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Climate and Education in Ghana: A Landscape Review

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Abbreviations and acronyms

ACE	Action for Climate Empowerment
CAMFED	Campaign for Female Education
CCE	Climate Change Education
CECOP	Climate Education Community of Practice
CENDLOS	Centre for National Distance Learning and Open Schooling
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
DA	District Assembly
DEM	Digital Elevation Model NaCCA
ECMWF	European Centre for Medium-Range Weather Forecasts
EPA	Environmental Protection Agency
GES	Ghana Education Service
GMet	Ghana Meteorological Agency
GSS	Ghana Statistical Service
JHS	Junior High School
LAYS	Learning-Adjusted Years of Schooling
LG	Local Government
LMIC	Low- and middle-income country
LULC	Land Use Land Cover
MANOBS	Manual of Surface Weather Observation Standards
MESTI	Ministry of Environment, Science, Technology and Innovation

MoE	Ministry of Education
NaCCA	National Council for Curriculum and Assessment
NADMO	National Disaster Management Organisation
NaSIA	National Schools Inspectorate Authority
NCCP	National Climate Change Policy
NDC	Nationally Determined Contribution
NEA	National Education Assessment
NGO	Non-governmental organisation
NOAA	National Oceanic and Atmospheric Administration
PET	Potential Evapotranspiration
RAIN	Rights & Advocacy Initiatives Network
SD	Standard Deviation
SHS	Senior High School
SPEI	Standardised Precipitation-Evapotranspiration Index
STEM	Science, technology, engineering, and mathematics
UNDP	United Nations Development Programme
UNEMG	United Nations Environment Management Group
UNEP	United Nations Environmental Programme
Unitar	United Nations Institute for Training and Research
VIIRS	Visible Infrared Imaging Radiometer Suite
WASH	Water, Sanitation and Hygiene

Executive summary

This landscape review synthesises existing evidence on climate change and education in Ghana in order to highlight key vulnerabilities and potential solutions for building a climate-resilient education system in critical areas.

The review comprised a mixed-methods approach. It combines thematic qualitative analysis of secondary evidence from academic and grey literature with quantitative analysis of historical satellite data.

The results of the review are presented in Section 4 and Section 5, drawing on existing literature and the satellite data analysis to present a holistic overview of evidence about recent climate patterns, their impact on Ghana's education system and current efforts to build resilience.

Section 4 examines climate hazards and their impact on education in Ghana, presenting data on four critical climate hazards and discussing the extent to which the literature explores the impact(s) of these hazards on education. A summary of findings for each hazard is presented in the boxes below.

Extreme Heat
Exposure to extreme heat is a much greater risk in the northern regions of Ghana, with mean maximum daily temperatures exceeding 35°C for nearly a third of 2024. Two studies on high temperatures in Ghanaian schools were identified, focusing on children's thermal comfort and the impact of different school infrastructures. However, current research does not examine the relationship between temperature, thermal comfort, and learning outcomes.

Precipitation
Analysis of satellite data indicates that precipitation is heaviest in the east and southwest of Ghana (particularly the Western Region), and driest in the north and the southeastern coastal belt (the Dahomey Gap). Recent trends also suggest consistently lower annual precipitation in the north, which has implications for precipitation-linked climatic events and education.

Flooding
A risk map of Ghana suggests that coastal areas are more prone to flooding, as is the Northern Region, due to a high concentration of rivers and the opening of the Bagre Dam. Two existing research studies were identified that examine the impact of flooding on education, including damage to infrastructure and reductions in short-term attendance and long-term enrolment at schools.

Drought
Much of Ghana is considered 'dryland', with the Dahomey Gap and the north being the most vulnerable to drought. Analysis also indicates that the central and southern areas are 'drying out' more rapidly compared to other regions, when considering the relative long-term climate 'normal'. No literature, however, examines the impact of drought specifically on education in Ghana.

Section 5 examines approaches to building a climate-resilient education system in Ghana, including current networks and initiatives that have been or could be utilised.

Stakeholder mapping
An overview of 12 stakeholders who are, or could be, well positioned to support climate-resilience-building initiatives in education in Ghana is provided, outlining each stakeholder's remit and current activities. The supporting literature highlights the challenges of coordinating different levels of governance in Ghana and opportunities to improve localisation and leverage climate financing to build resilience in the education system.

Existing climate-resilience initiatives
There is limited evidence on the effectiveness or impact of specific climate-resilience initiatives in education in Ghana. Instead, this report presents the objectives and scope of select initiatives. It also identifies that there are very few specific references to education within current climate change policy, nor standards against which adaptation efforts can be measured.

Opportunities to improve climate resilience through the education system
The literature indicates three main ways through which Ghana's climate resilience may be strengthened through the existing education system: developing cross-cutting infrastructural resilience, disaster risk reduction, and climate change education. Many of these opportunities require multi-sectoral coordination.

Section 6 presents the conclusion and recommendations. Satellite analysis identifies the Upper West, Upper East, North East, and Northern Regions as the most exposed to climate hazards, with the Greater Accra area also at high risk of flooding. Two main gaps, however, emerge from the landscape review: a lack of research on the direct and indirect impacts of extreme weather events on education in Ghana, and a failure in policy and existing resilience initiatives to address both climate and education directly. As such, recommendations are offered, grouped under the three broad areas of research, policy, and financing, to support future decision-making. The following recommendations are expanded upon in more detail in Section 6:

Research is needed to explicitly determine the national- and regional-level impacts of climate change and climate events on learning outcomes in Ghana, as well as the effectiveness of different mitigation efforts.

a. Determine the temperature threshold(s) at which exposure to extreme heat begins to affect learning in Ghana negatively.
b. Rigorously investigate what educational impacts are associated with different types of school infrastructure.
c. Commission long-term rigorous research to determine the differences and interactions between rapid-onset and slow-onset climate crises and their impacts on education.
d. Examine the potential of Ghana's existing School Feeding Programme as a strategy to mitigate the impacts of climatic hazards on education, particularly during drought.
e. Assess trends in precipitation, attendance rates, and other seasonal variables.

Education needs to have a defined focus within Ghana's existing climate change policy and resilience initiatives.

f. Establish specific roles and responsibilities for the Ministry of Education (MoE) and relevant education agencies within the National Climate Change Policy (NCCP), alongside those of the Environmental Protection Agency (EPA) and the Ministry of Environment, Science, Technology and Innovation (MESTI).
g. Develop clear targets and a mapping tool, aligned with the Basic Education Infrastructure Framework, to aid the implementation of the National Schools Inspectorate Authority guidelines.
h. Enhance the National Disaster Management Organisation's (NADMO) capacity to enable a shift towards anticipatory action alongside reactive disaster response.

i. Strengthen the climate change education (CCE) curriculum and pedagogy towards an action-focused approach.

Climate financing should be leveraged to build resilience in the education system. This requires a central role for the MoE and relevant agencies, especially when financing is multi-sectoral.

j. Ensure that education is a specific focus within Ghana's Nationally Determined Contribution (NDC).

k. Leverage climate financing for multi-sectoral projects to service education-related initiatives.

l. Establish incentives to increase investment in climate financing from the private sector.

1. Introduction

Ghana has made significant progress in the education sector in recent years. Access to formal education has expanded rapidly, driven by key policies and initiatives such as the removal of school fees, including Free Senior High School, and the expansion of school feeding programmes (↑GSS, 2022; ↑UNESCO Institute of Statistics, 2023). This has increased access to and enrolment in education in both primary and secondary schools to levels rarely seen in other low- and middle-income countries (LMICs) (↑Education Policy and Data Center (EPDC), 2018). However, the education sector still faces many challenges. In particular, increased access to education has not been fully accompanied by comparative improvements to educational quality or equity, with disparities remaining between the relatively well-resourced southern and the relatively poor northern areas (↑Mikessel & Ackwerh, 2018; ↑Nkrumah, 2023; ↑Radford & Ampofo, 2024; ↑World Bank, 2023a)

A worsening climate context also threatens education delivery. Ghana is becoming increasingly vulnerable to a range of climatic hazards, such as extreme heat, flooding, and drought (↑Adelphi & African Union, 2024; ↑Desjonqueres et al., 2024; ↑World Bank, 2021). For example, data from 2024 indicates that daily maximum temperatures in the northern regions frequently exceed 35°C, a level shown to reduce academic performance in other contexts (↑Srivastava et al., 2024).

The impact of this changing climate on education is twofold. First, there are direct consequences for educational infrastructure and service delivery, where extreme weather events (such as flooding) can damage schools and disrupt attendance (↑Mensah et al., 2023; ↑Prah et al., 2023), while more incremental shifts in climate patterns (such as rising temperatures) continuously disrupt the quality of the school environment (↑Amankwaa et al., 2025; ↑Appah & Koranteng, 2012). Second, there are impacts at the household or community level that affect behaviours and livelihoods, which have implications for education. As families increasingly grapple with climate-induced shocks, such as drought affecting agricultural yields, decisions taken to mitigate these impacts can deprioritise education. For example, the prioritisation of household labour over schooling can lead to lower attendance or increased dropout rates (↑Asare & Forkuor, 2024).

To sustain recent progress in the education sector and mitigate the multifaceted and multi-sectoral risks posed by climate-related hazards, there is a critical need for active resilience-building initiatives and evidence-based policy. This landscape review synthesises evidence on climate change and education in Ghana to highlight key vulnerabilities and potential solutions for building a climate-resilient education system. This review is not intended as an exhaustive catalogue of all climate issues in Ghana, but a structured analysis around two key areas:

1. **Climate hazards and their impact on education in Ghana.** This is covered in Section 4, which provides an analysis of key climate patterns and hazards (heat, precipitation, flooding, and drought), and a literature synthesis on how these identified climate risks are affecting education.
2. **Approaches to building a climate-resilient education system in Ghana** are covered in Section 5, which maps existing stakeholders, policies, and interventions that aim to strengthen climate resilience in education in Ghana.

2. Education context in Ghana

Before presenting the methods and results of the landscape review, this section presents an overview of Ghana's education system to provide context for how climate-related challenges may interact with education delivery.

2.1 Education system overview and governance

Ghana's education system (see Table 1) is overseen by the Ministry of Education (MoE), which is responsible for policy formulation, curriculum planning, and resource allocation, as mandated by the Education Act 778 and the Education Strategic Plan 2018–2030 (↑MoE, 2019; ↑Republic of Ghana, 2008). The implementation of policies for pre-tertiary education is managed by the Ghana Education Service (GES), which operates through a network of regional and district-level offices (↑UNICEF Innocenti et al., 2023).

Table 1. *The education system structure in Ghana*

Level of education	Duration	Standard Grades	Standard Age	Financing
Kindergarten (KG)	2 Years	KG 1–KG 2	4–5 years	Free and compulsory. High access but over-age enrolment is common.
Primary School	6 Years	Primary 1–6	6–11 years	Free and compulsory. Near-universal access achieved.
Junior High School (JHS)	3 Years	JHS 1–3	12–14 years	Free and compulsory. Significant drop-off in attendance.
Senior High School (SHS)	3 Years	SHS 1–3	16–18 years	Free (since 2017). Enrolment has surged, but per-student spending is 4x higher here than at the primary level (↑UNICEF & MoE, 2023).

Alongside the public system, the private sector is a major provider of education, accounting for approximately 30% of total enrolment as of 2020 (↑UNICEF Innocenti et al., 2023). There are significant urban–rural differences in private school provision in Ghana, and it is estimated that there are twice as many private kindergartens (8,398) as public ones (4,040) (↑Global Schools Forum, 2025).

2.2 Attendance statistics and enrolment trends

Ghana has achieved near-universal access to primary education, largely driven by policy interventions such as the removal of school fees at primary, JHS, and SHS levels and the introduction of the school feeding programme. Available data from the Ghana Statistical Service indicates that the Net Enrolment Rate for primary school is approximately 80% (↑GSS, 2022). This is a result of a long-term expansion in early childhood education. Gross Enrolment Rates at the kindergarten level have more than doubled over the last two decades, rising from 51% to 122% between 2000 and 2023[1] (↑GSS, 2025). However, retention becomes a significant challenge as students progress through the system. Attendance rates drop sharply at the JHS level, where the Net Enrolment Rate falls to 47.9%. This indicates that fewer than half of children aged 12 to 14 are enrolled at their appropriate grade level (↑GSS, 2022).

2.3 Quality of learning and human capital

While enrolment figures are encouraging, measures of educational quality reveal significant gaps. The World Bank's Learning-Adjusted Years of Schooling (LAYS)[2] measures how much children actually learn, not just how long they stay in school. In Ghana, a child can expect to complete 11.5 years of schooling by age 18. When adjusted for learning quality, this falls to 5.7 years (↑World Bank, 2023a). For this reason, 12 years of schooling in Ghana are estimated to be equivalent to 6 years of high-quality education.

Comparison with data from other countries in sub-Saharan Africa illustrates this potential gap in education quality: Eswatini achieves a similar LAYS score (around 5.5 years) with only 8 years of schooling, meaning children there learn more per year on average (↑Crawfurd et al., 2019); a child attending 9 years of school in Togo acquires more learning than a child attending 11.5 years in Ghana. This suggests that Ghana's high enrolment is not translating into proportionally higher learning outcomes compared to regional peers.

[1] Gross Enrolment Rate (GER) is total enrolment at a given education level as a percentage of the official age group, exceeding 100% when students outside the typical age range are enrolled.

[2] Learning-Adjusted Years of Schooling (LAYS) is a World Bank metric that combines expected years of schooling with harmonised test scores to estimate the years of quality-adjusted education a child can expect to receive.

2.4 Learning outcomes: Proficiency by subject

This lack of quality is further evidenced by many students not achieving grade-level competencies, particularly in foundational literacy and numeracy. Mathematics performance presents a notable concern across educational levels. The 2022 National Standardised Test indicated that Grade 4 primary learners achieved a national mean score of 47.8% in mathematics (↑NaCCA, 2023), falling within the 'Below Basic' proficiency level (below 50%). This indicates that the average student has not yet attained basic grade-level competency, with substantial gaps remaining in achieving the government's national educational goal of 70% of primary school students proficient in literacy and numeracy by the target year (↑Big Win Philanthropy, 2025). Literacy performance is marginally better than numeracy but remains below expected standards; in the 2022 National Standardised Test, the mean English score for Grade 4 primary was 55.3%, while mathematics lagged at 47.8% (↑World Bank, 2025). Table 2 provides a full breakdown of 2021 and 2022 National Standardised Test data at the national level.

Table 2. *Percentage of learners achieving different proficiency levels for foundational literacy and numeracy in 2021 and 2022. Data source:* ↑NaCCA, 2023

	2021 results		2022 results	
Proficiency level	**English**	**Maths**	**English**	**Maths**
Advanced	21	11	6.98	8.72
Proficient	14	13	11.31	15.27
Basic	15	14	33.02	25.2
Below basic	50	62	48.7	50.83

2.5 Regional differences and school ownership

Educational outcomes in Ghana are geographically stratified, with the country's northern areas generally performing worst (↑Mikessel & Ackwerh, 2018). For example, in foundational literacy, 7.9% of lower-primary-school boys and 15% of girls achieved the foundational literacy skills expected at Grade 2 in the northern areas, compared to the national average of 25.8% for males and 26.9% for females (↑Nkrumah, 2023). At a regional level, data from the 2022 National Standardised Test in English and maths shows significant variation (see Table 3). Regional averages for maths ranged from 73.9% (Volta Region) to 43.3% (North East Region), and for English, from

54.5% (Greater Accra) to 24.8% (North East Region) (↑NaCCA, 2023). The three worst-performing regions across both literacy and numeracy were Oti, Upper West, and North East, with the latter being ranked last for both metrics. The three highest-performing regions in both metrics were Volta, Greater Accra and Western Region (↑NaCCA, 2023). This highlights regional variation in education quality and, given that the relative regional rankings for both competencies follow a similar pattern, suggests that they reflect the holistic regional differences in education quality (rather than specific subject quality).

Table 3. *National Standardised Test results in 2022 for English and maths. Data source:* ↑NaCCA, 2023

Region	Average English score (%)	Average Maths score (%)
Ahafo	32.4	56.8
Ashanti	37.9	63.8
Bono East	33.0	60.1
Bono	36.3	60.5
Central	34.5	59.1
Eastern	38.3	60.5
Greater Accra	54.5	68.5
North East	24.8	43.3
Northern	38.6	61.1
Oti	25.2	49.9
Savannah	40.0	60.7
Upper East	30.5	58.0
Upper West	25.7	45.7
Volta	48.2	73.9
Western North	31.8	59.3
Western	44.7	67.9

In terms of school ownership, private schools consistently outperform public schools across all subjects, averaging 59% in mathematics compared to 47% in public schools (↑UNICEF Innocenti et al., 2023). National Standardised Test performance in 2022 also showed that private school students' average scores were significantly higher than those of their public school counterparts for both English (70.3% vs 37.0%) and maths (78.5% vs 61.2%) (↑NaCCA, 2023).

2.6 Other key challenges facing the sector

Infrastructure deficits and financing are two other main challenges to education in Ghana. Only 68% of schools nationally have functional electricity, a figure that drops to 58% in rural areas. Similarly, nearly 19% of public school classrooms require major repairs, compared to only 3% in private schools (↑UNICEF Innocenti et al., 2023). The vast majority of the education budget is allocated to recurrent expenditure, such as salaries, leaving very little fiscal space for capital investments, such as new classrooms or roofing repairs (↑UNICEF Innocenti et al., 2023). Additionally, teacher deployment can be highly variable (↑Takyi et al., 2025). While the national pupil-to-teacher ratio at the JHS level is reasonable at 15:1 in 2022/23, this ratio decreases at lower grades, with pupil-to-teacher ratios of 38:1 at the primary level and around 30:1 at the kindergarten level (↑GSS, 2025). There is also significant regional variation, particularly at the kindergarten and primary school levels; for example, in 2020/21 the Savannah Region had a pupil-to-teacher ratio at the kindergarten level of 86, compared to 29 in Greater Accra (↑GSS, 2025).

3. Methodology

The landscape review uses a mixed-methods approach, combining thematic qualitative analysis of secondary evidence from academic and grey literature with quantitative analysis of historical satellite data to determine climatic patterns.

3.1 Thematic qualitative analysis

Qualitative analysis entailed a review of published literature, structured according to two main themes:

1. The impacts of climate change on education in Ghana;
2. Efforts to build climate-resilient education systems in Ghana.

For each of these themes, the approach taken was akin to a rapid evidence review. This methodological approach is informed by the Cochrane Collaboration Rapid Review Methods Group guidance on producing rapid reviews (⇡Garritty et al., 2021). A three-stage process to systematically capture and analyse relevant literature was undertaken, including searches, screening, and analysis (outlined further below). The inclusion criteria for the literature reviewed were as follows:

- Has findings relating to or derived from Ghana specifically;
- Contains education-related findings from rigorous and high-quality research;
- Published between 2010 and 2026;
- Published in a peer-reviewed journal or published/endorsed by a recognised academic, governmental, or non-governmental organisation.

3.1.1 Literature searches

The first step involved creating search strings to identify relevant literature via Google Scholar. Search strings were designed to capture key terminology related to each theme (see Annex A). Additional grey literature was sourced from reputable organisational databases (such as those of UN agencies and the World Bank) to obtain a holistic collection of existing evidence.

3.1.2 Literature screening

Results from the first 10 pages (100 documents) of each search string were screened for eligibility based on title and abstract. All 100 results for each string were entered into the Rayyan software and manually screened based on content, thematic focus, publication date, source type, and language of publication. In total, 643 articles were screened using title and abstract, of which 83 were included in the second round of screening. The main reasons for exclusion were a lack of specific focus on education or climate. These 83 studies were then full-text screened to determine their relevance and quality for final inclusion. Of these 83 sources, 39 were included for final analysis (see Annex B).

3.1.3 Literature analysis

The 39 literature sources in the final selection were analysed in Google Sheets, with reviewers responding to a set of pre-determined questions to extract data from each source consistently. The analysis framework included a range of identifiers (title, authors, year of publication), methodological details (study design, geographical location), and study results (the effectiveness or impact of the evaluated variables). Data was then grouped by the main resilience-building or climate-resilience mechanism detailed by the source (e.g., disaster risk reduction, climate change education) to ensure thematic analysis across included studies.

3.1.4 Geographic mapping of included literature

Table 4 presents the geographic focus of the included literature within Ghana. It indicates that a significant proportion of research on climate and education uses a national lens to examine trends, patterns or findings across the whole country. Studies with a specific geographic focus are primarily centred on the major cities (Accra, Kumasi, and Tamale) and their surrounding regions, likely due to their accessibility and the concentration of resources and research capacity. Interestingly, the Upper East and Upper West Regions are also significantly represented. As discussed in Section 4, these are two of the most vulnerable regions in Ghana to the effects of climate change, and the literature reflects this trend, with studies examining the education-related impacts of climate change often focusing on these areas. The Western Region also has a noteworthy number of studies, mainly due to the focus on the impact of changing coastal patterns on education. However, mapping also shows that 9 of 16 districts in Ghana had only 1 or fewer studies included, suggesting a dearth of evidence on climate impacts in these regions compared to the far north and surrounding major urban areas. Additionally, the limited number of studies across all regions suggests that, in understanding the impact of changing climate patterns on education variables, almost all areas could benefit from additional evidence to better understand these impacts and potential mitigation strategies.

Table 4. *Literature mapping of included studies (see Annex A for full details of the studies)*

Region	Number of included studies
National coverage or no specific geographical focal area within Ghana	17
Accra/Greater Accra	5
Ashanti	5 (including 2 in Kumasi)
Northern* *including the definition of the Northern Region before it was further divided into the Savannah and North East Regions in December 2018	5
Upper East	5
Upper West	4
Western	3
Eastern	2
Central	1
North East	1
Savannah	1
Volta	1
Ahafo, Bono, Bono East, Oti and Western North Regions had no included studies.	0

3.2 Climate data analysis

Climate data analysis involved using QGIS[3] software to analyse satellite data for multiple climatic variables across Ghana to map climatic trends, patterns, and vulnerabilities. Climate data was sourced from publicly

[3] QGIS is a free, open-source Geographic Information System (GIS) software application used to process, analyse, and visualise geographical data.

available databases, such as the ECMWF ERA5 land model.[4] Climate data analysis is centred around four key vulnerabilities: temperature, precipitation, flooding, and drought.

Each variable examined trends across 2024 (at the time of analysis, the most recent full annual data available) and, where relevant, longer-term datasets. It is worth noting that 2024 was a relatively atypical year in terms of rainfall and temperature. However, 'atypical' climate years are becoming increasingly common across the globe due to a changing climate and are therefore reasonable indicators of the climatic challenges Ghana will continue to face. The exact approach taken for each strand of analysis varied significantly; Annexes C–F provide details.

[4] The ECMWF ERA5-Land model is a high-resolution dataset produced by the European Centre for Medium-Range Weather Forecasts providing decades-long satellite data of land-surface variables, such as temperature and precipitation.

4. Climate hazards and their impact on education in Ghana

This section provides an overview of the primary climate hazards in Ghana, exploring how these hazards and changing climatic patterns are impacting education delivery. Four primary hazards are explored:

- Extreme heat
- Precipitation (rainfall)
- Flooding
- Drought

For each hazard, the report includes a primary analysis of satellite data and secondary sources to determine vulnerability across Ghana. The report then discusses the impact of this measured vulnerability on education in Ghana (excluding precipitation), drawing on global evidence where appropriate, to provide additional detail. To support visualisation of the regional distribution of climatic impacts, Ghana's regions are shown in Figure 1 below.

Figure 1. *Regions of Ghana*[5]

[5] *All maps used in this review were generated by the authors using GIS software.*

4.1 Extreme heat

4.1.1 Mapping Ghana's vulnerability to extreme heat

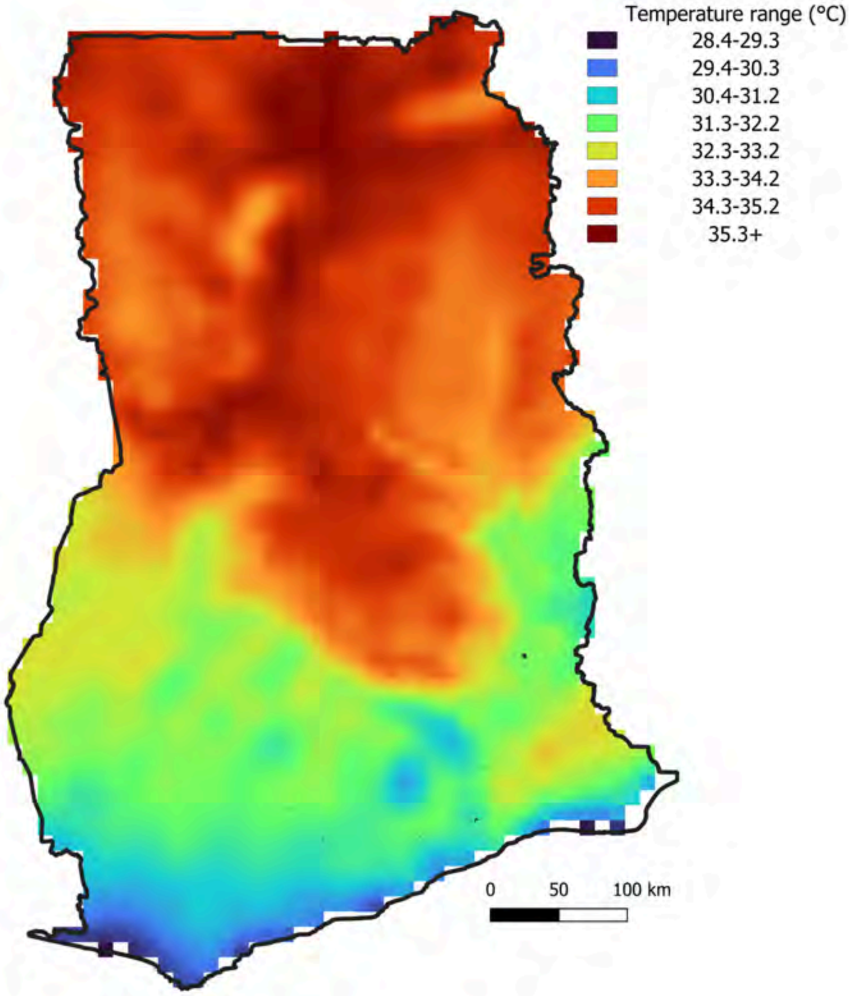
For the purposes of this analysis, the following parameters were used to map extreme heat:

- **Time scale:** temperature data from 2024 was used to ensure a full year of data was available to document recent temperature levels.
- **Heat analysis:** to measure extreme heat exposure, the analysis focused on the number of days in 2024 when a location exceeded a defined threshold (35°C). This provided insight into the relative regularity with which different locations in Ghana are exposed to extreme heat conditions.

Satellite data from the ECMWF ERA5 land model was used, specifically the ERA5-Land post-processed daily statistics model (↑Muñoz Sabater et al., 2024). This re-analysis model is appropriate for this task as it provides an accurate representation of air temperature at a height of ~2m, whereas other Land Surface Temperature models measure surface-level heat, which is often influenced by infrastructure (e.g., roads and buildings). The full methodology for this analysis is outlined in Annex C.

First, the mean maximum daily temperature in 2024 was calculated across Ghana (see Figure 2 below) to help determine which temperature thresholds should be explored as benchmarks for extreme heat in Ghana. One of the key questions of any extreme heat analysis is: 'How hot is too hot?' Evidence from high-income contexts (↑Park et al., 2021) puts this benchmark at around 27°C, but in reality this threshold is regularly exceeded in other contexts and is not useful as a benchmark for determining variation in extreme heat exposure in Ghana (see Figure 2 for example, showing how the mean average maximum daily temperature rises to more than 28°C across the whole of Ghana).

Figure 2: *Mean annual daily maximum temperature in Ghana in 2024 (°C). Data source:* ↑Muñoz Sabater et al., 2024



Due to the high average temperatures and a lack of empirical evidence on the impact of this level of heat on education in other contexts, it was decided that a higher temperature threshold of 35°C should be used as a benchmark for extreme heat exposure[6]—i.e. at the top end of maximum temperature shown in Figure 2. Further analysis was conducted to examine the number of days in 2024 when regions exceeded the daily maximum temperature threshold of 35°C. Figure 3 shows the results of this analysis.

[6] 35°C is also the value used in the Asia Pacific region for extreme heat analysis (e.g., ↑Philippine Atmospheric, Geophysical and Astronomical Services Administration, n.d.).

Figure 3: *Number of days in 2024 where daily maximum temperatures exceeded 35°C (regions). Data source:* ↑Muñoz Sabater et al., 2024

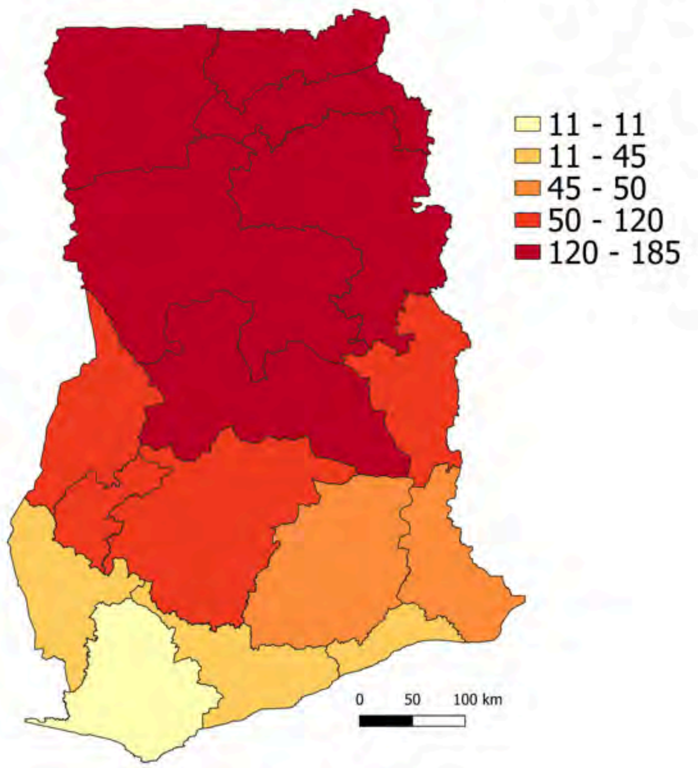


Figure 3 shows the extent of exposure to extreme heat in Ghana's northern regions. The Upper West, Upper East, North East, Savannah, Northern Region, and Bono East all experienced mean regional maximum daily temperatures exceeding 35°C for nearly a third of 2024 (32.8%). This demonstrates the regularity with which almost all of northern Ghana is exposed to extreme heat.

These findings support the literature, which concludes that exposure to extreme heat poses a much greater risk in the Northern areas of the country (↑Desjonqueres et al., 2024; ↑World Bank, 2021). Ghana is also expected to experience increased warming, with average temperatures rising by up to 5.3°C by the end of the century in some scenarios, although the exact extent of warming will depend on future carbon emission levels (↑GMet, 2025; ↑World Bank, 2021). There is, however, a high degree of certainty that temperatures will rise on average by 0.6°C to 3.1°C by 2080 compared to 2000 (↑Adelphi & African Union, 2024).

4.1.2 Impact of extreme heat on education

Two studies in the literature review examine the impact of temperature on educational settings in Ghana, but neither provides specific links to learning outcomes. In a thermal comfort analysis of a JHS block in Accra,

↑Appah & Koranteng (2012) found that only 29% of students reported being within a comfortable thermal zone (well below the recommended 80%) with measured temperatures between 29.4°C and 32.3°C, and students expressing a desire for cooler temperatures. The study demonstrates that high temperatures in Accra (which are regularly experienced and exceeded across other regions of Ghana) can be disruptive to student comfort, even though the same authors recognise that students in Ghana may have higher thermal comfort tolerance than students from cooler countries (↑Appah & Koranteng, 2012). This emphasises the importance of being attentive to context when answering the key resilience question of 'how hot is too hot?' for learning, as thresholds derived from high-income contexts may not translate to perceived heat in warmer climates.

The exposure of Ghanaian children to extreme heat was further demonstrated by a 2025 study in Accra, which found that the material of a school roof significantly impacts exposure to high temperatures (↑Amankwaa et al., 2025). Children in metal-roof classrooms were exposed to temperatures up to 39.8°C, which were 5.9 °C higher than comparable outdoor temperatures, equivalent to overheating for 72.5% of occupied hours. Concrete-roofed classrooms were the coolest roof type, being up to 5.8°C cooler than metal roofs and, on average, 1.2°C cooler than outdoor temperatures. The cooling benefit of concrete roofs over other roof types increased when outdoor temperatures exceeded 32°C.

However, neither of these studies explores how thermal comfort or reduced temperatures impact on learning indicators or outcomes. Global evidence suggests a link between temperature and cognitive performance, with extreme heat limiting learning outcomes (↑Graff Zivin et al., 2018; ↑Wargocki et al., 2019). Other studies quantify the level of impact (↑Cho, 2017; ↑Graff Zivin et al., 2018; ↑Park et al., 2021; ↑Srivastava et al., 2024). A study in Ethiopia found that 10 days of exposure to temperatures above 33°C can lead to a 2.28% decline in average exam performance (↑Srivastava et al., 2024). Similarly, research from the USA determined that a 1°F increase in temperature across a school year corresponded with an approximate 1% reduction of learning across the same time period, also noting the cumulative impact of increased temperatures across multiple years being substantially larger than that of a single school year (↑Park et al., 2021). The same study suggests that reducing the temperature by 1°C increases learning by 2% for the average student internationally.

A regional analysis of climate variables found that, in West and Central Africa, exposure to higher temperatures is associated with a decline in average schooling years, particularly when the head of the household has a secondary or higher level of education (↑Randell & Gray, 2019). Interestingly, they found that high heat only has a negative relationship with attainment in areas that are historically warm and wet, which emphasises the challenge of applying evidence from high-income countries on the relationship between heat exposure and learning to comparatively warmer contexts such as Ghana. Nonetheless, this research suggests that exposure to extreme heat is likely to impair cognitive function and learning outcomes in children in Ghana. More research is needed to fully determine the extent of heat's negative impact and the possibility of heat-reduction interventions in Ghana to mitigate this.

4.2 Precipitation patterns

Precipitation is a key variable related to a number of climate hazards (floods, droughts, storms), so understanding precipitation patterns provides a helpful baseline context for later in the section when these hazards are discussed. To establish national precipitation patterns, a 30-year analysis of long-term precipitation was conducted. This analysis shows the general distribution of annual precipitation across Ghana, with the 30-year average accounting for annual variation in precipitation patterns. The full methodological details are outlined in Annex D.

Figure 4: *Mean annual precipitation (mm) in Ghana between 1981 and 2010. Data source:* ↑Karger et al., 2025

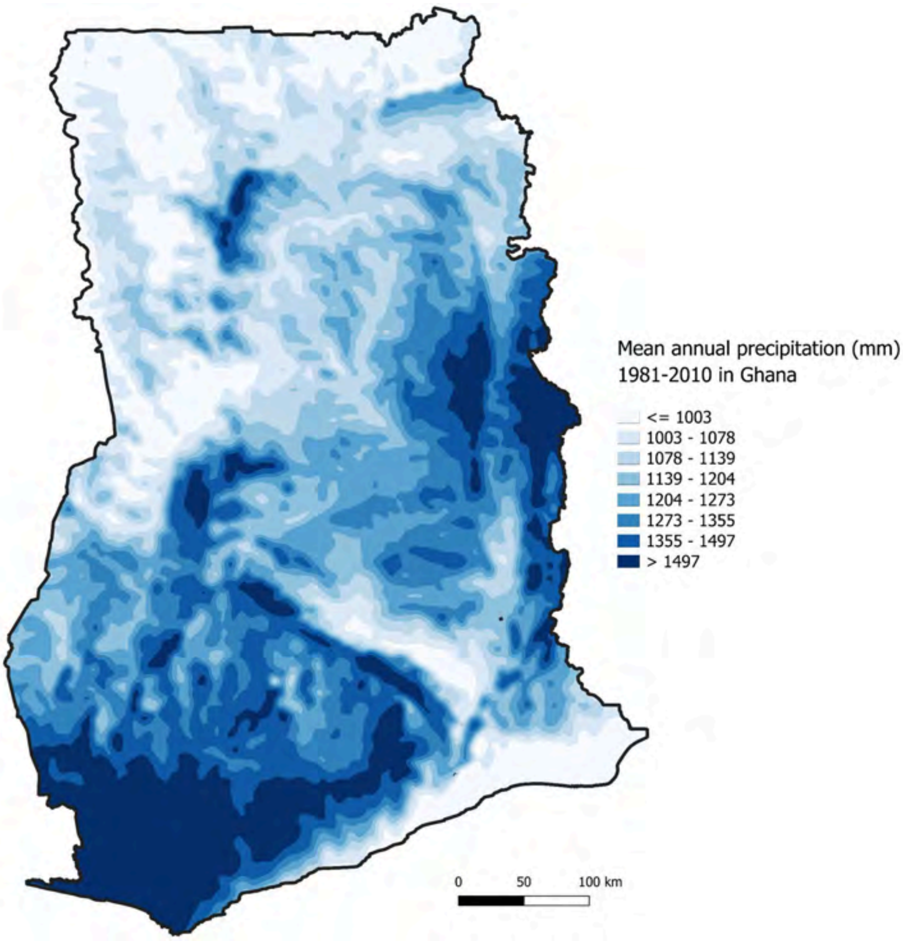


Figure 4 above provides an overview of long-term precipitation patterns in Ghana. It demonstrates that precipitation is heaviest in two concentrated zones: the East of the country (around the area between Oti and the Northern Region) and in the southwest, particularly in the Western Region.

Figure 4 also highlights the relative dryness of northern Ghana and the southeastern coastal belt. This latter area, known as the 'Dahomey Gap', is unusually dry due to prevailing weather conditions, with the dry harmattan winds blowing south (↑Salzmann & Hoelzmann, 2005). Low-pressure systems create an unusual pattern in which westerly winds (which are moisture-rich) are pushed eastward across the Dahomey Gap rather than westward, resulting in a relatively dry corridor. This is an important aspect of Ghana's climate with implications for exposure to hazards such as floods and droughts.

Analysis then focused on the previous 5 years of precipitation data (from 1 January 2020 to 31 December 2024), to get a sense of shifting precipitation patterns relative to this longer-term baseline (shown in Figure 5). The full methodological details for this analysis are outlined in Annex D.

Figure 5: *Mean annual precipitation (mm) in Ghana between 2020 and 2024. Data source:* ↑Climate Hazard Center, 2026

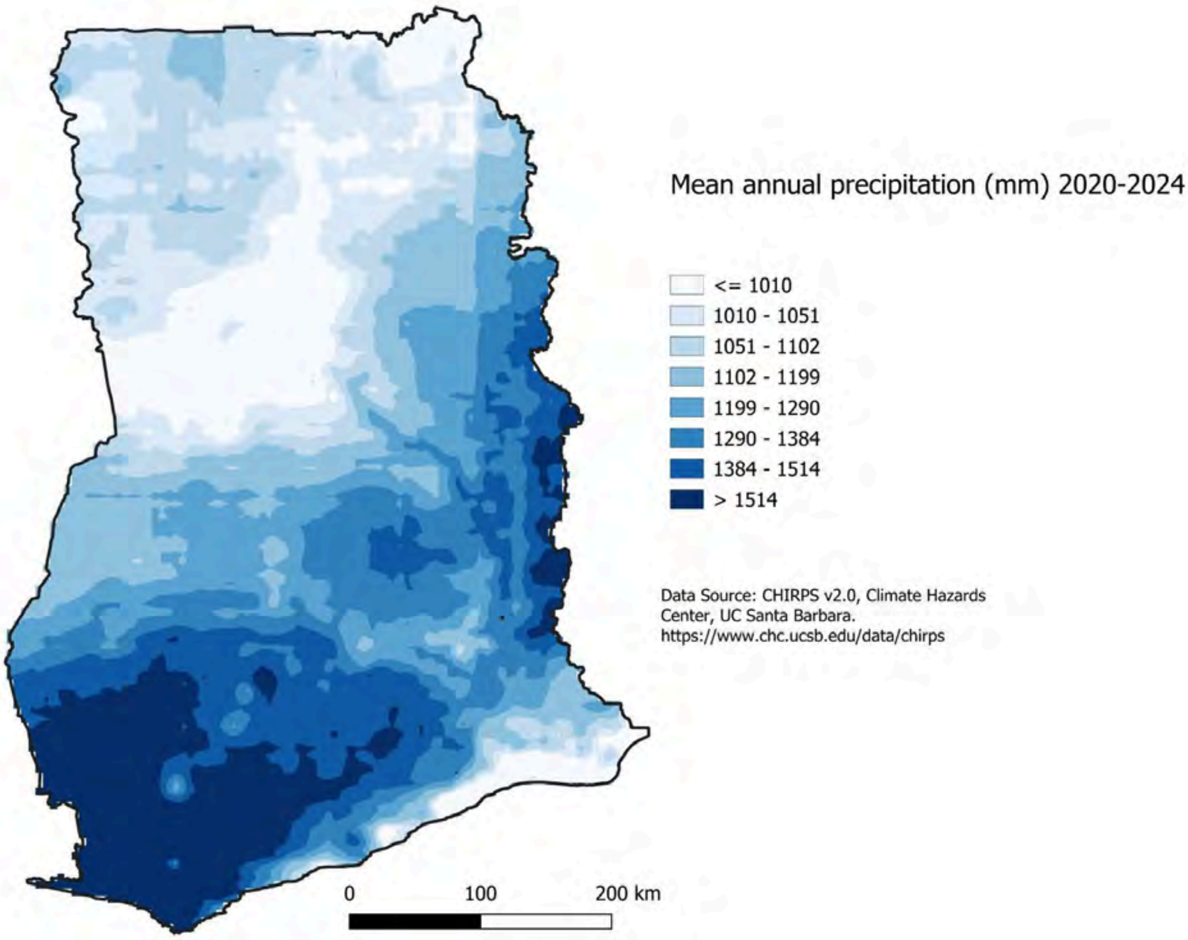


Figure 5 highlights trends similar to those outlined in Figure 4, with precipitation heaviest in the southwest of Ghana and along its eastern border. It also emphasises that northern Ghana is particularly dry, especially in the Savannah Region, as is the Dahomey Gap on the southeastern coastline. However, this analysis of more recent data shows that spots of heavier precipitation in the north (such as the patch in the Savannah Region shown in Figure 4) have been less intense in recent years, with more consistent trends of lower precipitation across the north of the country.

Predictions of future precipitation patterns are highly uncertain (↑Adelphi & African Union, 2024), with higher emissions scenarios likely to increase uncertainty about the total volume of annual rainfall. It remains unclear by how much this will increase or decrease annual precipitation (↑GMet, 2025). While these precipitation patterns do not show anything conclusive with respect to vulnerability to climate hazards, they present a detailed picture of precipitation patterns that are key influencers in exposure to other climate hazards, in particular, flooding and drought.

4.3 Flooding

4.3.1 Mapping Ghana's vulnerability to flooding

To assess Ghana's exposure to flooding, an experimental multivariable model was developed to assess flood risk.[7] This involved conducting a multi-criteria analysis to combine publicly available datasets on flood risk. These variables were processed and assigned weights to reflect their relative importance, producing a flood risk index map for the country (see Figure 6). It is important to note that this hazard is a static assessment that identifies where flooding is most likely to occur based on environmental factors and does not include risk based on social data (such as population density), coastal flooding, or how risk varies throughout the year. The full methodology, including limitations, for determining flood risk is outlined in Annex E. However, it is important to note the similarity of the results to other models, which highlight that flood risk is greatest in coastal areas and in northern regions of the country (particularly around Tamale), despite it being unclear how comparable the variables used across the models are.

[7] It is important to note that this model is one potential way of mapping risk, and other flood risk projections, such as those developed by the Ghana Climate Vulnerability Hub (see https://ghclimatevulnerabilityhub.com/floodrisk.php), Flowminder (see https://www.flowminder.org/what-we-do/population-distribution-and-mobility-analysis/disaster-management/dynamic-hazard-risk-mapping-in-ghana) and the International Water Management Institute (see https://www.arcgis.com/home/item.html?id=4dd577ee1b6c402ba6e0259e891b387a), should be consulted for a comprehensive picture. However, it is unclear how these models were calculated, with many also presenting multi-hazard risk models, and other models not being publicly accessible. Therefore, despite the limitations of the model used for this review, it represents a contribution by describing the methodology and data used to underpin it (Annex E) in a publicly available source.

Figure 6: *Flood risk index for Ghana*

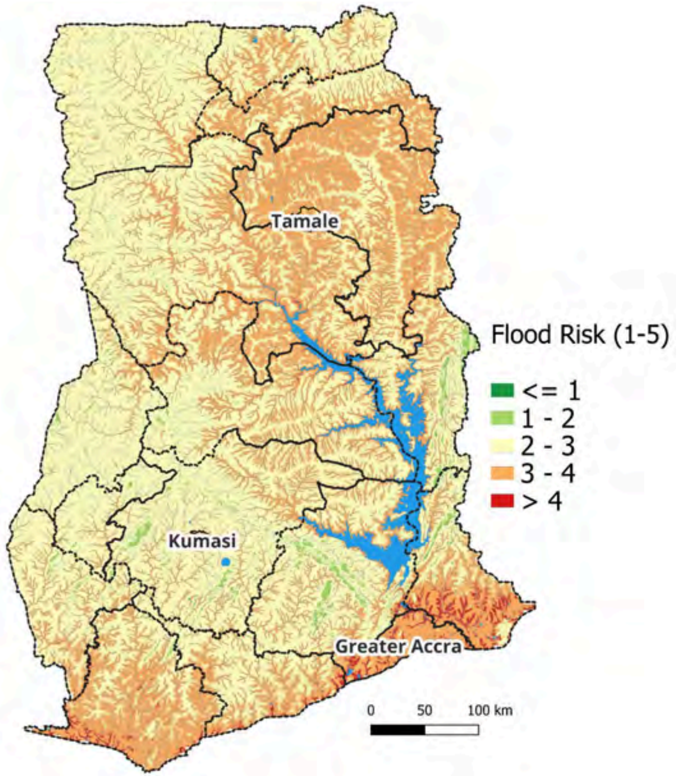


Figure 7: *Regional flood risk index for Ghana*

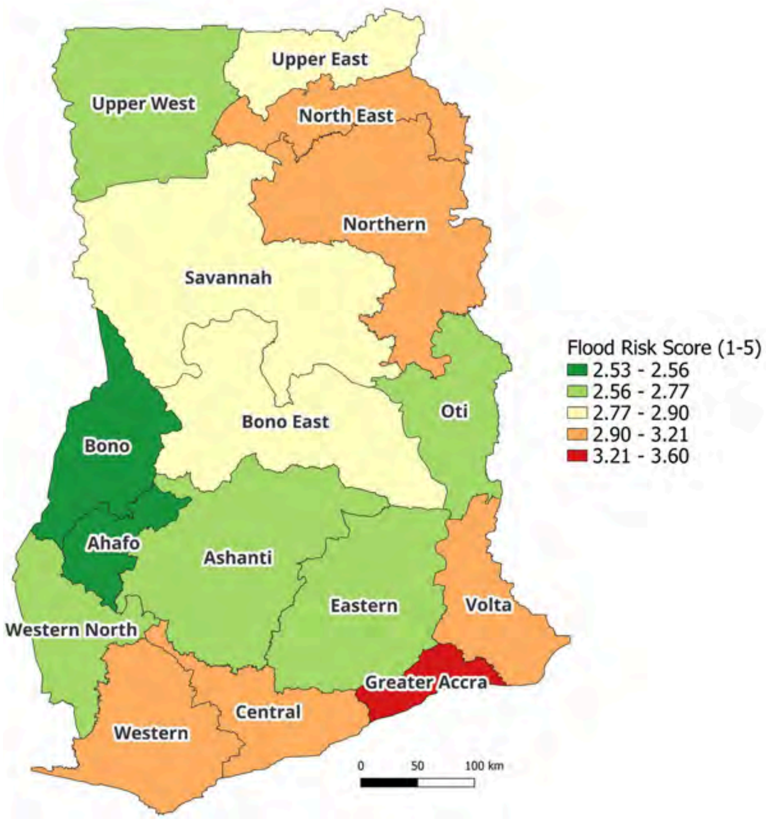


Figure 6 and Figure 7 show that year-round, coastal areas are more prone to flooding, even without accounting for coastal flooding in the model. The southeastern coastal strip and the Greater Accra Region are particularly at risk of flooding. In the centre of the country, there is a lower risk of flooding in the areas around Kumasi and East of Lake Volta, due to their significant elevation. In the northern areas, there is a relatively greater flood risk in the Northern Region and the areas around Tamale, partly due to the high concentration of rivers in this area. This corroborates existing evidence that anthropogenic patterns (such as unregulated urban expansion) are contributing to relatively heightened flood risk in cities in Ghana (↑Abass et al., 2022).

While not captured in Figures 6 and 7, it is also worth highlighting the impact of the opening of the Bagre dam, which causes regular, significant flooding in the White Volta basin in the northern regions (↑Atubiga et al., 2023; ↑Kansuk & Chimbar, 2020). While the timing can be erratic, spillages usually occur during the rainy season between August and September and are linked to the monsoon rains in Burkina Faso (↑Atubiga et al., 2023; ↑Kansuk & Chimbar, 2020).

Flood events in 2024

To demonstrate the prevalence of real flood events and to help contextualise and test the logic behind the flood risk index, 2024 flood events were mapped. The objective was not to model the intensity or duration of individual flood events, but to identify the number of 5-day periods in 2024 during which a given location was detected as having flooded land, as a proxy for flood frequency and persistence. The methodology for this process is outlined in Annex E.

Figure 8: *Number of 5-day periods in 2024 where land was detected as being flooded in Ghana. Data source:* ↑Ma et al., 2025

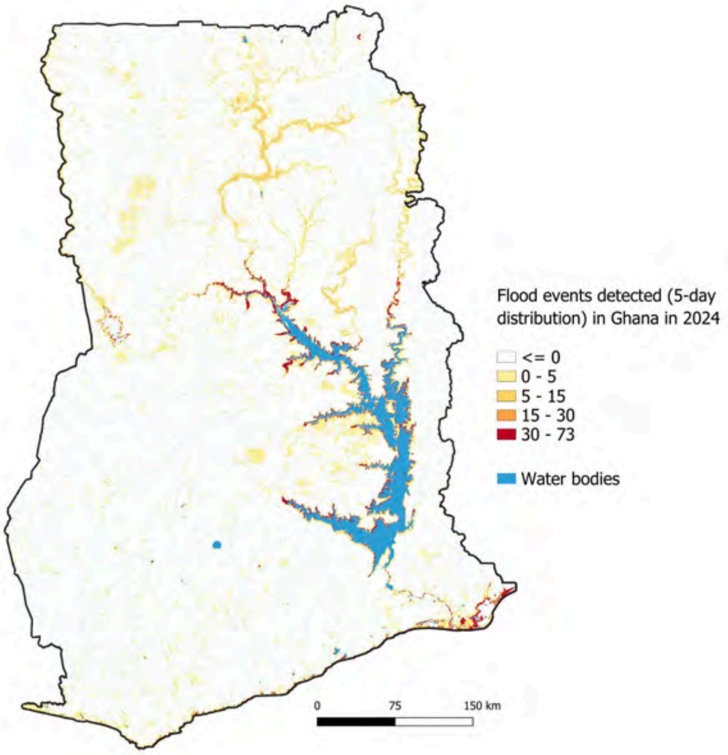


Figure 8 aligns with the flood risk index (Figure 6), as in 2024, the southeastern coast experienced a significant number of detected flood events over a 5-day period. There were also a significant number of flood events over 5-day periods in tributaries around Lake Volta and in the fluvial systems of the Northern and North East Regions of the country. This supports the analysis in Figure 6, which shows that these areas have a relatively higher flood risk than most of the country. However, Figure 8 does not support Figure 6 in identifying the remaining coastal areas as having a significantly greater flood risk, due to the low number of flood events in this area in 2024.

Because Figure 8 shows data for only one year, it cannot conclusively prove or disprove the logic underpinning the flood risk index. However, it is useful to highlight the key similarities and differences between the underlying vulnerability to flooding and the actual recent flood events. Broadly, though, these analyses demonstrate consistent agreement that the southeastern coastal areas and fluvial systems around Lake Volta and the Northern Region are particularly vulnerable to flooding.

To examine differences further, the analysis was split by dry season (January–March 2024 and November–December 2024) and rainy season (April–October 2024). For the purposes of the analysis, these were the benchmarks used for the seasons, but it is important to recognise that there are temporal variations in this seasonality across different parts of Ghana. The results of this analysis are shown below in Figure 9 and Figure 10, respectively.

Figure 9: *Number of 5-day periods in the 2024 dry season where land was detected as being flooded in Ghana. Data source:* ⇡Ma et al., 2025

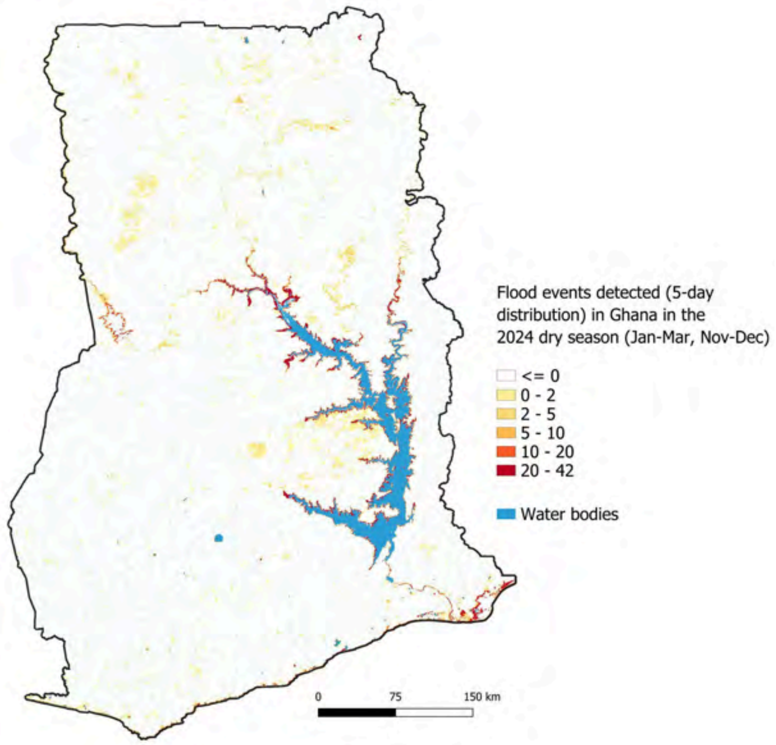
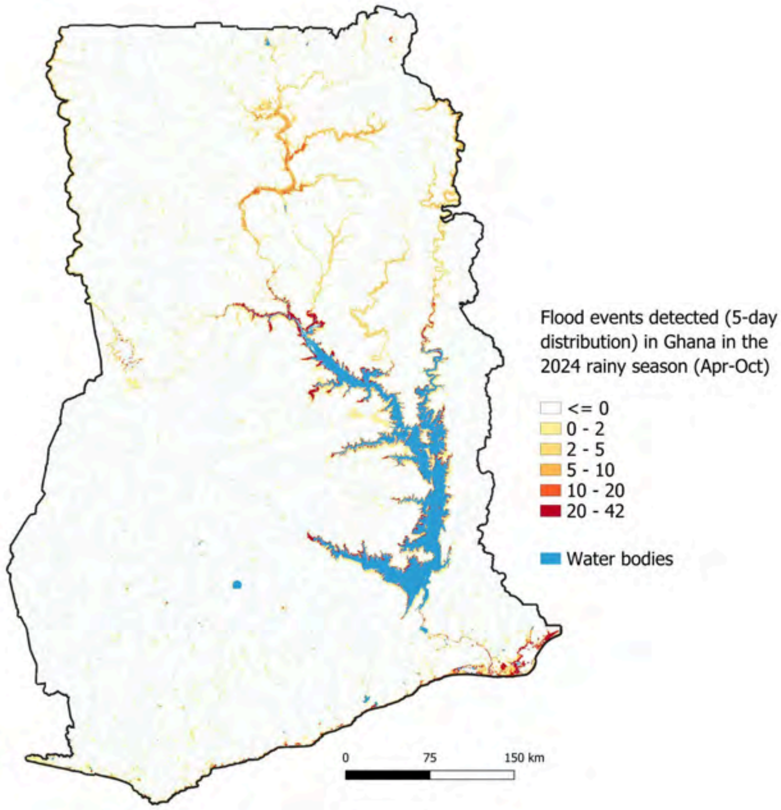


Figure 10: *Number of 5-day periods in the 2024 rainy season where land was detected as being flooded in Ghana. Data source:* ↑Ma et al., 2025



Figures 9 and 10 show seasonal flooding in 2024. While some areas (particularly the southeast and Lake Volta tributaries) experience year-round flooding, most fluvial flooding in the northern regions occurs during the rainy season (April–October). While this is perhaps an obvious conclusion, it is nonetheless a helpful illustration of the temporal variation regarding flooding vulnerability in these areas, compared to the year-round flood risk in the southeast. In the dry season, the Visible Infrared Imaging Radiometer Suite (VIIRS) satellite data shows flood water coverage across small patches in the central and northern parts of the country. However, it is important to emphasise that this is unlikely to be rainfall-driven flooding, but surface water caused by human activity. The VIIRS satellite data reflects water coverage and does not distinguish between natural flooding and human-induced water coverage. Therefore, these patches in the dry season are likely related to agriculture, such as irrigated fields or small reservoirs reserved for irrigation and livestock. As a result, this indicates agricultural activity rather than flood risk. These figures demonstrate that, while year-round flooding risk exists in many of the most vulnerable areas, large-scale river overflows present a risk during the rainy season, particularly in the northern areas of Ghana.

This analysis also helps confirm the validity of the flood risk model (see Figure 6). The predicted high-risk zone in the southeast of the country was affected by year-round flooding in 2024. The high-risk areas weighted by proximity to rivers, particularly in the northern areas of Ghana surrounding Tamale, show a strong spatial correlation with measured flood events during the 2024 rainy season. This emphasises that fluvial flooding is a dominant hazard in the northern regions, and that this risk is acutely concentrated within the rainy season, likely linked to the opening of the Bagre dam.

4.3.2 Impact of flooding on education

Two studies from the literature review examined the impact of flooding on education in Ghana, focusing on schools in Sagnarigu Municipality, Northern Region, and coastal communities in the Western Region. The findings indicate that flooding can cause significant damage to school infrastructure and learning materials, which negatively impacts attendance in the short term and enrolment in the long term (↑Mensah et al., 2023; ↑Prah et al., 2023). For example, ↑Prah et al. (2023) document the suspension of flooded schools in coastal areas of the Western Region and the temporary relocation of children to low-risk schools. While these schools are safe, they are often farther away and can be difficult to reach, creating a disrupted pattern of school attendance that results in flood-affected students having lower attendance during disruptions. However, these authors do not provide quantified details on the impact on learning outcomes or other measurable educational variables, and ↑Prah et al. (2023) suggest a need for further research on the academic performance of students relocated by coastal flooding.

School closures due to flooding are a significant challenge in other parts of the country, with over 100 schools closed in 2023 alone, impacting 34,000 children nationwide (↑UNICEF USA, 2025). Schools and districts located in dammed river basins are particularly vulnerable to closure during seasonal flooding; for example, over 300 schools were closed in 2023 due to spillages from the Akosombo dam, affecting 34,000 children and leaving nearly 20,000 students out of school (↑Senyah, 2023; ↑UNICEF, 2025).

Additionally, a study of two flood prone districts in the White Volta basin found that during dam spillages, participants of the study reported damage to school buildings, the use of school buildings as temporary community shelters (and hence the suspension of class activities), and lower attendance due to children being less able to travel to school safely due to flooded roads (↑Asamoah et al., 2024). The use of school buildings as temporary shelters is significant because it means that communities whose schools are not affected by floods also have their learning suspended, as flooding disrupts education in adjacent communities. The study also reported qualitative reflections on slower academic progression and lower attainment among students from flood-affected families, particularly due to livelihood disruptions that reduced the means to support education and learning materials (↑Asamoah et al., 2024).

These reported challenges are not surprising. In a report modelling different flood scenarios, ↑Desjonqueres et al. (2024) found that accessing education during large-scale flood events is likely to be a significant challenge across most of the country. Global evidence suggests that flood-related disruptions can have a significant negative impact on learning. For example, ↑Abrigo et al. (2024) assessed the impact of typhoons and flooding in the Philippines using 2019 TIMSS results, finding an average decline of 12%–14% in standard deviation for maths and science attainment for Grade 4 learners. This decline is equivalent to half a year's worth of learning and exceeds the comparable per-day learning losses observed during Covid-19-related school closures (↑Abrigo et al., 2024). Therefore, it is likely that flood-related school closures and accessibility challenges are negatively impacting learning outcomes. However, more rigorous research is needed to fully understand the short- and long-term impacts of flooding on education outcomes in Ghana.

4.4 Drought

4.4.1 Mapping Ghana's vulnerability to drought

A baseline drought hazard analysis was conducted to assess which areas of Ghana are inherently most vulnerable to drought, based on long-term climate data. It is important to note that the analysis does not focus on anthropogenic factors that cause drought, but rather maps the long-term climatological water deficit, which serves as a proxy for drought exposure. The methodology used for this process is outlined in Annex F. In the final figures, the value <1.0 indicates a 'water-deficit' environment throughout the year, and the value >1.0 indicates a 'water surplus' environment throughout the year. According to the United Nations Environment Management Group (↑UNEMG, 2018) 'drylands' are areas with an aridity index of <0.65, with the following further classifications :

- Hyper-arid (<0.05)
- Arid (0.05-0.20)

- Semi-arid (0.20-0.50)
- Sub-humid (0.50-0.65)

Figure 11: *Long-term (1981–2010) aridity index of Ghana. Data source:* ↑Karger et al., 2021

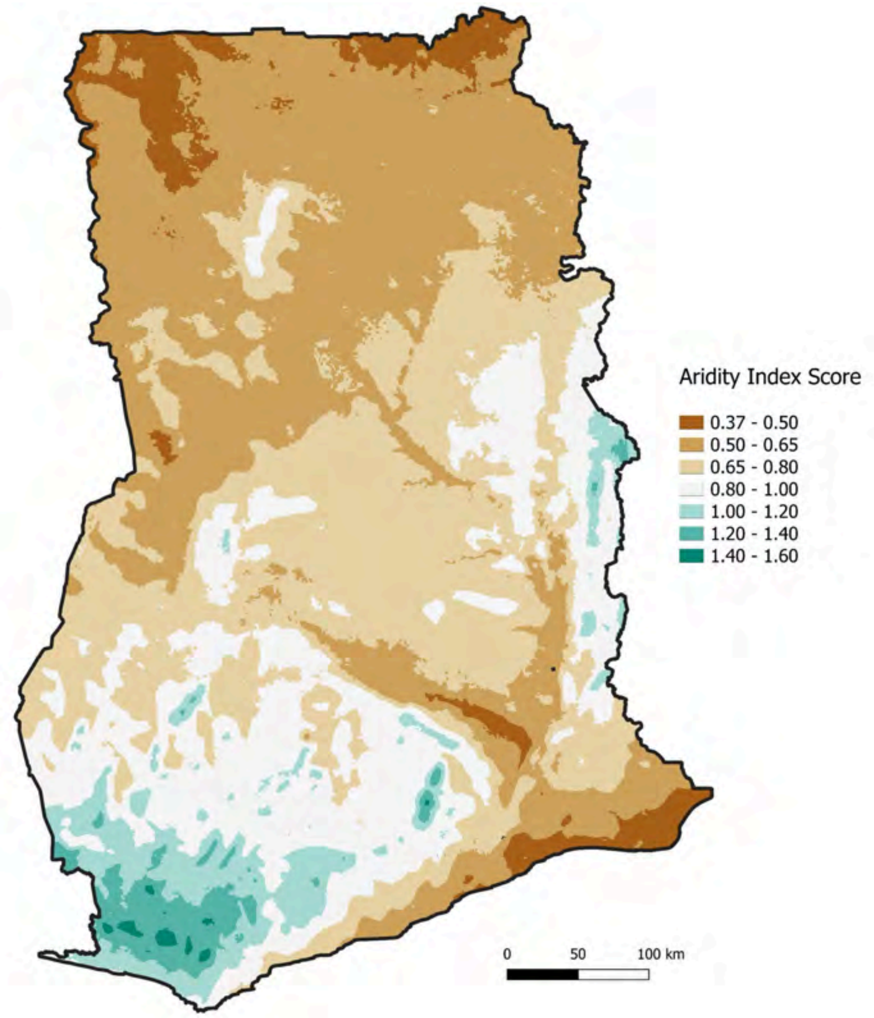


Figure 11 shows that much of Ghana is considered 'dryland' according to the UNEMG definition. This is particularly the case in the Dahomey Gap and in the north of the country, areas which are the most vulnerable to drought due to their relative dryness, and the lowest aridity index (~0.37, 'semi-arid') in Ghana. This data is supported by evidence from other sources indicating that the risk of water scarcity is much higher in the country's northern regions, and by communities from these areas noting their low resilience to droughts (↑Boafo et al., 2020; ↑World Bank, 2021). The southwest of Ghana, as well as the eastern strip of high precipitation, are the only areas where the aridity index exceeds 1 (due to high precipitation), suggesting that most of Ghana is vulnerable to drought based on long-term climatic conditions.

Further analysis indicates how dryness or drought patterns (again conceptualised as the climatological water balance) have shifted in recent years. The analysis used the Standardised Precipitation-Evapotranspiration Index (SPEI) data over a recent 5-year period (January 2020–December 2024), asking the question "*How relatively dry or wet have areas been over the past 5 years, compared to their 30-year climatological average?*" (see Annex F for the full methodology).

Figure 12 and Figure 13 show similar spatial patterns for exposure to dryness or drought. These figures both demonstrate that the central regions, particularly around Lake Volta, have generally experienced higher incidences of relative drought or dryness over the past 5 years. They also highlight that the northern parts of Ghana, which are the hottest, have experienced the fewest incidences of relative dryness over the past 5 years, particularly during seasonal (SPEI3) dryness.

Figure 12: *Number of months between 2020 and 2024 when SPEI3 was below -1.0 (representing short-term or seasonal drought conditions). Data source:* ↑Keune et al., 2025

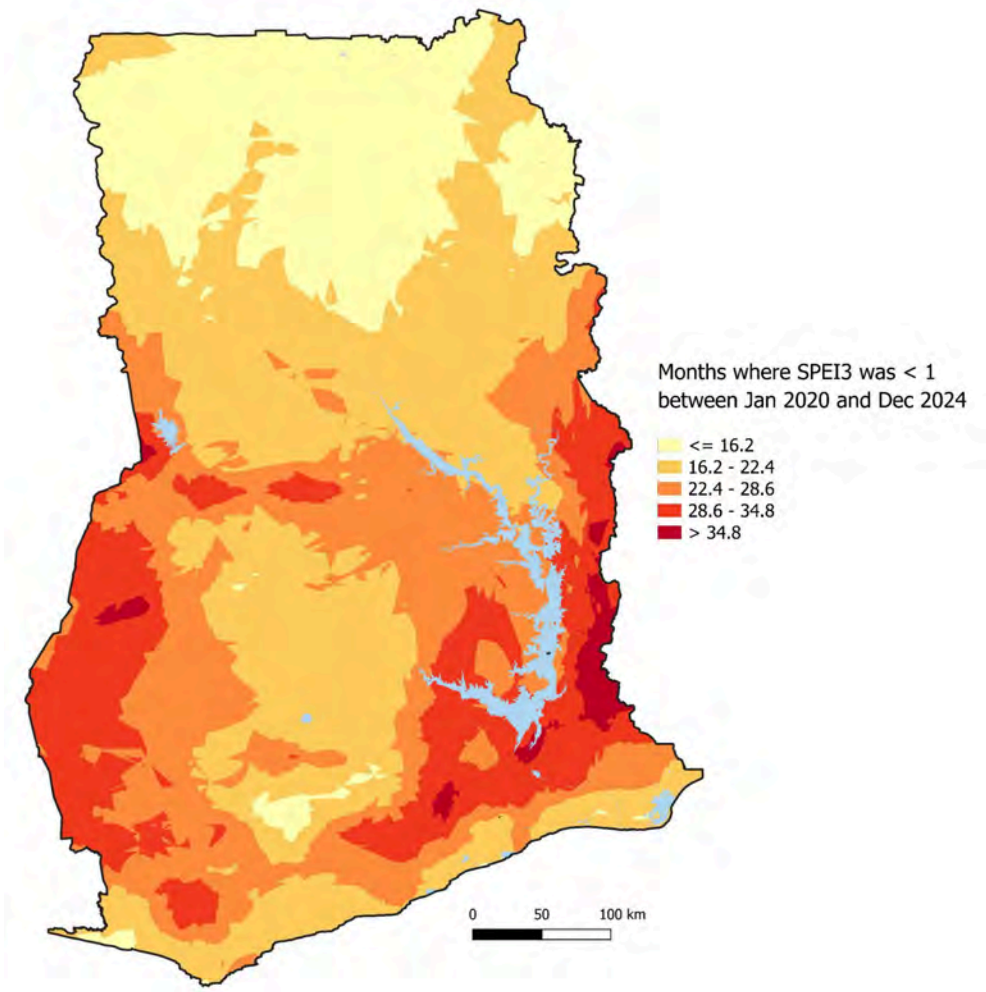
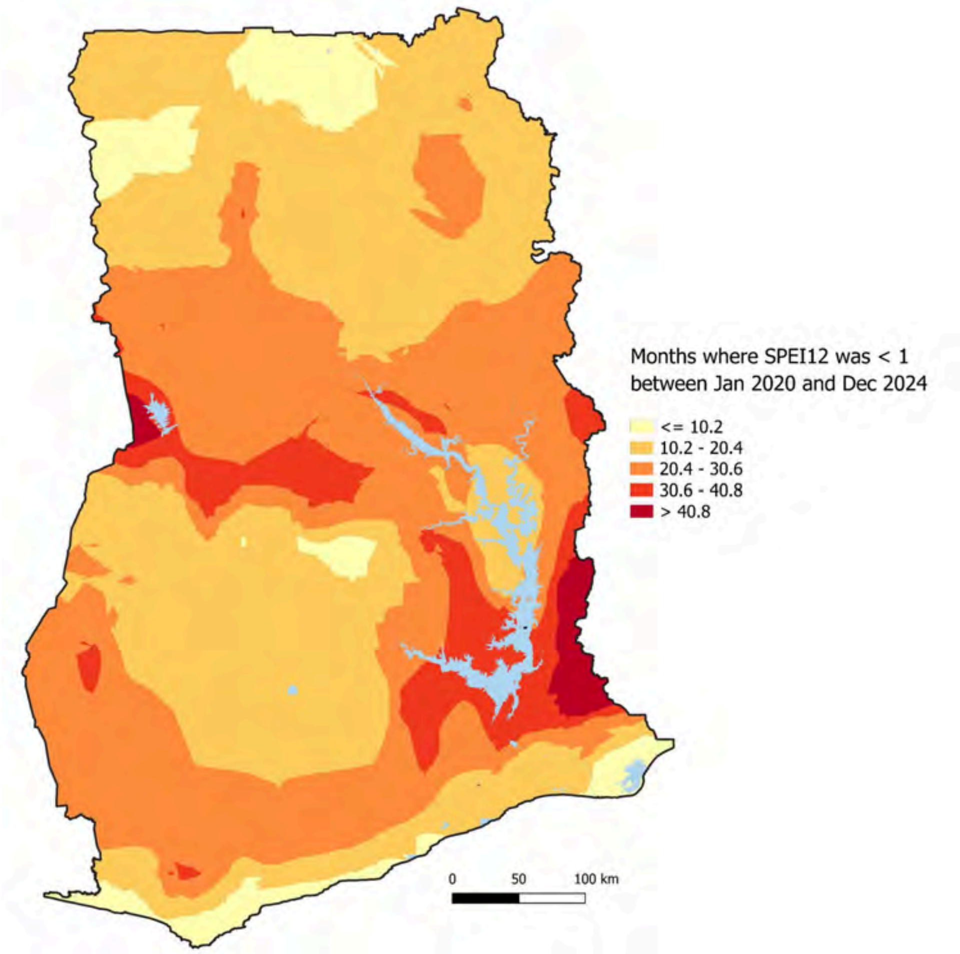


Figure 13: *Number of months between 2020 and 2024 when SPEI12 was below -1.0 (representing long-term drought conditions). Data source:* ↑Keune et al., 2025



While this may seem counterintuitive to the climate patterns of temperature, aridity, and precipitation outlined previously, it is important to emphasise that Figures 12 and 13 show incidences of *relative* dryness between 2020 and 2024 compared with their 'expected' long-term climatological norms. These figures do not show which parts of Ghana are most exposed to drought (as earlier illustrated in Figure 11). Instead, Figures 12 and 13 demonstrate that the darker red areas in the central and southern areas have experienced more frequent and significant decreases in their SPEI in that 5-year period, indicating a higher frequency of exposure to dryness relative to their own climate, which is cooler and wetter. The climate patterns that drive precipitation and potential evapotranspiration (PET) are becoming less reliable or changing more rapidly in these areas than in the rest of the country. These areas, therefore, are experiencing their climate 'drying out' more rapidly. The relative lack of change in the northern areas of Ghana (which are also the hottest) indicates fewer incidences of increased dryness than their long-term 'climate normal'. This finding is directly supported by ↑Desjonqueres et al. (2024), whose own analysis shows that regions with moderate temperatures and abundant rainfall are those experiencing the most extreme variations in their SPEI.

4.4.2 Impact of drought on education

None of the studies included in the literature review examine the impact of drought on education in Ghana. However, qualitative assessments have noted how drought conditions shift priorities away from education to other activities. For example, students in Yendi, Northern Region, have been found to travel farther to access clean water, resulting in later school attendance and reduced concentration in class (↑Fugu, 2023).

Studies from elsewhere on the African continent continue to outline how drought can impact education. One study in Uganda indicates that negative exposure to rainfall shock can reduce school attendance by nearly 10% (↑Agamile & Lawson, 2020), while an exploratory analysis found drought was likely to reduce years of schooling across sub-Saharan Africa (↑Mariussen, 2022). Conversely, ↑Nordstrom & Cotton (2025) found that drought exposure among girls in rural Zimbabwe increased attendance (particularly for the poorest), whereas girls experiencing food insecurity (a realisation of drought impacts) had lower learning assessment scores. This study emphasises the importance of examining attendance and outcomes in relation to the impact of drought and its subsequent impacts on livelihoods.

This evidence provides a mixed and incomplete picture of the impact of drought on learning outcomes in LMICs. Further research is needed to determine the impact on learning outcomes and to identify potential mitigation strategies for drought, especially given its slow onset and long-term nature compared to other climatic hazards. However, the importance of food assistance highlighted by ↑Nordstrom & Cotton (2025) suggests that ensuring the reliable functioning of the School Feeding Programme in Ghana could be an appropriate step to mitigate impacts on learning in situations of drought.

One regional study in West and Central Africa looked at the impact of rainfall on predicted years of schooling. Results indicated that, for children in the most educated households, those who experience 2 standard deviations (SDs) below average early-life rainfall have 1.8 years fewer predicted years of schooling compared to those who experience 2 SDs above average early-life rainfall. This number fell to 1.4 years of schooling for children whose household head has a primary education, and 0.8 years for children from the least educated households (↑Randell & Gray, 2019). This finding emphasises that relatively dry conditions can have a significant negative impact on expected schooling. It outlines a potential link between household education levels and how climate patterns (in this case, increased dryness) consequently impact education. This merits further research to explore how climatic impacts on education vary in relation to other social or demographic variables at a household level.

The notion of household variables being significant in determining the impacts of climate on schooling is further supported by ↑Asare & Forkuor, 2024), who highlight that, among farming families in Bongo District, Upper East Region, climate change has increased incidences of child marriage for girls (as it reduces the number of mouths to feed at a familial level). Among other negative consequences, this reduces their attainment and attendance in school, as increased familial responsibilities are prioritised once married (↑Asare & Forkuor, 2024). Once again, this demonstrates how household demographics and decision-making are interacting with climatic factors to disrupt education.

5. Approaches to build a climate-resilient education system in Ghana

This section examines approaches and networks that have been or could be utilised to build a climate-resilient education system in Ghana. This includes the following aspects:

- A stakeholder map of government departments, developmental partners and other actors that are well placed to support climate-resilience initiatives within the education sector.
- An overview of existing policies or initiatives in Ghana that aim to improve the climate resilience of education infrastructure or systems, including consideration of the barriers and enablers to implementing such policies and interventions.
- A thematic mapping of evidence indicating ways to strengthen climate resilience through the existing education system.

5.1 Stakeholder mapping

Using publicly available information, Table 5 below presents an overview of stakeholders who are, or could be, well positioned to support climate-resilience-building initiatives in education in Ghana. Table 5 includes summaries of each stakeholder's remit of responsibility and known work in this area.

Table 5. *Stakeholder map for building climate resilience*

Stakeholder	Stakeholder type and geographical scope	Summary of stakeholder work	Summary of how stakeholders are or could be engaged in building climate resilience building in education in Ghana	Citations
Ministry of Environment Science, Technology and Innovation (MESTI)	Government Department, National	MESTI leads policy development for the environment, science, technology and innovation, coordinating intersectoral work for climate action and sustainable development.	MESTI oversees the implementation of the National Climate Change Policy (NCCP) and Green Economy Learning Strategy. The body provides leadership for integrating climate resilience into education, chairs multi-sector implementation of climate action, and supports curriculum integration and teacher training in collaboration with the Ghana Education Service and the Environmental Protection Agency (EPA).	↑Unitar, 2015 ↑MESTI, 2016b ↑UNESCO, n.d. ↑Unitar, n.d.
Environmental Protection Agency (EPA)	Government Department, National	The EPA sits under MESTI as the technical body responsible for coordinating climate initiatives, compliance with climate resilience policies (including disaster risk reduction) and delivering public education on the environment.	The EPA supports schools and educational institutions with knowledge on climate change adaptation, coordinates awareness and community campaigns, and provides evidence-based recommendations for education system reforms. It works with the Ghana Education Service (GES) on teacher training on the 'Climate Change and Green Economy Learning Strategy', which also encompasses public education. The national climate data hub, under the EPA's climate change unit, is used to enhance capacity and knowledge sharing on climate change issues.	↑Unitar, 2015 ↑UNDP & UNEP, n.d. ↑MESTI, 2016b

Stakeholder	Stakeholder type and geographical scope	Summary of stakeholder work	Summary of how stakeholders are or could be engaged in building climate resilience building in education in Ghana	Citations
Ghana Education Service (GES)	Government Department, National	Lead body that implements and monitors education policy, manages curriculum reforms, integrates climate change into curricula, and trains teachers.	GES mainstreams climate change and green economy concepts in basic education, led national efforts to revise curricula and train teachers, and partners with NGOs and multilateral organisations for rollout.	↑Nkansah, 2024
Ministry of Education (MoE)	Government Department, National	Overall coordination of education, planning, budgeting, and delivery, including infrastructure improvements.	The MoE supports school-level climate adaptation through infrastructure upgrade policies and guidance for district and regional offices, linking climate policy with broader educational outcomes. The MoE organises national forums and multi-stakeholder platforms to foster consultation on sustainability, climate change, and education policy, working with the Ghana National Association of Teachers, the National Teaching Council, and other partners. The Ghana Education Trust Fund (which finances infrastructure) could be made contingent on climate-resilient design practices.	↑GNA, 2021 ↑UNESCO, n.d.

Stakeholder	Stakeholder type and geographical scope	Summary of stakeholder work	Summary of how stakeholders are or could be engaged in building climate resilience building in education in Ghana	Citations
EduSpots & Climate Education Community of Practice (CECOP)	NGO/Network, Regional (operating in 50 'spots', i.e. community-led education centres across 11 regions in Ghana).	Coalition of 10 Ghanaian NGOs focused on complementary climate education for schools, student-centred practical activities (such as EcoSTEM challenges aiming to build practical science, technology, engineering and mathematics (STEM) and sustainability education), and community-driven innovations for climate learning.	EduSpots facilitates CECOP, enabling peer exchanges, toolkits, pilot projects, and teacher workshops to advance locally relevant climate resilience. It is funded by the Gower Street Trust, active in rural and peri-urban schools.	↑EDUSPOTS, n.d. ↑EDUSPOTS, n.d.
CAMFED Ghana	NGO, Regional (primarily Northern Region)	Supports girls and rural communities through education, focuses on gender-responsive climate resilience and digital skills, and supports teacher professional development.	CAMFED runs digital climate education projects with experiential learning for girls, aligns with climate-smart agriculture, and partners with governments on strategies for climate-resilient education in rural schools. It has partnered with the Centre for National Distance Learning and Open Schooling (CENDLOS) to expand the reach of digital climate education programmes.	↑60 million girls, no date ↑CAMFED, n.d.

Stakeholder	Stakeholder type and geographical scope	Summary of stakeholder work	Summary of how stakeholders are or could be engaged in building climate resilience building in education in Ghana	Citations
Green for Change Ghana	NGO, Tamale	Champions climate action, natural resource protection, and community ecosystem conservation, focusing on youth engagement	Implements climate resilience and environmental education in schools and communities, and is recognised for championing local leadership and practical conservation solutions.	↑Joy Online, 2025
Gower Street Trust	Financial institution, National	Philanthropic funding for climate education innovation and partnerships.	The trust funds CECOP, recognised as a catalyst for scaling community-driven climate education and teacher training for resilience. It supports NGO collaboration and pilot projects.	↑EDUSPOTS, n.d.
Rights & Advocacy Initiatives Network – (RAIN) Ghana	NGO, Kumasi	Wide range of work in education access, community climate adaptation, and youth leadership development through networks and capacity-building.	RAIN participates in CECOP and similar initiatives, delivering school and district-level projects to build climate resilience through student and teacher engagement, curriculum tools, and community partnerships.	↑EDUSPOTS, n.d.
National Disaster Management Organisation (NADMO)	Government Agency, National	Has a mandate to manage disasters and emergencies, with a focus on response and relief efforts.	NADMO is engaged in response to climate emergencies. An increase in their financing could shift their approach from reactive emergency response to Anticipatory Action to disasters, including frameworks and processes to mitigate the impact of climate shocks on education.	↑OCHA, 2025

Stakeholder	Stakeholder type and geographical scope	Summary of stakeholder work	Summary of how stakeholders are or could be engaged in building climate resilience building in education in Ghana	Citations
UNICEF Ghana	International development partner, National	UNICEF works across the globe to promote the well-being of children, focusing heavily on WASH, education and safety.	UNICEF is working in West and Central Africa (including Ghana) to implement the regional Green Schools Initiative (GSI), which aims to build resilience and accelerate climate action for children in and through education. UNICEF also provides temporary classrooms and learning materials to communities affected by climate-related disasters, and plans to mainstream climate-focused interventions across its programmes and expand climate-resilient education infrastructure.	↑UNICEF, 2024 ↑UNICEF Green School Initiative, 2024 ↑UNICEF, 2025
World Bank	International development partner/financial institution, National	Provides large-scale funding for climate and disaster-resilience initiatives and infrastructure.	Recent World Bank funding includes the USD 150 million financing for the Greater Accra Resilient and Integrated Development Project (GARID), which improves flood risk management and supports communities, schools, and education systems in flood-prone areas. GARID supports resilient infrastructure, drainage improvement, solid waste management, and climate adaptation measures in the Accra region, and indirectly increases school safety and continuity during disasters.	↑World Bank, 2023b

In the literature screening undertaken as part of this landscape review, several sources had findings related to climate-resilience building in Ghana. This section presents an overview of this literature – it is not an exhaustive stakeholder analysis, but presents supplementary findings to the map in Table 5.

A number of sources discussed successes and challenges associated with different levels of governance in Ghana (local, regional, national, etc.). ↑Musah-Surugu et al. (2019) assessed the capacity of six local governments (LGs) to adopt decentralised governance of climate change adaptation, finding that effective local governance relies on cooperation between local and central governments, crucially with appropriate powers ceded to the local level.

Several studies, however, found that LGs often lack the appropriate power to implement effective localised governance of climate change adaptation. ↑Musah-Surugu et al. (2019) note that LGs have limited internal capacity to implement this kind of governance and must balance competing priorities and limited resources. This is reflected in comments from LG practitioners who expressed that any locally led implementation of climate change adaptation would be slow and sporadic, owing to their lack of capacity and means (↑Musah-Surugu et al., 2019). Additionally, ↑Alhassan & Hadwen (2017) conclude that climate change has not been mainstreamed into WASH development planning because the adaptive capacity of municipalities themselves is low. ↑Asante et al. (2015) further argue that, at the local level, there is little awareness of the content of the National Climate Change Policy (NCCP) and of what is required of sub-national governance structures to deliver on policy objectives. Therefore, local administrative bodies often lack the capacity or means to successfully take on governance of climate change adaptation measures.

Due to perceived limitations in local governance, several studies examine the nature of top-down governance and policy in implementing climate change adaptation. ↑Alhassan & Hadwen (2017) note that climate change in national development policy has been very top-down, with little accompanying legislative support at the local level. This is supported by ↑Ofoegbu & New (2021)'s discussion of governance in the agriculture sector, which argues that measures are too often directed from a centralised or national level rather than locally led. This leads to adaptation efforts being ineffective at addressing local challenges and not supporting structures for farmers to provide feedback on local conditions and challenges that should be prioritised. This points to a critical need to strengthen local governance of climate change adaptation; yet there are often few structures or little legislation in place at the local level to enable local governments to effectively integrate climate change adaptation into their work or coordinate efforts across different sectors and stakeholders (↑Alhassan & Hadwen, 2017).

In terms of solutions, ↑Alhassan & Hadwen (2017) suggest there are opportunities for improved localisation through increased awareness and capacity, as well as legislative or institutional changes. The same authors also recommend that continuous collection of reliable information on local climatic threats and exposures to accompany any policy shifts, so that stakeholders involved in resilience-building can access relevant information on specific challenges and climatic risks (↑Alhassan & Hadwen, 2017). Furthermore, ↑Echendu (2021) proposes regional partnerships for disaster risk reduction in the context of flood risk, arguing that Ghana and Nigeria could collaborate on risk assessments, monitoring, data sharing, and resource pooling to strengthen their responses to flooding.

While challenges have been identified with top-down governance, ↑Amponsah (2022) recognises that Ghana's natural hazard emergency response has improved significantly since the establishment of the National Disaster Management Organisation (NADMO) in 1996. However, ↑Amponsah (2022) also asserts that resource constraints mean NADMO mostly engages in post-disaster management, which points to the need for improved data, frameworks, and systems to be in place for more anticipatory action, which could act pre-emptively to climate risks rather than reactively.

Other sources also discuss the potential for financing climate change adaptation and mitigation across multiple sectors in Ghana. Although slightly outdated, ↑Asante et al. (2015) examine the landscape of climate change financing in Ghana, noting that the NCCP has a small budget for its overall objectives, with no stated funding strategy or documented processes. This lack of capacity and detail means it is likely to fall short of its stated objectives. Additionally, ↑Adshead et al. (2022) examine the viability of financing climate-resilient infrastructure across a range of key sectors. While education is not included, the authors suggest that a multi-sectoral approach, which includes education, could be a sensible step for building and financing climate-resilient infrastructure and systems. This may be viable given Ghana's existing financing for climate action, as outlined in the Nationally Determined Contribution (NDC). The NDC highlights the financial commitments to resilience, adaptation and mitigation measures in the face of climate change (↑EPA & MESTI, 2021). While financing for education is not specifically mentioned, there is USD 827m funding for citywide resilient infrastructure planning (↑EPA & MESTI, 2021). For this funding, the development of a multi-sectoral approach that includes education could be a critical step in ensuring climate-resilient infrastructure across a range of key public services. A full mapping of stakeholders engaged in NDC implementation is presented by ↑Onuoha et al. (2025). This mapping similarly concludes a lack of specific focus on education, although it does recognise a small number of NGOs, civil society organisations and research institutions across different sectors that are engaged in delivering education initiatives and awareness campaigns that aim to strengthen support for climate-resilience initiatives and practices.

Several sources assess investment opportunities, particularly from the private sector, for financing climate change mitigation and adaptation in Ghana. ↑Ahenkan (2020) examines financing across a range of sectors, acknowledging the need for private investment due to the shortfall in public finances. However, several studies note that the current climate finance market is not yet developed to support the required investment (↑Ahenkan, 2020; ↑Akomea-Frimpong et al., 2025). In particular, it is seen as a high-risk sector due to the lack of good-quality data to approximate risk and returns on investment. The dominance of short-term financing in Ghana is a significant barrier to pursuing long-term investment opportunities, as is often the case with climate financing (↑Ahenkan, 2020). Further issues identified include the relative volatility of the Ghanaian cedi and a lack of guidance from the government on what constitutes climate change financing for investors (↑Ahenkan, 2020). Another study also recommends the need for further government incentives to attract more private sector investment, as well as climate change sensitisation and education among the private sector to help steer activity towards climate change mitigation (↑Ahenkan et al., 2018).

5.2 Climate-resilience initiatives in Ghana

There is a lack of evidence on specific climate-resilience initiatives in Ghana's education sector. While not comprehensive, this section presents a selection of high-level initiatives or policies that have resilience-building as a key component.

The ↑National Climate Change and Green Economy Learning Strategy (MESTI, 2016a) aims to systematically integrate climate change and green economy concepts into the education system as a form of structured learning, in order to build climate literacy among students and ensure they possess sufficient knowledge to address climate-related issues in the future. It has led to curricula revisions to include climate change indicators (usually in science subjects), and is led by the Ministry of Environment, Science, Technology and Innovation (MESTI) and the Environmental Protection Agency (EPA), in partnership with the Ghana Education Service

(GES). This approach is supported by evidence across a range of contexts, which has shown people with higher levels of education demonstrate stronger preparedness for and resilience to disasters and can recover more quickly from shocks, such as by being more likely to stockpile essential supplies in advance of a climate disaster (↑Sabarwal et al., 2024). Climate change education is also a central part of Ghana's Action for Climate Empowerment (ACE) strategy, delivered through the EPA, in both formal and non-formal channels. The aim is for education to increase awareness of climate change, with a focus on inciting behavioural change and community action (↑EPA, 2020).

The programme ↑Empowering girls with digital climate education and experiential learning in rural Ghanaian senior high schools (60 million girls, n.d.) run by CAMFED is working with 3,500 students (the majority of whom are girls from rural and disadvantaged backgrounds) to expand climate education and equip girls with the skills and knowledge needed to build both digital literacy skills and climate resilience. The project delivers climate education aligned with the national curriculum, equipping girls with knowledge for adaptation and resilience, while also addressing disruptions to their education caused by climate events. The project has four key activities to achieve these goals:

- Enhance digital, science, technology, engineering and mathematics (STEM), and climate education for girls in rural schools through Mobile Learning Lab sessions co-facilitated by learner guides and teachers.
- Establish Climate Resilience Clubs as platforms for student-led innovative projects (e.g., sustainable water conservation, agroforestry).
- Organise community forums to share knowledge about climate change and climate action, to build resilience at the community level.
- Introduce CAMFED's Climate Education Curriculum to the government and adapt and integrate it to align with its objectives.

CAMFED has partnered with CENDLOS to record and broadcast climate-smart projects on Channel MOE (a curriculum-based TV station accessible digitally or via satellite). This collaboration will extend access to climate education and to the project's outcomes.

The ↑UNICEF Green School Initiative (2024) is a regional programme in West and Central Africa that focuses on building climate-resilient schools. There are four main pillars to the initiative:

1. The Foundational pillar aims to integrate climate action into education strategies, supporting governments to develop national strategies for disaster risk management and adaptation in education, and integrating climate resilience into education management information systems.
2. Pillar 1 aims to build climate-resilient and greener school facilities so that they can operate as normal during climate emergencies. This includes providing climate-resilient WASH facilities in schools, enforcing building codes and retrofit policies, and advocating for green spaces on school grounds.
3. Pillar 2 aims to strengthen school safety and protect educational continuity through mapping school capacity to overcome climate hazards and developing emergency response protocols, while ensuring schools have the appropriate support (e.g., early warning, psychosocial support) to act during emergencies.
4. Pillar 3 aims to promote disaster risk reduction and climate change education in curricula to ensure that students have sufficient knowledge and skills to respond to a changing climate, including skills for the green economy. This also includes investing in appropriate teacher professional development to support the education initiatives.

Through these pillars, the initiative aims to protect schools against the worst effects of climate shocks, build resilience and prevent school closures, as well as equip students with the long-term skills needed to participate in a green economy. The project is managed by UNICEF Ghana and implemented in coordination with the GES.

In terms of national policies, while the NCCP provides a comprehensive overview of adaptation to climate change across Ghana, there is very little detail or few specifics about the role of education (except discussing the need for climate change education at several levels), how to build resilience within the education sector, or the role of the Ministry of Education in delivering climate-resilient systems. Similarly, in its standards, the ↑National Schools Inspectorate Authority (2022, p. 21) includes directives such as, ensuring that “the roof is made of a safe material that doesn’t generate too much heat” and that the school compound “must not be flood prone” (p. 20). However, no specific standards for adhering to these objectives are provided, and the guidelines contain no other details on thresholds, processes or practices for building resilience to climatic hazards.

Evaluation or evidence from specific initiatives was distinctly absent in the screened literature. One study noted that school gardening programmes are rarely implemented in Ghana nor integrated into classroom curricula, but global evidence suggests such programmes can be an important contribution to environmental education, particularly for students and for community awareness of climate change adaptation techniques (↑Nalumu et al., 2021). However, its potential as a solution or successful initiative is largely untested in a Ghanaian context.

5.3 Opportunities to improve climate resilience through the education system

While evidence on the impact of climate-resilience initiatives is sparse, the literature indicates several ways in which resilience can be strengthened through the existing education system. Below, findings are grouped under three themes: cross-cutting infrastructural resilience, disaster risk reduction, and climate change education.

5.3.1 Cross-cutting infrastructural resilience

Research suggests that strategies to build infrastructural climate resilience within the education sector need to be holistic. The ability of schools and institutions to be resilient to specific climate hazards (such as extreme heat or flooding) often relies on a range of cross-cutting issues, including WASH and access to energy (↑Bangay, 2024). Beyond educational infrastructure, these variables are also significant at the household level in building climate resilience, which has implications for the education of children within households. Furthermore, infrastructure location planning can significantly enhance its resilience when accounting for vulnerability to climatic risk (↑Fab Inc, 2024). If infrastructure is strategically located in lower-risk areas, it is immediately more resilient against those risks without the need for further adaptations. Therefore, there are key cross-cutting areas affecting education that decision-makers should account for when developing education infrastructure resilient to multiple climatic hazards (↑Brugha et al., 2025).

↑Nsenkyire et al. (2023), for example, examined household multidimensional energy poverty across Ghana. They found that a 1 SD increase in multidimensional energy poverty reduces child education and cognitive skills by 0.13 and 0.402 SD, respectively, with children in energy-poor households less likely to be in formal education or to have access to energy-dependent tools or content at home that can enhance their education and cognitive development. This finding emphasises that energy-resilient infrastructure, both at home and within the education system, is significant in preventing a decline in education-related variables. This is particularly important given Ghana's reliance on hydropower, and the capacity to generate energy using this method may become strained as electrification increases and water becomes scarcer due to rising temperatures.

↑Alhassan & Hadwen (2017) explored the extent to which climate change adaptation has been mainstreamed regarding WASH in development planning. They found that it has been poorly adopted at the local level, with further investment needed so that stakeholders involved in resilience-building have access to relevant information for specific WASH-related risks and variables (↑Alhassan & Hadwen, 2017). WASH is important for building climate resilience in both households and schools. For example, if these facilities lack access to safe drinking water, any infrastructure adaptation efforts to reduce temperatures will be less effective, as children will suffer from dehydration, leading to significant heat-related effects on cognitive functioning. The lack of WASH integration into resilience-building, therefore, undermines the extent to which climate-resilient education systems can be built, and highlights the importance of infrastructural-related solutions (alongside energy supply) that address the multidimensional nature of specific climatic impacts on learning.

5.3.2 Disaster risk reduction

Several studies comment on the relationship between education and disaster risk reduction in relation to climatic events. ↑Mensah et al. (2023) found that during flooding, children often rely on their instincts to seek shelter in perceived temporary safe havens, as they lack knowledge of specific actions to take in a flood. They argue that this reality highlights the importance of integrating flood disaster management in school curricula in Ghana, so that children are equipped with the knowledge to undertake appropriate disaster risk reduction actions. Regarding coastal flooding in the Western region, ↑Prah et al. (2023) noted that when schools were sufficiently impacted to be temporarily closed, children were reallocated to temporary learning spaces. While these were in low-risk flood zones, they were often too far from students' houses to be regularly accessible, resulting in lower attendance rates than usual (↑Prah et al., 2023). This emphasises the importance of careful location planning with respect to temporary learning spaces or other planned climate-resilient educational infrastructure—balancing risk with opportunities for learning continuity—to make systems more resilient to flood risk (see also ↑Fab Inc (n.d.), which discusses this issue in the context of Sierra Leone).

Two further studies note a general lack of preparedness among educational institutions with respect to climate-related hazards. ↑Mohammed et al.'s (2025) survey of 120 facility managers from Higher Education Institutions across Ghana, found that most institutions are underprepared for natural disasters, lacking formal preparedness policies, an appropriate budget for disaster preparedness, or adequate knowledge among facility managers Furthermore, ↑Apronti et al. (2015) found significant gaps in disaster pedagogy in the curricula of basic schools and in classroom learning. Teachers tend to deliver preparedness information through lecture-style teaching rather than the interactive techniques recommended by the curricula, largely due to a lack of appropriate supporting teaching materials and insufficient professional development opportunities in this area (↑Apronti et al., 2015). While the observed teaching strategy was seen as creating something of a culture of prevention in basic schools, it does not foster a culture of resilience and appropriate safety measures among students. Therefore, it is argued that processes of disaster risk reduction training and integration into both curricula and teacher professional development should be strengthened in Ghana to enhance the institutional climate resilience of educational facilities to climate risks.

5.3.3 Climate change education and information for resilience

While climate change education (CCE) has been shown to directly enhance climate resilience in multiple contexts (↑Sabarwal et al., 2024), evidence from Ghana suggests opportunities to improve the curriculum and the quality of CCE delivery.

At the community level, one study in the Western and Central Region coast zones found that while a majority (53%) of residents agreed that District Assemblies (DAs) play a crucial role in delivering CCE, almost three quarters (72%) of those surveyed felt DAs had not provided adequate education to their communities in the past 5 years (↑Baffour, 2025). Additionally, slightly fewer than half (45%) felt that access to CCE from DAs was 'very poor' (↑Baffour, 2025).

At the school level, the literature indicates that low levels of knowledge about climate resilience may hinder effective action. Examining three cities across Ghana, ↑Ampong & Yadav (2025) found that while students are mostly aware of the impacts of flooding and drought, overall, they demonstrate low awareness of climate change issues, with misunderstandings and misconceptions (driven in part by social media) hindering their knowledge for productive adaptation efforts. This finding is echoed in a study focused on teachers, which found that pre-service knowledge of climate change and patterns (specifically ozone depletion) is basic (↑Nyarko & Petcovic, 2021). This is further emphasised by ↑Atuguba (2019), who surveyed teacher training colleges and found that teachers' experiences influenced their delivery of CCE, which came to reflect their personal values, attitudes, and knowledge towards the environment rather than following the curriculum. Clearly, teacher experience and knowledge are significant factors in shaping the quality of CCE that students receive and, therefore, will shape any resilience-building efforts that are delivered through curriculum-based CCE.

Evidence suggests that knowledge of climate change is important for facilitating action. ↑Akakpo et al. (2024) surveyed tertiary-age students in Accra, and found that their climate change knowledge was positively associated with pro-environmental behaviour (however, the nature of these behaviours was not described). Furthermore, ↑Akakpo et al. (2024) find that knowledge of climate change is associated with increased climate anxiety. Global evidence highlights how action-focused teaching could help alleviate student anxiety in the face of climate change (e.g., ↑Brophy et al., 2022; ↑Fuxman & Goddard, 2024; ↑Pikhala, 2020). Action-focused teaching has been identified as a weakness of current CCE efforts in Ghanaian education. Although slightly outdated, ↑Boakye (2015) examined relevant curricula from Grade 1 through to SHS, finding that CCE is only partially included and, crucially, that where it is taught, it is largely knowledge-based rather than action-focused. If this is still the case, existing CCE efforts may need to be restructured to place greater focus on how students can take meaningful action against climate change, not only to enhance practical steps towards building resilience but also to reduce student anxiety associated with climate change.

To improve the relevance of CCE and its ability to lead to meaningful action, several authors highlighted the importance of tying it to local experiences and climatic patterns. ↑Glago (2019) found that irrespective of their level of education, and due to their frequent experiences of flooding, residents in the West Akim Municipality, Eastern Region, had a high level of awareness of disaster risk reduction for flood events. This emphasises that lived experiences, in addition to formal education or information dissemination, are crucial in shaping people's understanding of climate change and for building resilience against its impact. Similarly, a study in the Greater Kumasi Metropolitan Area found that locals were much less likely to support nature-based solutions to flood risk due to a lack of awareness or evidence of its effectiveness compared to traditional 'hard' engineering solutions (solutions using non-natural materials such as concrete flood walls) (↑Enu et al., 2024). The authors contrast evidence on nature-based solutions from European studies, where a preference for 'greener' spaces and solutions was positively associated with higher levels of education, whereas in Kumasi, those with lower levels of education preferred nature-based solutions. This is an interesting contrast that underscores that evidence from high-income contexts cannot be assumed to be globally consistent, with local context essential to how education levels or initiatives influence responses to climate change.

6. Conclusion and recommendations

This report presents findings from a rigorous review of academic and grey literature and an analysis of historical satellite data to offer a comprehensive overview of existing research on climate and education in Ghana. The review highlights key vulnerabilities and potential solutions for building a climate-resilient education system. This concluding section draws on identified trends and gaps in the current evidence landscape to offer critical areas for future research and policy development.

Satellite data analysis identifies clear spatial differences in vulnerability to climatic hazards. The Upper West, Upper East, North East and Northern Regions are the most exposed to extreme heat and face a high risk of fluvial flooding during the rainy season due to both rainfall patterns and water release from the Bagre Dam. Additionally, the northern area of Ghana is the most arid. This suggests that these parts of the country are most exposed to extreme climatic hazards and should be the primary focus of any climate-resilience-building initiatives or research. Greater Accra and the surrounding area should also be the focus of flood-resilience efforts, given their high risk of this hazard.

There is, however, a clear lack of research on the direct and indirect impacts of extreme weather events on education. The literature identified in this review tends to discuss the impact of climate change either in terms of specific climatic variables within schools (e.g., temperature) or in terms of broader education trends, such as school closures and attendance levels. On the other hand, there is no evidence of the direct impact of climate-related events on learning outcomes. The research also often lacks specificity, either geographically or in terms of subpopulations. This undermines opportunities for evidence-based decision-making to enhance the climate resilience of Ghana's education system, especially since evidence from other contexts (especially high-income countries) may not cross-apply.

Finally, there are few initiatives and little existing policy that directly address both climate and education. While national policies and objectives to address climate change exist, education is rarely a central focus. Likewise, references to climate resilience within education policy are often nonspecific. This has resulted in a lack of clear guidelines and coordination efforts regarding targets, financial contributions, and organisational responsibility for building climate resilience in the education sector. In light of this scenario, recommendations to support future decision-making for research, policy and financing are grouped below

6.1. Recommended areas for research

Research is needed to explicitly determine the national- and regional-level impacts of climate change and climate events on learning outcomes in Ghana, as well as the effectiveness of different mitigation efforts. Without establishing the causal relationship between specific hazards and education outcomes, it will be challenging to design and prioritise appropriate response mechanisms. Specific priorities identified by the landscape review for further research are listed below.

1. Determine the temperature threshold(s) at which exposure to extreme heat begins to affect learning in Ghana negatively

While analysis clearly shows exposure to high temperatures, it is crucial to understand at what temperatures thermal comfort and learning performance are affected, given that regular exposure to extreme heat suggests this value is likely higher in Ghana than in other contexts where research has been conducted. Determining these specific thresholds is a vital precursor to designing any heat-reduction interventions or thermal regulations for indoor spaces.

2. Rigorously investigate what educational impacts are associated with different types of school infrastructure

Specifically, it is important to assess whether particular materials (including metal-roofed classrooms) are significantly correlated with poor learning outcomes and attendance, and to what extent this can be mitigated by adapting infrastructure.

3. Commission long-term rigorous research to determine the differences and interactions between rapid-onset and slow-onset climate crises and their impacts on education

Research on these issues should particularly focus on the northern regions of Ghana that are most exposed to both flooding and drought. Testing how these variables interact and how short- and long-term climatic impacts affect learning outcomes is critical to fully understanding the risks associated with specific climatic hazards.

4. Examine the potential of Ghana's existing School Feeding Programme as a strategy for mitigating the impacts of climatic hazards on education, particularly during drought

The literature suggests that access to food can improve access to education during drought conditions. Evaluating the impact of the School Feeding Programme may therefore be a sensible first step towards building evidence on drought response efforts in Ghana, given the comparative ease of scaling existing initiatives if proven impactful.

5. Assess trends in precipitation, attendance rates, and other seasonal variables

Currently, it is challenging to determine whether rainfall has a causal impact on school attendance or whether other factors, such as seasonal changes in agricultural practices, are stronger determinants. Further research to establish the relationship between these metrics will aid the design of school-level initiatives to boost attendance.

6.2. Recommendations for policymaking

Education needs to have a defined focus within Ghana's existing climate change policy and resilience initiatives. Currently, it is unclear how the education sector fits into broader efforts to build climate resilience. Cross-sectoral policy and coordination are required both to mitigate potential risks to children's learning and leverage opportunities for community-led resilience initiatives. Initial ways to achieve this are given below.

1. Establish specific roles and responsibilities for the MoE and relevant education agencies within the NCCP, alongside those of the EPA and MESTI

Cross-sectoral coordination is required to ensure a comprehensive approach to climate resilience. Defining the roles of the MoE and relevant agencies is a starting point for ensuring that the National Climate Change Policy (NCCP) and related policies can explicitly support education.

2. Develop clear targets and a mapping tool, aligned with the Basic Education Infrastructure Framework, to aid implementation of National Schools Inspectorate Authority guidelines

Standards should be aligned for both the construction of new school buildings and the assessment of existing school infrastructure to aid adaptation measures. Clear numerical targets should be set for climate-related metrics, including the target thermal range of classrooms (to support optimal environments for learning) and a clear definition of what constitutes 'flood-prone' (to support anticipatory action initiatives). Establishing specific metrics will provide a means for systematic measurement and compliance. The development of these standards should take place alongside the adoption of the recently revised Basic Education Infrastructure Framework to ensure alignment between the MoE, the National Schools Inspectorate Authority (NaSIA), and other relevant agencies. All standards and resources for assessing existing infrastructure should also be made easily accessible and actionable for district-level education officials, for implementation alongside existing Environmental Compliance guidelines.

3. Enhance NADMO's capacity to enable a shift towards anticipatory action alongside reactive disaster response

This will require the development of specific anticipatory action frameworks and financing mechanisms. Crucially, such frameworks should incorporate education-focused strategies (e.g., action plans for learning continuity during floods) to reduce the disruption caused by climate hazards and support learning continuity.

4. Strengthen the climate change education curriculum and pedagogy towards an action-focused approach.

This will require embedding action-focused teaching within existing teacher professional development. Additionally, ensuring that curriculum and teaching can be contextualised to draw on local climatic patterns and experiences may support more meaningful community-level knowledge and action.

6.3. Recommendations regarding financing

Climate financing should be leveraged to build resilience in the education system. This requires a central role for the MoE and relevant agencies, especially when financing is multi-sectoral.

1. Ensure that education is a specific focus within Ghana's Nationally Determined Contribution

This is required to ensure that climate funds are allocated to adaptation efforts that support resilience-building in education. Any cross-sectoral funds should also explicitly include education targets.

2. Leverage climate financing for multi-sectoral projects to service education-related initiatives

For example, climate financing invested in public infrastructure-building projects should include schools as part of its wider remit.

3. Establish incentives to increase investment in climate financing from the private sector

This is an area which requires further investigation, but offers an opportunity to leverage a range of funds to support both economic and social development.

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These references are available digitally in our evidence library at https://docs.edtechhub.org/lib/32UFVWGA

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Annex

Annex A: search strings

The strings used for each theme are listed below.

For the impacts of climate change on education in Ghana:

Ghana AND (education OR school OR learning OR literacy OR numeracy OR teach OR student) AND (climate OR "climate change" OR weather OR "global warming" OR "natural hazard") AND (impact OR outcome OR performance OR effect OR relationship OR results)

Ghana AND (education OR learning OR school) AND (flood OR drought OR storm OR heat OR "extreme weather" OR "natural hazard" OR "natural disaster") AND (attendance OR attainment OR results OR outcomes OR impact OR effect)

Ghana AND ("basic education" OR literacy OR numeracy OR "foundational learning") AND (environmental OR climate OR disaster) AND (assessment OR "test scores")

For efforts to build climate-resilient education systems in Ghana:

Ghana AND (climate OR "global warming" OR "extreme weather" OR environment OR "natural hazard" OR "natural disaster" OR flood OR drought OR storm OR heat) AND (school OR education) AND (solution OR adaptation OR resilience OR resilient OR intervention)

Ghana AND (climate OR "extreme weather" OR environment OR "natural hazard" OR "natural disaster" OR flood OR drought OR storm OR heat) AND (infrastructure OR construction OR retrofit OR adaptation OR design OR build) AND (school OR education OR class)

Ghana AND (climate OR "extreme weather" OR environment OR "natural hazard" OR "natural disaster" OR flood OR drought OR storm OR heat) AND (school OR education OR learn) AND ("early warning system" OR preparedness OR risk OR management OR planning)

Ghana AND (climate OR "global warming" OR "extreme weather" OR environment OR "natural hazard" OR "natural disaster" OR flood OR drought OR storm OR heatwave) AND (school OR education) AND ("remote learning" OR "distance learning" OR "online learning")

Annex B: final list of included literature

Source title	Author (s)	DOI/URL	Date
A thermal comfort evaluation of a junior high school building in Accra, Ghana	D.J. Appah and C. Koranteng	https://hdl.handle.net/10520/EJC131242	2012
Assessing students' perceptions and awareness of climate change: A comparative study of three cities in Ghana	Faustina Ampong , Pinnika Syam Yadav	https://doi.org/10.69968/ijisem.2025v4i280-85	2025
Assessing the Impact of Tidal Waves on Learners' Education of Residents of Some Coastal Communities in the Western Region of Ghana	Kojo Amuah Prah, James Nweah-Ackah Mochiah, Rev. Sr Joana Duker	https://doi.org/10.47941/jep.1340	2023
Barriers to financing climate change actions in infrastructure projects in Ghana	Isaac Akomea-Frimpong, Amma Kyewaa Agyekum, Taden John, Alexander Baah Amoakwa, Comfort Owusu Kedjah	https://doi.org/10.7771/3067-4883.1797	2025

Challenges and Opportunities for Mainstreaming Climate Change Adaptation into WaSH Development Planning in Ghana	Salley Alhassan and Wade L. Hadwen	https://doi.org/10.3390/ijerph14070749	2017
Citizens' acceptability and preferred nature-based solutions for mitigating hydro-meteorological risks in Ghana	Kirk B. Enu, Aude Zingraff-Hamed, Yaw Agyeman Boafo, Mohammad A. Rahman, Stephan Pauleit	https://doi.org/10.1016/j.jenvman.2024.120089	2024
Climate Change Adaptation Among Smallholder Farmers in Rural Ghana	Peter Asare-Nuamah and Athanasius Fonteh Amungwa	https://doi.org/10.1007/978-3-030-42091-8_279-1	2021
Climate change and educational attainment in the global tropics	Heather Randell and Clark Gray	https://doi.org/10.1073/pnas.1817480116	2019
Climate Change Education: The Role of Pre-Tertiary Science Curricula in Ghana	Boakye	https://doi.org/10.1177/2158244015614611	2015
Climate change finance in Ghana	Felix Ankomah Asante, Simon Bawakyillenuo, Neil Bird, Nella Canales Trujillo, Cynthia Addoquaye Tagoe and Nicholas Ashiabi	https://media.odi.org/documents/9684.pdf	2015
Determinants of Adaptive Capacity to Climate Change among Smallholder Rural Households in the Bongo District, Ghana	Issaka Kanton Osumanu, Philip Aniah, Augustine Yelfaanibe	https://doi.org/10.4314/gjds.v14i2.8	2017

Determinants of choice of climate change adaptation practices by smallholder pineapple farmers in the semi-deciduous forest zone of Ghana	Philip Antwi-Agyei, Esther Ako Wiafe, Kofi Amanor, Frank Baffour-Ata, Samuel Nii Ardey Codjoe	https://doi.org/10.1016/j.indic.2021.100140	2021
Does the use of climate information contribute to climate change adaptation? Evidence from Ghana	Victor Owusu, Wanglin Ma, Alan Renwich, Dorcas Emuah	https://doi.org/10.1080/17565529.2020.1844612	2020
Education for Disaster Risk Reduction (DRR): Linking Theory with Practice in Ghana's Basic Schools	Priscilla T. Apronti, Saito Osamu 1, Kei Otsuki and Gordana Kranjac-Berisavljevic	https://doi.org/10.3390/su7079160	2015
Enhancing disaster preparedness in higher education institutions in Ghana: the role of facility managers	Abubakar Sadiq Mohammed; Christopher Amoah; Jannat Abbas	https://doi.org/10.1108/IJES-08-2024-0050	2025
Environmental education in colleges of education in Ghana: experiences and perceptions of environmental educators	Atuguba, Juliet Atawuula	https://etheses.bham.ac.uk/id/eprint/9462/	2019
Exploring the perspective of school children on flood risk management in developing countries: lessons from Ghana	Henry Mensah, Grace Wanma, Divine Kwaku Ahadzie, Eric Kwame Simpeh	https://doi.org/10.1201/9781003160823	2023

Factors influencing the access and utilization of climate information by farmers from different climate vulnerable districts of Northern Region, Ghana	Iddisah Alhassan, Philip Antwi-Agyei, William Adzawla, Mihaela Sima	https://doi.org/10.1016/j.cliser.2025.100557	2025
Farm households' flood adaptation practices, resilience and food security in the Upper East region, Ghana	Hamdiyah Alhassan	https://doi.org/10.3389/fsufs.2023.1091812	2020
Farm households' flood risk perception and adoption of flood disaster adaptation strategies in northern Ghana	Gideon Ntim-Amo, Qi Yin, Ernest Kwarko Ankrah, Yunqiang Liu, Martinson Ankrah Twumasi, Wonder Agbenyo, Dingde Xu, Stephen Ansah, Rabia Mazhar, Vivian Kimayong Gamboc	https://doi.org/10.1016/j.ijdrr.2022.103223	2022
Financing climate change mitigation: An assessment of the private sector investment opportunities in Ghana	Albert Ahenkan	https://doi.org/10.1002/bsd2.84	2020
Flooding in Nigeria and Ghana: opportunities for partnerships in disaster-risk reduction	Adaku Jane Echendu	https://doi.org/10.1080/15487733.2021.2004742	2021

Gender and climate risk management: evidence of climate information use in Ghana	Samuel T. Partey, Angela D. Dakorah, Robert B. Zougmoré, Mathieu Ouédraogo, Mary Nyasimi, Gordon K. Nikoi & Sophia Huyer	https://doi.org/10.1007/s10584-018-2239-6	2018
Ghana: Roadmap for resilient infrastructure in a changing climate	Adshead, Daniel Thacker, Scott Fuldauer, Lena I. Gall, Sarah S.	https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A2002407&dswid=-7769	2022
Ghanaian preservice science teachers' knowledge of ozone depletion and climate change, and sources of their knowledge	Samuel Cornelius Nyarko & Heather L. Petcovic	https://doi.org/10.1080/09500693.2021.1922779	2021
Household disaster awareness and preparedness: A case study of flood hazards in Asamankese in the West Akim Municipality of Ghana	Frank J. Glago	https://doi.org/10.4102/jamba.v11i1.789	2019
Household Multidimensional Energy Poverty: Impact on Health, Education, and Cognitive Skills of Children in Ghana	Elizabeth Nsenkyire, Jacob Nunoo, Joshua Sebu & Omowumi Iledare	https://doi.org/10.1007/s12187-022-09970-0	2022

How do sensemaking and climate change education affect climate engagement at the grassroots level? A study of five communities in Southeastern Ghana	Henry Adobor	https://doi.org/10.1007/s10584-024-03701-w	2024
Impact of roofing materials on school temperatures in tropical Africa	Ebenezer F. Amankwaa, Ben M. Roberts, Peter Mensah, Katherine V. Gough	https://doi.org/10.5334/bc.581	2025
Local government and climate literacy: exploring community perspectives in Ghana's coastal zones	Abednego Adjei Baffour	https://doi.org/10.1080/14693062.2025.2566938	2025
Mainstreaming Green Economy: An Assessment of Private Sector Led Initiatives in Climate Change Adaptation in Ghana	Albert Ahenkan, Jane Osei Erasmus, Henaku Owusu	https://doi.org/10.5539/jsd.v11n2p77	2018
Natural Hazards Governance in Ghana	Paulina Amponsah	https://doi.org/10.1093/acrefore/9780199389407.013.444	2022

Pro-environmental behavior: the relationship with information literacy self-efficacy, climate knowledge and climate anxiety among students in Ghana	Martin Gameli Akakpo, Hayford Alufar Bokpin, Sylvia Hagan	https://doi.org/10.1093/oxfclm/kgae015	2024
Resilience against climate variability: The application of nature based solutions by cocoa farmers in Ghana	Enoch Kwame Tham-Agyekum, Supernatural Ntem, Evans Sarbah, Katja Anno-Baah, Prince Asiedu, John-Eudes Andivi Bakang, Ebenezer Osei Jones	https://doi.org/10.1016/j.indic.2023.100310	2023
Restoring the school garden programme in Ghana: an exploration of the key issues from the past and implications for the future	Dorothy Julian Nalumu, Henry Mensah, Stephen Appiah Takyi, Owusu Amponsah & Jodingam Marija	https://doi.org/10.1007/s43545-021-00209-3	2021
The role of farmers and organizational networks in climate information communication: the case of Ghana	Chidiebere Ofoegbu; Mark New	https://doi.org/10.1108/IJCCSM-04-2020-0030	2021

The social consequences of climate change: a qualitative analysis of early girl child marriage as an informal adaptation strategy among rural communities in Northern Ghana	Asare, Loretta Adowaa, Forkuor, John Boulard	https://doi.org/10.1080/23311886.2024.2319703	2024
Too weak to lead: motivation, agenda setting and constraints of local government to implement decentralized climate change adaptation policy in Ghana	Issah Justice Musah-Surugu, Albert Ahenkan & Justice Nyigmah Bawole	https://doi.org/10.1007/s10668-017-0049-z	2017
Traditional and Local Knowledge Practices for Disaster Risk Reduction in Northern Ghana	Nsioh Macnight Ngwese, Osamu Saito, Akiko Sato, Yaw Agyeman Boafo, Godfred Jasaw	https://doi.org/10.3390/su10030825	2018

Annex C: temperature measurements

For the purposes of an exercise to map regional and district vulnerability across Ghana to extreme heat, the following parameters were used to map extreme heat:

- **Time scale:** Temperature data from 2024 was used to ensure a full year of data was available, providing an accurate reflection of current climatic conditions.
- **Heat analysis:** to measure extreme heat exposure, the analysis focused on determining the number of days in 2024 when a location exceeded a defined threshold (e.g., 35°C). This provided insight into the relative regularity with which different locations in Ghana are exposed to extreme heat conditions.

Satellite data from the ECMWF ERA5 land model was used, specifically the ERA5-Land post-processed daily statistics model. This re-analysis model is appropriate for this task as it provides an accurate model of air temperature at ~2m height, as opposed to other Land Surface Temperature models, which measure surface-level heat, which is often influenced by infrastructure (roads, buildings, etc.). The reanalysis model also accounts for atmospheric forcing and lapse rate correction to ensure that modelled conditions reflect real conditions. This means the ERA5 reanalysis model provides a much more accurate projection of air temperature and the thermal conditions felt by humans, which is critical for determining extreme heat exposure that will impact educational performance. Additionally, the daily statistics model (using 1-hour frequency intervals) allowed the maximum daily temperature for each day to be accessed directly, negating the need for additional analysis to determine temperature exposure from a continuous time series for 2024. The model has a 0.1° x 0.1° native resolution, providing a 9 km^2 area for each temperature data point (visualised as a pixel). This provides a detailed picture of temperature variation within districts and regions in Ghana to determine their exposure to extreme heat. Data for 2024 was accessed from the Copernicus Climate Data Store and was analysed using QGIS and Python.

Annex D: precipitation measurements

For the purposes of drought analysis, which is outlined later, the 30-year period of precipitation needed to represent a directly comparable 30-year dataset to potential evapotranspiration (PET). As a result, the analysis used the CHELSA (Climatologies at high resolution for the Earth's land surface areas) V2.1 dataset (↑Karger et al., 2025). This provided high-resolution (30 arc-second, approx. 1km resolution) monthly precipitation data encompassing the years 1981–2010. Monthly precipitation data measured as kg m-2 month-1 was downloaded from January 1981 up to and including December 2010. In hydrology, 1kg of water spread over 1m^2 represents 1mm of rainfall, as the density of water is 1000kg/m^3. Therefore, this measurement represents the total precipitation in millimetres (mm) per month. Precipitation data for each year (1981–2010) was calculated by adding the 12 monthly data points, then averaging the annual precipitation by combining these annual totals and dividing by 30. This resulted in a precipitation map (Figure 6) that outlines the mean annual precipitation (mm) across Ghana between 1981 and 2010.

In order to analyse the previous 5 years (from 1 January 2020 to 31 December 2024) of precipitation data, as the CHELSA dataset did not extend to this time period, satellite data was downloaded from CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) (↑Climate Hazard Center, 2026). This is a blended dataset that uses satellite infrared data calibrated with microwave satellite data, and calibrates these estimates with ground-based rain gauge station data. This blended approach provides a more accurate representation of actual rainfall than satellite data alone and has a high spatial resolution (~5.5km). The CHIPRS v2.0 dataset was used for this analysis due to its accurate representation of mean rainfall patterns that form the basis of this analysis. Monthly rainfall data was combined for each year, with the average of these annual totals providing a map of annual precipitation from January 1 2020, to December 31 2024.

For analysis of precipitation volume per day, CHIRPS v3.0 data5 was used due to its enhanced estimation of temporal precipitation variance compared to CHIRPS v2.0.

The analysis used different daily rainfall thresholds based on the MANOBS definitions of rainfall volumes (↑MANOBS, 2023). The thresholds used for the analysis were:

- Zero rainfall day (<=0.1mm)
- Light rainfall day (>0.1mm and <=2.5mm)
- Heavy rainfall day (>7.5mm)

The analysis calculated the distribution of different rainfall days across Ghana. A key limitation is that this information does not account for rainfall intensity, only reporting rainfall as a daily quantity.

Annex E: flood measurements

The datasets used in the flood risk mapping are outlined in Table 6.

Table 6. *Variables used in flood risk mapping for Ghana*

Variable	Data Source	Description
Topography	DEM: European Space Agency (2024). Copernicus GLO-30 Global Digital Elevation Model. Distributed by OpenTopography. https://doi.org/10.5069/G9028PQB. Accessed 2025-10-29—	Digital Elevation Model (DEM) of Ghana. This was further processed into elevation and slope variables for the risk analysis.
Hydrology	HydroSHEDS (Rivers and Lakes) database. Available at: https://www.hydrosheds.org/	Shapefiles of major rivers, lakes and water bodies in Ghana. These were combined and processed into proximity to water bodies for the risk analysis.
Land use and land cover	The Copernicus Global Land Cover 2019 (CGLS-LC100) (100m Resolution). https://doi.org/10.2909/c6377c6e-76cc-4d03-8330-628a03693042	The Land Use / Land Cover (LULC) model denotes how land is utilised by humans (land use) and the physical material comprising the land surface (land cover).
Soil	SoilGrids Soil Classification World Reference Base (2006) Soil Groups. Available at: https://soilgrids.org/	Soil type classification data utilising (↑FAO, no date) classifications denoting land by its soil.
Rainfall	CHIRPS v2.0[5]	Mean annual precipitation data between 2020 and 2024, as shown in Figure 8 was used.

To prepare these datasets for analysis, all layers were standardised to a common grid system. Data was reprojected to the EPSG:32630 coordinate system (WGS 84 / UTM Zone 30N) to convert spatial units from degrees to metres. This made the dimensions of each layer consistent and enabled further processing of the data into variables (such as slope or proximity to water) used in the risk analysis. All layers were also reprocessed to the same resolution. The Copernicus Land Use Land Cover (LULC) dataset served as the master grid, with the other layers converted to match its 100 m x 100 m resolution for consistency.

These standardised base layers were then processed into hazard-specific raster layers, all of which were reclassified onto a common risk scale ranging from 1 (very low risk) to 5 (very high risk) for flooding. First, two derived layers (slope and proximity to water sources) were created from the Digital Elevation Model (DEM) and the rivers and lakes shapefiles, respectively.

To calculate slope, the DEM was processed to generate a slope map in degrees, then reclassified to assign higher risk scores to flatter areas and lower risk scores to steeper areas. The classifications are outlined in Table 7.

Table 7. *Risk classification for flooding from slopes*

Minimum slope (degrees)	Maximum slope (degrees)	Risk rating
0	2	5
2	5	4
5	10	3
10	20	2
20	90	1

To calculate water proximity, the lakes and rivers shapefiles for Ghana were processed to display data as proximity to either lakes or rivers. These two layers were then combined to create a single file showing proximity to a water body. This layer was then reclassified, assigning high risk to areas closest to water, and low risk to areas further away (Table 8).

Table 8. *Risk classification for flooding from proximity to water bodies*

Minimum distance (m)	Maximum distance (m)	Risk rating
0	500	5
500	1000	4
1000	2000	3
2000	5000	2
5000	999999	1

All other layers were reclassified in a similar way, with data converted into a value of 1–5 (from low risk to high risk). It is important to note that the risk classes for continuous data sources were based on the data range specific to Ghana. For example, the highest risk for precipitation (5) corresponds to the wettest areas in Ghana, rather than the wettest areas on Earth. The hazard scores are therefore relative to Ghanaian environmental conditions. These additional continuous variables are in Tables 9 and 10 below.

For categorical data (LULC and soil, risk scores were assigned to each categorisation in the base data, based on its known physical properties that impact flooding, such as its permeability and tendency to produce runoff. These classifications are highlighted in Tables 11 and 12 below.

Table 9. *Risk classification for flooding from land elevation*

Minimum DEM altitude (m above sea level)	Maximum DEM altitude (m above sea level)	Risk rating
-100	50	5
50	100	4
100	200	3
200	500	2
500	9999	1

Table 10. *Risk classification for flooding from mean annual precipitation*

Minimum mean annual precipitation (mm)	Maximum mean annual precipitation (mm)	Risk rating
750	1000	1
1000	1300	2
1300	1600	3
1600	1900	4
1900	3000	5

Table 11. *Risk classification for flooding from land use land cover (note that legend values represent the numerical value (map code) assigned to each data point in the data layer, as shown in* ↑Buchhorn et al. (2020)

Minimum legend value	Maximum legend value	Risk rating	Layer type and justification
0	0	3	No input data available (treated as moderate/neutral)
20	20	2	Shrubs
30	30	2	Herbaceous vegetation
40	40	3	Cropland (cultivated/managed)
50	50	5	Built-up (impermeable surface, so high risk)
60	60	4	Bare/sparse vegetation (high runoff likely, so higher risk)
70	70	1	Snow and ice
80	80	1	Permanent water bodies
90	90	5	Herbaceous wetland (saturated, so very high risk)
100	100	2	Moss and lichen
111	116	1	All “closed forest” types (high infiltration, so low risk)
121	126	1	All “open forest” types (high infiltration, so low risk)
200	200	1	Open sea (masked from analysis)

Table 12. *Risk classification for flooding from soil categories*

Corresponding layer value	Soil type	Risk rating	Justification
0	Acrisols	2	Generally well-drained, but subsoil clay accumulation can slow deep drainage.
1	Albeluvisols	4	Abrupt textural change often leads to temporary water stagnation above the clay layer.
2	Alisols	3	High clay activity; can have drainage issues depending on structure/slope.
3	Andosols	2	Very porous, volcanic soils, generally excellent drainage.
4	Arenosols	1	Sandy soils, very high infiltration rate, rapid drainage.
5	Calcisols	2	Typically occur in drier areas, often well-drained unless cemented hardpan exists.
6	Cambisols	3	Weakly developed, variable drainage, but often moderately well drained.
7	Chernozems	2	Grassland soils, typically well-structured and well-drained.
8	Cryosols	3	Permafrost impedes drainage, and seasonal waterlogging is common during thaw.
9	Durisols	3	Cemented silica layer (duripan) can impede drainage if shallow.
10	Ferralsols	1	Deeply weathered tropical soils, stable structure, usually very well drained.
11	Fluvisols	5	Soils on active floodplains inherently prone to flooding and often poorly drained.
12	Gleysols	5	Defined by prolonged water saturation, very poor drainage, often in depressions.
13	Gypsisols	2	Occur in arid areas, typically

Corresponding layer value	Soil type	Risk rating	Justification
			well-drained unless gypsum hardpan forms.
14	Histosols	5	Organic soils (peat) form in waterlogged conditions with very poor drainage.
15	Kastanozems	2	Similar to Chernozems but drier climate, typically well-drained.
16	Leptosols	2	Shallow soils over rock, drainage varies but often excessive runoff, less accumulation.
17	Lixisols	2	Similar to Acrisols/Luvisols but lower clay activity, generally well-drained.
18	Luvisols	3	Clay accumulation in subsoil (argic horizon) can impede drainage somewhat.
19	Nitisols	2	Deep, well-structured clay soils, typically good drainage and permeability.
20	Phaeozems	2	Dark, fertile grassland soils, generally well-drained.
21	Planosols	5	Abrupt, often impermeable layer below topsoil causes severe seasonal waterlogging.
22	Plinthosols	4	Contain plinthite, which can harden irreversibly, often associated with fluctuating water tables and impeded drainage.
23	Podzols	1	Typically sandy, leached soils with rapid drainage.
24	Regosols	3	Very weakly developed soils, properties vary greatly with parent material, drainage unpredictable.
25	Solonchaks	4	Saline soils, often in low-lying areas or depressions, frequently poorly drained.
26	Solonetz	4	Sodic soils with dense, poorly permeable subsoil, impeded drainage.

Corresponding layer value	Soil type	Risk rating	Justification
27	Stagnosols	5	Defined by surface water stagnation (similar to Planosols/Albeluvisols), poor permeability.
28	Umbrisols	2	Dark, acidic soils, typically permeable and well-drained.
29	Vertisols	5	High shrink-swell clay content, very low permeability when wet, prone to ponding/runoff.

All of these processed 'risk factors' data layers, with each data value representing between 1 and 5 depending on their risk, were then combined with a weighted calculation to create a final risk map. The following calculation was used:

(Elevation risk * 0.3) + (Water proximity risk * 0.2) + (Rainfall risk * 0.15) + (LULC risk * 0.15) + (Slope Risk * 0.1) + (Soil Risk * 0.1)

Before presenting the findings, it is important to be aware of some key limitations of the model:

- The model is a static model that shows where conditions are suitable for flooding, and does not estimate when a flood will occur or what its severity will be.
- Rainfall data used is a proxy for saturation and is not a measure of rainfall intensity (mm/hour) or duration, which are key triggers for flash flooding.
- River data does not include river discharge or flow rates. As a result, the model treats all rivers and water sources equally, meaning that proximity to a small stream is weighted the same as proximity to a large river. Incorporating discharge data to assign higher risk to larger bodies of water would improve this kind of analysis in the future.
- The data resolution of 100m may be too coarse to capture small drainage channels and storm drains/culverts that heavily influence urban flooding.

- The final weighting and risk classifications are based on logical inference, but are nonetheless subjective. A different weighting or risk classification process would yield a different risk map.
- Variables included in the map are not comprehensive and include only those that contribute to flood risk; they do not include variables that might reduce flood risk, such as temperature, which would affect soil saturation.
- The risk map captures only geographical exposure to risk and does not include demographic variables that would affect the severity of a flood event's impact (such as population density).
- The model also captures only rainfall-driven flooding and does not account for coastal flooding risk.
- Data had to be open source, and limitations of processing on a laptop meant that narrower data sets and variables (such as precipitation) had to be used to work within lower processing capabilities.

To calculate the frequency of flood events in 2024, the National Oceanic and Atmospheric Administration (NOAA) JPSS Visible Infrared Imaging Radiometer Suite (VIIRS) 375m-5 day composite flood data (↑Ma et al., 2025) was used and acquired from the NOAA Open Data on the Amazon Web Services (AWS) archive. The data is a composite generated from the VIIRS optical sensor, providing a spatial resolution of approximately 375m.

A 5-day composite product was used for two reasons. First, it mitigates the impact of cloud cover. Floods frequently occur during periods of heavy cloud cover, which can obscure single-day data files. By compiling the maximum measured water levels over a 5-day period, the probability of capturing a cloud-free image of the surface is much higher. Second, it helps capture the peak extent of multi-day flood events by depicting peak inundation for each 5-day period, rather than the daily extent of each day.

To avoid over-counting a single, persistent flood event which would appear in multiple consecutive 5-day composite files, consecutive 5-day composite files were analysed, for each 5-day period of the year (excluding December 31 2024). This resulted in a sample of 73 consecutive 5-day composite files being analysed (the first file covering 1–5 Jan 2024, the second covering 6–10 Jan 2024, etc.), covering 365/366 days in 2024.

A batch process reclassification was run on these files to classify whether each data pixel indicated flooding. A pixel was classified as flooding if its value was between 1% and 100% floodwater coverage. All other pixels (including land, clouds, shadows, and permanent water sources) were classified as non-flooded. The number of ‘flooded’ and ‘not flooded’ occurrences for each pixel was then summed to calculate the total number of 5-day periods in 2024 in which each pixel was detected as flooded. This is shown in Figure 8. As with the flood risk index mapping, there are some key limitations to this analysis:

- The map does not show the number of distinct flood events. A long-lasting flood would be counted across multiple files (e.g., 12) while 12 separate flash floods in 12 separate 5-day periods would show the same value.
- The map provides no information on flood depth or velocity.
- Cloud cover, though mitigated, can persist for 5-day periods or obscure single-day flood events, leading to flooded areas being missed.

Annex F: drought measurements

To develop a baseline drought hazard map, analysis was based on CHELSA datasets for precipitation and potential evapotranspiration (PET) covering the years 1981–2010. This 30-year period was selected because it is the most recent 30-year period with a set of directly comparable data sources for precipitation and PET to produce the drought analysis. PET is a measure of climatic hazard, indicating how much moisture can escape into the atmosphere by measuring how hot, dry, and humid the air is. A high PET means a high drought hazard, as any precipitation will evaporate more quickly with a high PET. It is crucial to measure PET rather than total evaporation or transpiration, as in dry conditions, actual evaporation will be low due to the low moisture content, even if the PET is high (for example, due to extreme heat).

Monthly mean precipitation and mean PET data (as kg m-2 month-1, equivalent to mm) was downloaded for each month during this period, representing the averages for that month between the years 1981 and 2010. The total mean annual precipitation in mm/year was then calculated by combining the monthly precipitation files into a single 12-band raster and summing the values for each data pixel across all bands. A parallel process was applied to the 12 monthly PET files to calculate the total mean PET in mm/year.

The ‘Aridity Index’ was then calculated by dividing the total precipitation by the total PET. The outcomes of the aridity index calculation are shown in

Figure 11. Figure 11 shows a standardised measure of long-term water availability and drought stress. A value <1.0 indicates a 'water-deficit' environment throughout the year, where annual PET exceeds precipitation. A value >1.0 indicates a 'water surplus' environment throughout the year, where annual precipitation exceeds PET. According to UNEMG, 'drylands' are areas with an aridity index <0.65, with the following additional classifications (↑UNEMG, 2018):

- Hyper-arid (<0.05)
- Arid (0.05-0.20)
- Semi-arid (0.20-0.50)
- Sub-humid (0.50-0.65)

To calculate changing dryness patterns, the Copernicus monthly drought indices from 1940 to the present day, derived from the ERA5 reanalysis dataset, were used (↑Keune et al., 2025). The analysis used the Standardised Precipitation-Evapotranspiration Index (SPEI) data for Ghana over a recent 5-year period (January 2020–December 2024).

SPEI is a metric that can be used to infer drought severity by calculating the difference between precipitation and PET (as was conducted earlier). Negative values represent drier than usual periods, while positive values indicate wetter than usual periods. 'Usual' for this data source refers to the baseline SPEI (or aridity index) over the period 1991–2020 for each data point. While not an exact replica, Figure 11 serves as a useful representation of these long-term 'usual' trends. Analysis of SPEI data from 2020 to 2024 therefore, asks the question "*How relatively dry or wet have areas been over the past 5 years, compared to their 30-year climatological average?*"

This analysis also used two SPEI data sets, SPEI-3 and SPEI-12. The numerical values represent the number of months of accumulated data used to compare with the 1991–2020 climatological baseline. Each monthly SPEI-3 data point asks how wet or dry the last 3 months (using the accumulation point up to the month of data specified, e.g., January 2020) have been relative to the 1991–2020 baseline. Each monthly SPEI-12 data point asks the same question, except looking at how wet or dry the last 12 months have been compared to the 30-year baseline.

Looking at both SPEI-3 and SPEI-12 is useful for different reasons. SPEI-3 allows for a more detailed interrogation of seasonal and short-term drought patterns and will uncover any unusual shifts in seasonal climate patterns. SPEI-12 data will miss seasonal patterns that shift throughout the year, but can more robustly identify persistent, long-term climatic changes that are likely to impact multiple years or be more representative of longer-term shifts in climate patterns.

To perform this analysis, the same workflow was replicated for both SPEI-3 and SPEI-12 datasets. Sixty monthly files from January 2020 to December 2024 were downloaded and reprojected to a common coordinate system (EPSG:32630 — WGS 84 / UTM Zone 30N) and resolution (100m) to align with the rest of the data used in flood and drought analyses. Data for each month was then converted to a binary drought or no drought value. If the SPEI was below -1 for that month's accumulation period (including either the previous 3 or 12 months' worth of SPEI data), it was marked as being in drought (because it was significantly drier than the 30-year baseline), with values above -1 marked as not being in drought.

The resulting values for the 60 months of SPEI-3 and SPEI-12 data were then summed and visualised in Figures 12 and 13. Figure 12, which shows SPEI-3 data, is a visual representation of how many months in the 5 years from 2020 to 2024 were in areas experiencing seasonal drought (a significant 3-month water deficit). Figure 13, which shows SPEI-12 data, is a visual representation of how many months in the same 5-year period were in areas part of a long-term, significant 12-month water deficit.