reading and science scores.

It is important to note that electrically powered cooling systems may not necessarily be reliable in contexts of unstable electricity supply (e.g. where load shedding is practised).

Box 9 Potential impact of ventilation

Based on data from primary and secondary schools in three English climatic regions, Dong et al. (2024) ran a series of simulations and found that increasing ventilation rates to around 8 l/s[105] per person was effective in reducing loss of cognitive performance, but that effectiveness would diminish with higher classroom air temperatures (above 21°C). Increasing air conditioning would offset this learning loss at higher temperatures. As noted in Section 8, air conditioning has a strong protective effect against the learning loss associated with hot weather: in their study in the US, Park et al. (2020) found that learning losses in fully air-conditioned schools were only one-fifth of the losses in schools with no air conditioning. However, increasing air conditioning can exacerbate climate change because of its huge demands for energy and can increase inequalities by leading to increased external air temperatures in areas with high uptake, worsening the heat exposure of people who cannot afford air conditioning (Graff Zivin and Shrader, 2016).

Infrastructure for access and resilience

Three studies examined the impact of infrastructural initiatives to protect learning resilience in regions vulnerable to typhoons, floods or droughts. The Typhoon-Resistant Secondary School Building and Instructional Equipment Program (TRSBP) in the Philippines deployed prefabricated classrooms and science labs made of typhoon-resistant technology, leading to the construction of 252 schools with 902 classrooms and 153 science labs. Studying its impact, Herrera-Almanza and Cas (2021) found that the programme almost entirely mitigated the negative effects of typhoons on educational attainment. Children who studied in schools with this improved infrastructure were also more likely in adult life to work in a high-skilled occupation (not defined), in a non-agricultural sector, and to migrate internationally. As discussed in Section 6, having school water storage systems mitigated the effects of droughts on learning outcomes in north-east Brazil (Branco and Féres, 2018).

A study of a programme in Indonesia (INPRES) that accelerated primary school construction also points to the potential of school infrastructure strengthening to alleviate the effects of climate-related shocks. Banerjee et al. (2025) found that attending a school that had been constructed under the INPRES programme enabled children's grade attainment to recover completely from an early-life rainfall shock. The effect did not persist past the end of primary school, which the authors attribute to increased competition for middle and high school places.

105 Litres per second is a standard measure of ventilation rates.

12.4 Teaching and learning initiatives

Curriculum

Two studies (one econometric, one other) examined the impacts of curriculum changes to promote disaster resilience or healthy behaviour during a climate-related shock. Studying a typhoon awareness curriculum (of 100 minutes delivered over two units) for secondary school students in Taiwan, Chang and Chang (2010) found increases in students' learning achievement and more positive attitudes towards taking action to reduce typhoon hazards. The study found that group discussions were particularly effective. Li et al. (2022), studying a heat awareness curriculum in two primary schools in Jiangsu, China, found that it enhanced knowledge of safe and healthy behaviour during heatwaves. Li et al. also found that participatory and experiential activities were particularly effective in enhancing parents' and students' knowledge, attitudes and practices related to staying healthy in hot weather. These insights are consistent with established findings about the role of education in managing and reducing specific risks and the pedagogical value of participatory and experiential learning (Mutasa and Coetzee, 2019; Xerri et al., 2024).

Recommendations for building resilience to climate change also highlight the importance of adapting curricula to build awareness of different aspects of climate change and skills for adaptation and mitigation (Kagawa and Selby, 2024; Venegas Marin, Schwarz and Sabarwal, 2024b). However, as Pankhurst (2022) points out, the evidence around the impact of such changes is limited – this may be because typically the effects of curriculum change would be seen in the medium term and would not be identified by studies of learning outcomes. Similarly, the evidence base for the impact of enhancing teacher and student agency on learning that can reduce climate hazards is limited. However, both disaster risk reduction studies and the wider pedagogical literature point to the importance of this approach (Aghaei, Seyedin and Sanaeinasab, 2018; Xerri et al., 2024).

Remote learning

One study investigated the potential of different ways of delivering education to promote continued learning in the context of climate-related shocks. In the Philippines Angrist et al. (2023) examined the impact of phone call tutorials and SMS messages in maintaining learning after a typhoon. The SMS messages included numeracy content and nudges to engage in educational activities. Phone calls were provided once a week for 20 minutes over an eight-week period covering foundational numeracy, and aimed to target instruction to student learning levels via low-cost, high-frequency assessments. The study found that phone tutorials were effective in keeping students on track, but SMS messages alone were not enough to stem learning losses. Findings align with EdTech research indicating that high-touch, low-tech interventions may be most cost-effective (Global Education Evidence Advisory Panel, 2020).

12.5 Other adaptation measures

Potential interventions for improving the resilience of education systems to climate change are outlined in Table 22. These are drawn from literature that typically examines the effectiveness of an approach on a mediating factor (e.g. thermal comfort, access to water in schools) but does not directly link findings to impacts on learning outcomes.

Table 22 Promising approaches emerging from intervention-focused reviews

Approach	Examples
Passive solar reduction	Painting roofs white (Alwi et al., 2022; Baba et al., 2023)
	Reducing window to wall ratio, enhancing window overhangs for shading, blinds, night ventilation (Al-Yasiri and Szabó, 2021; Gómez et al., 2021; Alwi et al., 2022; Baba et al., 2023; Sanz-Mas et al., 2024).
Nature-based solutions	Increasing vegetation around schools (Bangay, 2023)
	Green roofs, tree planting (Gómez et al., 2021; Kazemi et al., 2021)
School scheduling changes	Starting the school day earlier in summer and later in winter (Kagawa, 2022f; Chigwanda, Mutopo and Mutanana, 2023; Lala and Hagishima, 2023; Preña and Labayo, 2024).
	Limiting outdoor play and exercise and making greater use of indoor and shaded areas (Lala and Hagishima, 2023)
	Scheduling hydration breaks (Preña and Labayo, 2024)
Dress codes	Allowing students to dress more comfortably in hot or cold weather (Chigwanda, Mutopo and Mutanana, 2023; Lala and Hagishima, 2023)
Water conservation measures	School-level water infrastructure maintenance (Booysen, Ripunda and Visser, 2019)
Installing renewable energy systems	Incentives or support for schools to install solar power for lighting, cooling and water purification systems and/or to enhance energy efficiency (Aguilar-Jiménez et al., 2020; Nusche, Fuster Rabella and Lauterbach, 2024; Moner-Girona et al., 2025)
Changing building codes to enhance resilience	Use of cyclone or fire-resistant materials; zoning designated 'defensible areas'; elevating buildings and installing/improving guttering to reduce flood risk (Nusche, Fuster Rabella and Lauterbach, 2024; World Bank, 2025)
School-based MHPSS	Providing support/counselling post-disaster (Nusche, Fuster Rabella and Lauterbach, 2024); strengthening socio-emotional learning and children's social support networks (Kagawa and Selby, 2024)

13 Conclusion

The resilience of education systems can be enhanced through ensuring they are integrated with national and local climate forecasting and strategic foresight systems (Nusche, Fuster Rabella and Lauterbach, 2024). This is vital to allow for anticipatory action that reduces the impact of climate-related stresses and events – as, for example, temporary cash transfers to help families cope with the effects of drought (Kagawa and Selby, 2024). In the absence of funding for more comprehensive or effective measures to deal with the impacts of climate change on education and learning, schools often improvise solutions to protect children. For example, schools can change class schedules, and allow for greater flexibility with dress codes, or keep children indoors to manage temperature increases. Studies from India and the Philippines highlighted the limitations to these measures (Lala and Hagishima, 2023; Miranda et al., 2024). However, for ensuring learning continuity and access, the broader challenges affecting already under-resourced education systems also need to be addressed.

13.1 Research gaps and policy recommendations

Climate change threatens to reverse decades of progress in educational attainment and equity across LMICs. This review demonstrates that climate-induced hazards – whether acute (cyclones, floods) or chronic (droughts, heatwaves) – have measurable, often disproportionate effects on access, learning and attainment, particularly for marginalised children. Yet education remains peripheral to climate adaptation policy and financing priorities. Effective adaptation requires recognising education not just as a sector impacted by climate change, but as a foundational pillar of societal adaptation and resilience. As both a right and a public good, education must be protected, adapted and mobilised to confront the climate crisis. In order to do so, we propose the following research directions and policy recommendations.

13.2 Research gaps

Regional gaps on the educational impacts of specific hazards: This review finds considerable geographical variation in the distribution of studies discussing the educational impacts of specific hazards. The US studies mostly discuss temperature and thermal discomfort and hurricanes, while studies from Asia have a slightly greater emphasis on temperature and floods. Many of the African studies focus on rainfall variability and droughts, while those from Latin America and the Caribbean span all the hazards examined. While this distribution could be indicative of the kinds of hazards impacting education systems in different regions, it may also be skewed based on data and resource availability.

Meta analyses: Apart from the effects of temperature, meta analyses across other hazards are a critical research gap. Such an analysis currently faces the challenge of comparative analysis across educational outcomes as the studies are distributed across learning and access and attainment outcomes.

Further analysis of pathways by which climate change affects educational outcomes: While impacts on infrastructure and livelihoods are relatively well-documented, mediators such as mental health and teacher wellbeing are

understudied in the context of climate change and education. Only a few high-income country studies address mental health and psychosocial support in post-disaster contexts (Brown et al., 2021; Cannon, Davis and Long, 2023), with near-absence in LMIC-focused research.

Long-term impacts: A key insight from this review is the strong association between early childhood climate shocks (especially in utero and the first two years) and long-term education outcomes (found in 14 studies). However, few studies trace educational trajectories across the life course or explore compounding effects of multiple shocks.

Specific learning outcomes: Most studies of learning outcomes discuss impacts on maths or literacy/language competence (34 and 31 studies respectively), and general cognitive skills (18 studies). Few studies (five) examine the effects on socioemotional learning. Within the cluster of studies on temperature and learning outcomes, which are most consistently disaggregated by subject, there are some indications that maths learning is particularly affected (five out of 10 studies). This merits further investigation across hazards, and if more widespread may indicate a particular need for targeted additional catch-up or strengthening maths education as a preventative measure.

Marginalised groups: Consistent with a wide literature on social vulnerability to climate change, the review found that the educational outcomes of socially marginalised groups of children (e.g. poor, racially minoritised) were disproportionately affected. Thirty-three econometric studies investigated gender-based impacts. Fourteen found girls were more affected, eight found boys were more affected, and 16 found no gender-based differences. The total among these categories equates to more than 33 as some studies found mixed gender results dependent on other factors such as time and age. Only one econometric study and two qualitative studies examined impacts on children with disabilities; only one study made specific mention of gender diversity; only two econometric studies discussed the experience of climate-related displacement on children's educational outcomes. Greater disaggregation in future studies would help illuminate the specific pathways and challenges in supporting the education of marginalised groups of children in the context of particular climate hazards and events.

Interventions: Given the scale and urgency of the climate crisis, urgent research is needed to ensure education access and quality are maintained. We found only 20 rigorous studies that examined education-focused interventions to promote learning resilience. These were skewed towards livelihood interventions, probably reflecting the availability of data. There is an urgent need for studies that examine the whole 'impact chain' from intervention impacts on a mediating factor through to learning outcomes. (For example, studies examining the effectiveness of passive cooling options not only on classroom temperatures but also on educational outcomes.) The absence of such evidence limits options for effective policy-making.

13.3 Interventions and policy recommendations

Despite limited causal evidence, a range of intervention types show promise in strengthening education system resilience to climate shocks.

Social protection: Conditional cash transfers and employment guarantee programmes offer moderate protection for education outcomes in

climate-affected settings. For instance, Mexico's Progresa/Oportunidades programme and Colombia's Familias en Acción mitigated rainfall shock effects on enrolment and attainment (Duque, Rosales-Rueda and Sanchez, 2018; Adhvaryu et al., 2023). Though the available evidence suggests they play a particular role in protecting younger children's education outcomes, as effects can persist throughout childhood,[106] transfers may need to cover both young and school-age children. Both employment programmes examined – Ethiopia's PSNP and India's NREGA – reduced the learning impacts of heatwaves (Garg, Jagnani and Taraz, 2020) and rainfall shocks (Freund et al., 2024). They thus show moderate promise in reducing the impacts of climate change on educational outcomes in rural areas in low- and lower-middle income countries.

Infrastructure resilience and temperature regulation: Air conditioning, improved ventilation and passive cooling measures (e.g. roof painting, tree planting) consistently improved classroom learning conditions and outcomes in both high-income and low- and middle-income countries (Haverinen-Shaughnessy and Shaughnessy, 2015; Park et al., 2020). Infrastructure interventions like the typhoon-resistant school programme in the Philippines mitigated long-term typhoon effects on attainment and labour market outcomes (Herrera-Almanza and Cas, 2021). More evidence of the impact of such programmes is needed.

Remote and accelerated learning: Evidence for technology-enabled or alternative education models post-disaster is limited. However, a study in the Philippines showed that weekly phone call tutorials post-typhoon significantly reduced learning losses (Angrist et al., 2023). Findings align with EdTech research indicating that high-touch, low-tech interventions may be most cost-effective.

School feeding and nutrition: School meal programmes provided buffers against drought-induced dropout in Malawi (Staffieri, Sitko and Maluccio, 2023) and supported older children's continued enrolment. These programmes act via improved household food security and motivation to attend school. These findings are consistent with wider evidence on school feeding programmes, which does not refer specifically to the context of climate change.

Curricula and teacher engagement: Curricular initiatives such as climate awareness modules (Chang and Chang, 2010) showed more-informed attitudes and greater knowledge, though evidence on actual education outcomes remains limited. Similarly, teacher-led adaptation initiatives (e.g. schedule changes, hydration breaks) are frequently used but poorly evaluated and need further research.

Cost issues: It has been challenging to map the cost implications of climate change on education. The Global Partnership for Education (GPE) and Save the Children map the different cost implications of building climate-smart education systems. Only 2.4% of climate finance disbursed between 2006 and 2023 from four key multilateral climate funds has been found to support projects incorporating child-responsive activities, with education-specific projects being negligible (Munnelly, Tammi and Martinez, 2023). Despite growing evidence on the impacts of the climate crisis on access to education and learning

106 For example Nübler et al. (2021) found that the effects of drought on educational expenditure can persist for 10 years, hence the need for longer-term support.

outcomes, there is a clear gap in identifying the additional costs the climate crisis imposes on education systems. There is a large body of evidence from Disaster Risk Reduction (DRR) and preparedness which can be used as a proxy for climate-induced disasters to a certain extent. Together, this body of evidence emphasises the need to strengthen education systems, including the education workforce, to support the delivery of quality climate change adaptation strategies.[107]

107 Some relevant frameworks are outlined in Appendix 3.

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Appendices

Appendix 1 Further methodological details

Table A1.1 Search strings used

DROUGHT
TITLE-ABS-KEY((Drought OR "water scarcity") AND impact AND (school OR education OR learning)) AND PUBYEAR > 2009
TITLE-ABS-KEY((Drought OR "water scarcity") AND impact AND school AND access) AND PUBYEAR > 2009
TITLE-ABS-KEY((Drought OR "water scarcity") AND impact AND school AND (enrolment OR attendance OR absenteeism)) AND PUBYEAR > 2009
TITLE-ABS-KEY((Drought OR "water scarcity") AND impact AND school AND (dropout OR completion)) AND PUBYEAR > 2009
TITLE-ABS-KEY((Drought OR "water scarcity") AND impact AND ("school performance" OR "school attainment" OR "exam scores" OR "exam pass rate")) AND PUBYEAR > 2009
TITLE-ABS-KEY((Drought OR "water scarcity") AND impact AND (numeracy OR math*)) AND PUBYEAR > 2009
TITLE-ABS-KEY((Drought OR "water scarcity") AND impact AND (literacy OR reading OR writing)) AND PUBYEAR > 2009
TITLE-ABS-KEY((Drought OR "water scarcity") AND impact AND digital skills) AND PUBYEAR > 2009
TITLE-ABS-KEY((Drought OR "water scarcity") AND impact AND (Life OR transferable OR "21st century" OR foundational) AND skills) AND PUBYEAR > 2009
TITLE-ABS-KEY ((Drought OR "water scarcity") AND impact AND ("cognitive skills" OR "cognition")) AND PUBYEAR > 2009

HEAVY RAINFALL
TITLE-ABS-KEY((Extreme OR heavy) AND (rainfall OR precipitation) AND impact AND (school OR education OR learning)) AND PUBYEAR > 2009
TITLE-ABS-KEY((Extreme OR heavy) AND (rainfall OR precipitation) AND impact AND school AND access) AND PUBYEAR > 2009
TITLE-ABS-KEY((Extreme OR heavy) AND (rainfall OR precipitation) AND impact AND school AND (enrolment OR attendance OR absenteeism)) AND PUBYEAR > 2009
TITLE-ABS-KEY((Extreme OR heavy) AND (rainfall OR precipitation) AND impact AND school AND (dropout OR completion)) AND PUBYEAR > 2009
TITLE-ABS-KEY((Extreme OR heavy) AND (rainfall OR precipitation) AND impact AND ("school performance" OR "school attainment" OR "exam scores" OR "exam pass rate")) AND PUBYEAR > 2009
TITLE-ABS-KEY((Extreme OR heavy) AND (rainfall OR precipitation)' AND impact AND (numeracy OR math*)) AND PUBYEAR > 2009
TITLE-ABS-KEY((Extreme OR heavy) AND (rainfall OR precipitation) AND impact AND (literacy OR reading OR writing)) AND PUBYEAR > 2009
TITLE-ABS-KEY((Extreme OR heavy) AND (rainfall OR precipitation) AND impact AND "digital skills") AND PUBYEAR > 2009
TITLE-ABS-KEY((Extreme OR heavy) AND (rainfall OR precipitation) AND impact AND (Life OR transferable OR "21st century" OR foundational) AND skills) AND PUBYEAR > 2009
TITLE-ABS-KEY ((Extreme OR heavy) AND (rainfall OR precipitation) AND impact AND ("cognitive skills" OR "cognition")) AND PUBYEAR > 2009

Table A1.1 Search strings used (continued)

FLOODING
TITLE-ABS-KEY(Flood* AND impact AND (school OR education OR learning)) AND PUBYEAR > 2009
TITLE-ABS-KEY(Flood* AND impact AND school AND access) AND PUBYEAR > 2009
TITLE-ABS-KEY(Flood* AND impact AND school AND (enrolment OR attendance OR absenteeism)) AND PUBYEAR > 2009
TITLE-ABS-KEY(Flood* AND impact AND school AND (dropout OR completion)) AND PUBYEAR > 2009
TITLE-ABS-KEY(Flood* AND impact AND ("school performance" OR "school attainment" OR "exam scores" OR "exam pass rate")) AND PUBYEAR > 2009
TITLE-ABS-KEY(Flood* AND impact AND (numeracy OR math*)) AND PUBYEAR > 2009
TITLE-ABS-KEY(Flood* AND impact AND (literacy OR reading OR writing)) AND PUBYEAR > 2009
TITLE-ABS-KEY(Flood* AND impact AND digital skills) AND PUBYEAR > 2009
TITLE-ABS-KEY(Flood* AND impact AND (Life OR transferable OR "21st century" OR foundational) AND skills) AND PUBYEAR > 2009
TITLE-ABS-KEY (Flood* AND impact AND ("cognitive skills" OR "cognition")) AND PUBYEAR > 2009
HIGH TEMPERATURE
TITLE-ABS-KEY(("extreme temperatures" OR "heatwave" OR "extreme heat") AND impact AND (school OR education OR learning)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("extreme temperatures" OR "heatwave" OR "extreme heat") AND impact AND school AND access) AND PUBYEAR > 2009
TITLE-ABS-KEY(("extreme temperatures" OR "heatwave" OR "extreme heat") AND impact AND school AND (enrolment OR attendance OR absenteeism)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("extreme temperatures" OR "heatwave" OR "extreme heat") AND impact AND school AND (dropout OR completion)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("extreme temperatures" OR "heatwave" OR "extreme heat") AND impact AND ("school performance" OR "school attainment" OR "exam scores" OR "exam pass rate")) AND PUBYEAR > 2009
TITLE-ABS-KEY(("extreme temperatures" OR "heatwave" OR "extreme heat") AND impact AND (numeracy OR math*)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("extreme temperatures" OR "heatwave" OR "extreme heat") AND impact AND (literacy OR reading OR writing)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("extreme temperatures" OR "heatwave" OR "extreme heat") AND impact AND digital skills) AND PUBYEAR > 2009
TITLE-ABS-KEY(("extreme temperatures" OR "heatwave" OR "extreme heat") AND impact AND (Life OR transferable OR "21st century" OR foundational) AND skills AND PUBYEAR > 2009
TITLE-ABS-KEY (("extreme temperatures" OR "heatwave" OR "extreme heat") AND impact AND ("cognitive skills" OR "cognition")) AND PUBYEAR > 2009

Table A1.1 Search strings used (continued)

COLD
TITLE-ABS-KEY((extreme OR severe) AND cold AND impact AND (school OR education OR learning)) AND PUBYEAR > 2009
TITLE-ABS-KEY((extreme OR severe) AND cold AND impact AND school AND access) AND PUBYEAR > 2009
TITLE-ABS-KEY((extreme OR severe) AND cold AND impact AND school AND (enrolment OR attendance OR absenteeism)) AND PUBYEAR > 2009
TITLE-ABS-KEY((extreme OR severe) AND cold AND impact AND school AND (dropout OR completion)) AND PUBYEAR > 2009
TITLE-ABS-KEY((extreme OR severe) AND cold AND impact AND ("school performance" OR "school attainment" OR "exam scores" OR "exam pass rate")) AND PUBYEAR > 2009
TITLE-ABS-KEY((extreme OR severe) AND cold AND impact AND (numeracy OR math*)) AND PUBYEAR > 2009
TITLE-ABS-KEY((extreme OR severe) AND cold AND impact AND (literacy OR reading OR writing)) AND PUBYEAR > 2009
TITLE-ABS-KEY((extreme OR severe) AND cold AND impact AND digital skills) AND PUBYEAR > 2009
TITLE-ABS-KEY((extreme OR severe) AND cold AND impact AND (Life OR transferable OR "21st century" OR foundational) AND skills) AND PUBYEAR > 2009
TITLE-ABS-KEY ((extreme OR severe) AND cold AND impact AND ("cognitive skills" OR "cognition")) AND PUBYEAR > 2009

WILDFIRES
TITLE-ABS-KEY(wildfire* AND impact AND (school OR education OR learning)) AND PUBYEAR > 2009
TITLE-ABS-KEY(wildfire* AND impact AND school AND access) AND PUBYEAR > 2009
TITLE-ABS-KEY(wildfire* AND impact AND school AND (enrolment OR attendance OR absenteeism)) AND PUBYEAR > 2009
TITLE-ABS-KEY(wildfire* AND impact AND school AND (dropout OR completion)) AND PUBYEAR > 2009
TITLE-ABS-KEY(wildfire* AND impact AND ("school performance" OR "school attainment" OR "exam scores" OR "exam pass rate")) AND PUBYEAR > 2009
TITLE-ABS-KEY(wildfire* AND impact AND (numeracy OR math*)) AND PUBYEAR > 2009
TITLE-ABS-KEY(wildfire* AND impact AND (literacy OR reading OR writing)) AND PUBYEAR > 2009
TITLE-ABS-KEY(wildfire* AND impact AND digital skills) AND PUBYEAR > 2009
TITLE-ABS-KEY(wildfire* AND impact AND (Life OR transferable OR "21st century" OR foundational) AND skills) AND PUBYEAR > 2009
TITLE-ABS-KEY(wildfire* AND impact AND ("cognitive skills" OR "cognition")) AND PUBYEAR > 2009

Table A1.1 Search strings used (continued)

STORMS
TITLE-ABS-KEY(("tropical storms" OR cyclone OR hurricane OR typhoon OR windstorm) AND impact AND (school OR education OR learning)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("tropical storms" OR cyclone OR hurricane OR typhoon OR windstorm) AND impact AND school AND access) AND PUBYEAR > 2009
TITLE-ABS-KEY(("tropical storms" OR cyclone OR hurricane OR typhoon OR windstorm) AND impact AND school AND (enrolment OR attendance OR absenteeism)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("tropical storms" OR cyclone OR hurricane OR typhoon OR windstorm) AND impact AND school AND (dropout OR completion)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("tropical storms" OR cyclone OR hurricane OR typhoon OR windstorm) AND impact AND ("school performance" OR "school attainment" OR "exam scores" OR "exam pass rate")) AND PUBYEAR > 2009
TITLE-ABS-KEY(("tropical storms" OR cyclone OR hurricane OR typhoon OR windstorm) AND impact AND (numeracy OR math*)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("tropical storms" OR cyclone OR hurricane OR typhoon OR windstorm) AND impact AND (literacy OR reading OR writing)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("tropical storms" OR cyclone OR hurricane OR typhoon OR windstorm) AND impact AND digital skills) AND PUBYEAR > 2009
TITLE-ABS-KEY(("tropical storms" OR cyclone OR hurricane OR typhoon OR windstorm) AND impact AND (Life OR transferable OR "21st century" OR foundational) AND skills) AND PUBYEAR > 2009
TITLE-ABS-KEY(("tropical storms" OR cyclone OR hurricane OR typhoon OR windstorm) AND impact AND ("cognitive skills" OR "cognition")) AND PUBYEAR > 2009

COASTAL EROSION AND LANDSLIDES
TITLE-ABS-KEY(("coastal erosion" OR landslides) AND impact AND (school OR education OR learning)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("coastal erosion" OR landslide*) AND impact AND school AND access) AND PUBYEAR > 2009
TITLE-ABS-KEY(("coastal erosion" OR landslide*) AND impact AND school AND (enrolment OR attendance OR absenteeism)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("coastal erosion" OR landslide*) AND impact AND school AND (dropout OR completion)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("coastal erosion" OR landslide*) AND impact AND ("school performance" OR "school attainment" OR "exam scores" OR "exam pass rate")) AND PUBYEAR > 2009
TITLE-ABS-KEY(("coastal erosion" OR landslide*) AND impact AND (numeracy OR math*)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("coastal erosion" OR landslide*) AND impact AND (literacy OR reading OR writing)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("coastal erosion" OR landslide*) AND impact AND digital skills) AND PUBYEAR > 2009
TITLE-ABS-KEY(("coastal erosion" OR landslide*) AND impact AND (Life OR transferable OR "21st century" OR foundational) AND skills) AND PUBYEAR > 2009
TITLE-ABS-KEY(("coastal erosion" OR landslide*)AND impact AND ("cognitive skills" OR "cognition")) AND PUBYEAR > 2009

Table A1.1 Search strings used (continued)

EDUCATION STRINGS
TITLE-ABS-KEY(("climate change") AND impact AND school AND (access OR enrolment OR attendance OR absenteeism OR dropout OR completion)) AND PUBYEAR > 2009
TITLE-ABS-KEY(("climate change") AND impact AND ("school performance" OR "school attainment" OR "exam scores" OR "exam pass rate")) AND PUBYEAR > 2009
TITLE-ABS-KEY(("climate change") AND impact AND (Life OR transferable OR "21st century" OR digital OR foundational) AND skills) AND PUBYEAR > 2009
TITLE-ABS-KEY(("climate change") AND impact AND ("cognitive skills" OR "cognition")) AND PUBYEAR > 2009

Table A1.2 List of databases examined in preliminary search phase

No	Database	Decision	Reasoning
1	NCBI	Yes	Relevant papers for effects of climate change on children's health that impact educational outcomes
2	Web of Science (WoS)	Yes	Number of relevant papers found
3	ERIC	Yes	Few but relevant papers found
4	Google Scholar	Yes	Number of good search results (first 10 pages)
5	Google	Yes	Mixed type of publications: blogs/working papers/grey literature (first 10 pages)
6	Scopus	Yes	Smaller total hits than WoS but good percentage hit. Strong reach into health science journals relevant for understanding health/nutrition-related impacts on education
7	Medline	No	No relevant papers
8	CEEDER	No	No relevant papers
9	3ie	No	Few relevant papers
10	EconLit	No	No relevant papers found
11	Campbell	No	No relevant papers found
12	KiX databases	No	No relevant papers found
13	Jstor	No	mixed results - unlikely to be worth the time to sort through
14	Global Adaptation Mapping Initiative	No	Number of irrelevant articles, would require significant time sifting
15	ResearchGate	No	Substantial overlap with other databases but sometimes useful for accessing papers not available elsewhere

Table A1.3 Websites used for hand searches

Websites		
ADB	IADB	UNDP
AfDB	IFPRI	UNECA
Brookings	IIED	UNEP
Busara	IIEP	UNESCO
CGDev	INEE	UNFCCC
ECLAC	IPCC	UNICEF
FCDO/Gov.uk	IRC	WHO
Grantham Institute	NBER	World Bank

Appendix 2 Additional details on distribution of studies found

Table A2.1 Frequency of econometric impact studies using the same datasets

Dataset	Frequency
ASER	4
Colombia Census	2
Colombian Longitudinal Survey	3
Ethiopia Rural Household Survey	3
Malawi Integrated Household Survey	3
Mongolia Panel	2
PROGRESA (Programa de Educacion, Salud y Alimentacion)	4
Regents exam data (New York)	2
Stanford Education Data Archive	2
Young Lives	10

Appendix 3 Additional tables and boxes

Table A3.1 Comparative impact of hazards on education outcomes

Country/ Region	Comparative impact of hazards	Type of educational outcomes	Authors
Malawi	Droughts > floods	Access	(Abiona, 2017)
Mexico	Droughts and floods > rainfall shocks (positive and negative)	Access and attainment	(Adhvaryu et al., 2023)
	Droughts > floods	Attainment (some metrics)	
	Droughts = floods	Attainment (some metrics)	
Colombia	Floods and landslides > rainfall shocks (positive)	Learning	(Brando and Santos, 2015)
Ethiopia	Droughts > floods	Access and learning	(Hyder and Behrman, 2016)
	High temperatures > droughts (in spring and summer only) Droughts > high temperatures (in winter only)	Attainment	(Randell and Gray, 2016)
	Floods > drought	Learning	(Zamand and Hyder, 2016)
	Floods > drought and hailstorms/frosts	Attainment	(Nguyen and Nguyet, 2018)
Vietnam	Floods > drought and hailstorms/frosts	Access, attainment and learning	(Nguyen and Nguyet, 2018)
Peru	Floods =! droughts	Learning	(Zamand and Hyder, 2016)
India	Floods > droughts and hailstorms/frosts	Attainment	(Nguyen and Nguyet, 2018)
	Droughts and hailstorms/frosts > floods	Learning	(Nguyen and Nguyet, 2018)
	Floods > droughts	Learning	(Zamand and Hyder, 2016)
	Floods > droughts	Access, attainment and learning	(Dasgupta and Karandikar, 2021)
Madagascar	Cyclones > rainfall shocks (positive or negative)	Access	(Marchetta, Sahn and Tiberti, 2019)
Latin America	Floods and landslides > cyclones	Attainment	(Caruso, 2017)
West and Central Africa	Rainfall shocks (negative) > higher temperatures	Attainment	(Randell and Gray, 2019)

Box A3.1 Relevant EiE and DRR frameworks

Prominent EiE and DRR frameworks that can be contextualized for education sector resilience and recovery in the light of climate change:

1. The International Network for Education in Emergencies (INEE) Minimum Standards for Education: Preparedness, Response, Recovery (INEE MS) framework (Appendix Table 9) (INEE, 2024).
2. The UN Office for DRR (UNDRR) Worldwide Initiative for Safe School (WISS) attempts to ensure school safety during crises (UNDRR, 2023). The Comprehensive School Safety (CSS) framework was endorsed in 2015 by the Global Alliance for Disaster Risk Reduction and Resilience in the Education Sector (GADRRRES), an alliance facilitated through the UNDRR.
3. UNICEF remote learning readiness index, a composite indicator to assess resilience of education sector against crises and emergencies (Avanesian, Mizunoya and Delamonica, 2022)
4. The Australian Council for Educational Research (ACER) framework for building resilient education systems which has been developed through a rapid review of EiE literature (Tarricone, Mestan and Teo, 2021)
5. The World Bank's RAPID framework for a contextually suitable learning recovery program (World Bank, 2022)
6. The IDMC proposes a framework for education system resilience in the context of climate-linked displacement (Pye, Seeger and Ndabananiye, no date)
7. UNICEF tool designed to raise awareness and promote reflection, dialogue and assessment of progress among national and sub-national level education stakeholders for creating climate resilient education systems (Kagawa, 2022h)
8. UNICEF guidance on risk informed education programming for resilience (UNICEF, 2019a)
9. GPE climate smart education systems tool (GPE and Save the Children, 2023)
10. Guidelines for climate-proofing the education system (Krishnamurthy, 2019).
11. Sendai framework for DRR – broader than education (UNDRR, 2015)

Appendix 4

A spreadsheet with full details of the studies included in the systematic review can be found here

ODI Global

ODI Global advises leaders on driving positive change. We turn bold ideas, evidence, and broad expertise into actionable strategies for a more resilient, just and equitable future.

ODI Global
4 Millbank
London SW1P 3JA
United Kingdom

+44 (0)20 7922 0300
info@odi.org

odi.org
www.linkedin.com/company/odi/
bsky.app/profile/odi.global