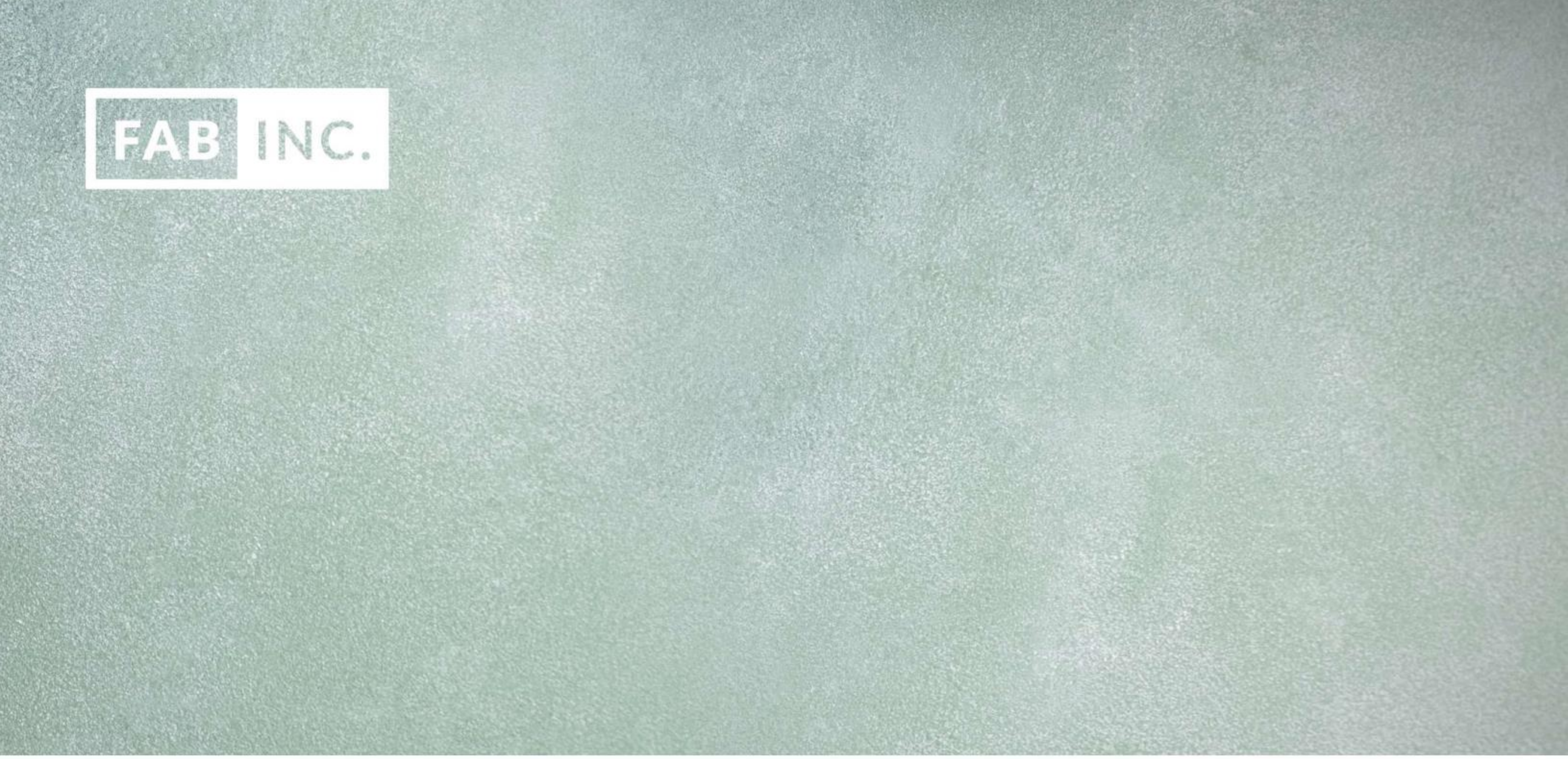


Flooding and Schooling in Sierra Leone

Flooding and schooling in Sierra Leone

Contents

Introduction

This project aims to create an understanding of the extent of flooding that impacts on schools, the ways in which schools in Sierra Leone are vulnerable to the impacts of flooding, and the risks that schools are exposed to from flooding. In this report, we use a combination of satellite imagery data and education data to understand more about the recent frequency, distribution, and impact of flooding on schools in Sierra Leone.

To achieve this, we have divided this report into three workstreams. First, to create a picture of how many schools in Sierra Leone are in flood prone areas and therefore how many schools are likely to be impacted by flooding. For this, we utilise administrative data on school locations along with historical data on flooding based on the National Oceanic and Atmospheric Administration (NOAA) satellite data to identify which schools are in flood prone areas.

Second, we assess how vulnerable schools are in the event of flooding, which requires an analysis of the physical and social characteristics of schools that are in flood prone areas. To do this we use the Ministry of Basic and Senior Secondary Education's (MBSSE) Annual School Census (ASC) data to understand more about school characteristics across all of Sierra Leone and then in flood prone areas. We look at a range of factors, such as the year of establishment of school, building materials used, school catchment population, water supply source, and other parameters. We use this information and draw on a range of methodologies for determining flood vulnerability to develop a school flood vulnerability index. Once a school flood vulnerability index was established, a vulnerability score was created for each public school in Sierra Leone. Our third workstream involved combining the vulnerability score with the flooding information to develop a flood risk index for schools in Sierra Leone.

This analysis is timely and relevant given the context of climate change and how it is impacting Sierra Leone. Warming, due to climate change, has already reached around 1.1 degrees globally, and is expected to rise to above 1.5 degrees over the next 20 years[1]. This will impact developing countries such as Sierra Leone the most over the coming decades, through a combination of slow onset problems and more "frequent and intense extreme events"[2]. This includes extreme heat, uncertain seasons, droughts, extreme rainfall, and increased flooding. These intersecting crises will impact on children and on education systems, threatening access, continuity, and outcomes. Sierra Leone has experienced extreme weather-related events, most notably the 2017 mudslides which followed three days of torrential rainfall resulting in 1,141 deaths leaving 3,000 people homeless.

---

[1] IPCC, 2021: Summary for Policymakers. https://www.ipcc.ch/report/ar6/wg1/chapter/summary-for-policymakers/

[2] IPCC, 2022: Summary for Policymakers. https://www.ipcc.ch/report/ar6/wg2/chapter/summary-for-policymakers/

While there has been significant research on the wider impacts of climate change, the impact of climate change on education is less understood, particularly in the context of lower income countries. Sierra Leone has made tremendous gains in access to education over the last five years, with enrolment rising from 2 million in 2018 to 3.3 million in 2022. Yet the facilities have not been able to keep pace, meaning that schools are more crowded than ever. These improvements could potentially be lost due to climate change impacts[3], as Sierra Leone is in the top 10% most vulnerable countries to the impacts of climate change and ranks 46th from 54 countries in the Africa Development Bank Infrastructure Index[4].

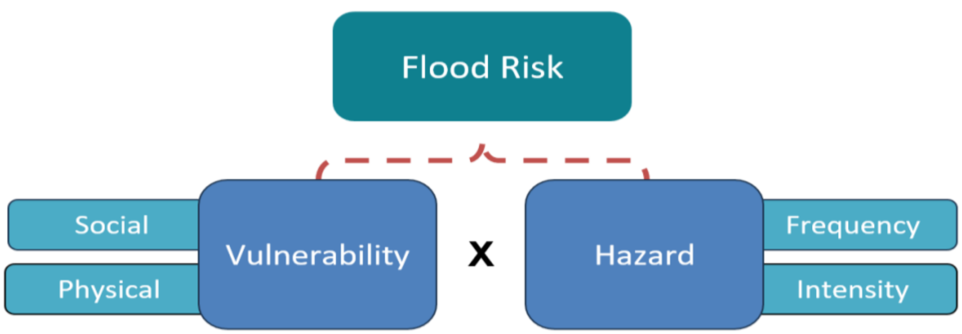
Key Terms – Hazard, vulnerability, risk

Flood hazard – The frequency and intensity of flooding that a school experiences.

Flood vulnerability – *"the extent of harm, which can be expected under certain conditions of exposure, susceptibility and resilience"[i]*

Flood risk - potential adverse effects resulting from the interaction of hazard and vulnerability.

Flood risk emerges from the synergy between hazard and vulnerability, which is specific to each school. For a school to face a flood risk, it must be exposed to flooding and vulnerable to its impacts. In simpler terms, a school's vulnerability alone isn't sufficient to be at risk; it must also confront a likelihood of flooding. This document aims to conduct a flood risk assessment for each school. Consequently, we develop a flood hazard index (Section One) and a vulnerability index (Section Two) to comprehensively evaluate the potential risk of flooding (Section Three). We outline our method and the data sources that we used for calculating hazard and vulnerability in Annex B.



[3] Global Partnership for Education. 2023. *Towards climate-smart education systems*.
[4]Government of Sierra Leone. 2021. *National Adaptation Plan.*

Section 1: Identifying schools located in flood-prone areas

Defining "Flood prone"

Flooding occurs when an area of normally dry land becomes submerged in water. In the context of Sierra Leone, flooding occurs primarily through coastal flooding, flash floods in urban areas, and river flooding in urban and rural areas, especially in areas defined as wetlands. We take a simple approach to defining "flood prone" for this initial exploration work *and use previous occurrences of flooding as a proxy for future occurrences*. This assumes that those areas that have been flooded in the past are likely to be flooded in the future.

To do this, we use publicly available data on flood water coverage[5], which is an estimate of the flood water coverage (from 1-100%) for ~375m^2 areas. As the schools in Sierra Leone are geo-referenced, we overlay school locations using the Annual School Census onto this flood data to allow us to get an estimate of the flood water percentage for the 375m^2 area in which the school is located for each day over the last three school years.

An important caveat to this report is that as the area for the school is smaller than the area that is measured by the satellite, this potentially introduces bias into the measures, particularly for those schools who have existing water sources right next to them. There are 495 schools that are located close to a water source, which is primarily rivers but some coastal. To reduce bias, we have analyzed these schools separately from the main data. This means that our figures are most likely a conservative estimate of flooding in Sierra Leone schools and should be read as such.

How much flood water is 'flooded'

To categorize the magnitude of flooding events, we must first set a threshold for how much water coverage means a school was "flooded." The raw data has a value from 1-100% for each 375m^2 pixel.

For this study, we selected a simple, relatively conservative threshold of 50% flood water within the area of land captured by the satellite image on the day of measurement.

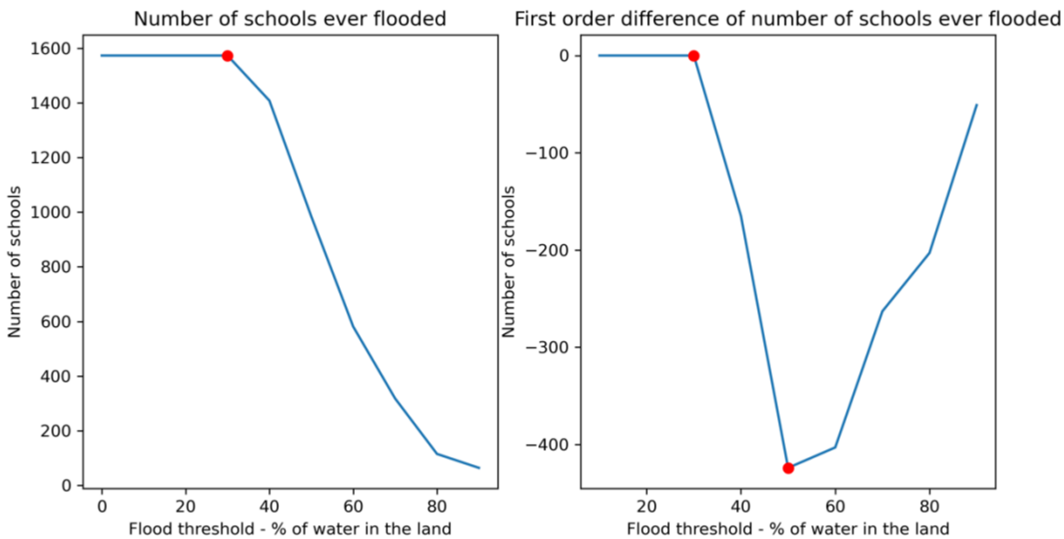
We calculated the number of times a school experienced flooding exceeding a 50% threshold, and, for each time this happens, we look at the flood duration, and how many days that this was the case. We can then ask how many times within the last three school years this combination of flooding occurred.

---

[5] The Geostationary and JPSS Flood map product is processed in near real time at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) utilizing data provided by the direct broadcast and GRB antennas at CIMSS. Available from: https://jpssflood.gmu.edu/

Figure 1.1 shows how sensitive the number of schools is to this threshold. Using the number of schools ever flooded in different flooding threshold (left panel), we found that when the percentage of water in the land is beyond 30%, the number of flooded schools does not change much with each increment[6].

Figure 1.1 Number of schools flooded in the last three years



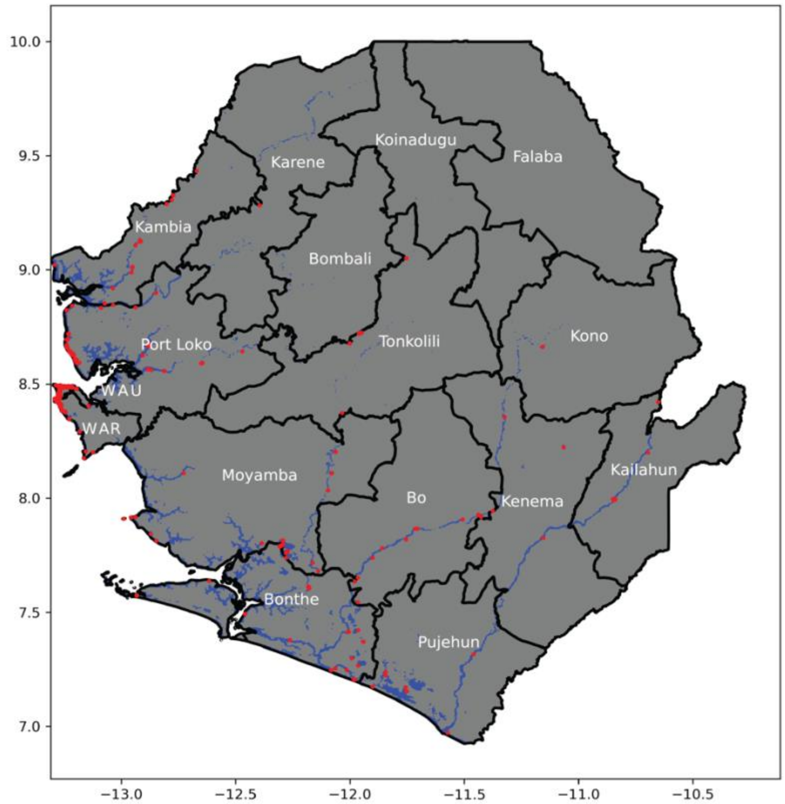
Total Schools affected by flooding

Using a threshold of 50% flood water coverage, we find that out of 12,204[7] total (geo-referenced) schools, 984 were flooded at least once in the last three years, which is approximately 8% of schools in Sierra Leone. However, as stated above, this is a conservative estimate as 495 schools cannot be analyzed accurately due to their proximity to water. Map 1.1 (below) shows these 495 schools, the districts that they are in and the water source that they are close to (river or coastal). As these schools are close to a water source it can be assumed that they are likely to flood. What this means is that **up to 12.1% of schools in Sierra Leone could be in flood prone areas and liable to regular flooding.**

Map 1.1 Schools in permanent inundation

[6] Technically, if we look at the first order difference, we found that the inflection point on the change in the number of schools is around 50%.

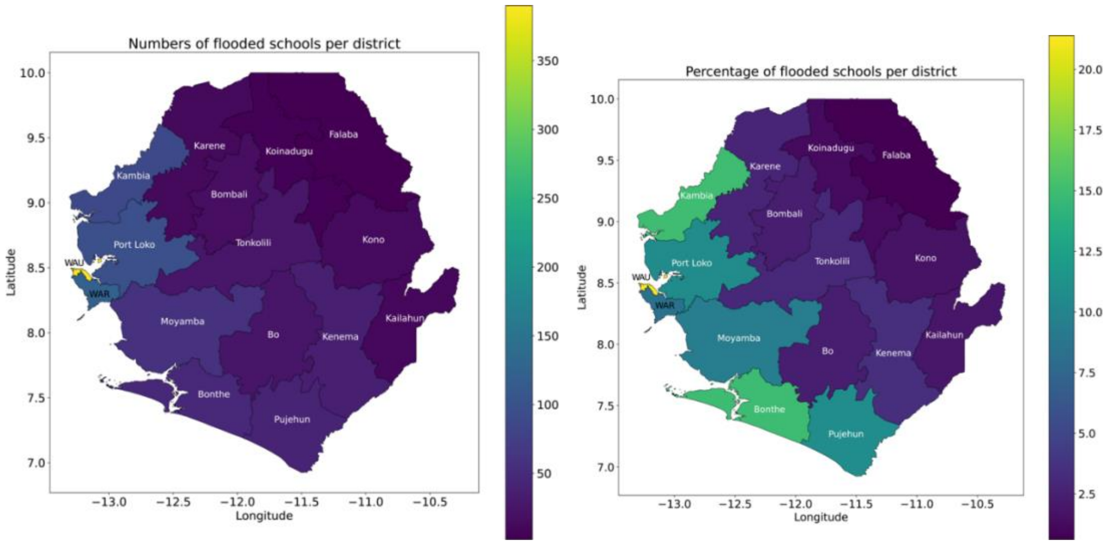
[7] Note that this is the number of schools that we can find via geo-referencing, which is slightly less than the number in the school census that is reported in section Two.



By merging school location with information from the Annual School Census (ASC) we estimate that 245,794 pupils attend schools that have been impacted by flooding in the previous three years (see Table 1.2 for more information).

We disaggregate this for each district, to get a sense of the scale of the issues in different locations. This is important when thinking about vulnerability and how to respond to reduce vulnerability and build resilience. This can inform decisions on where to invest money, prioritise infrastructure development, develop institutional capacity, and support community responses. By viewing flooding in terms of the district level impacts supports the approach undertaken by the *National Disaster Management Agency* (see Annex A).

Figure 1.2 Number of flooded schools and share by district.



The maps illustrate (Figure 1.2) that school flooding is most prevalent in districts across the West of the country nearest the coast. The map on the left looks at the total number of schools that are impacted. **This highlights that Western Area Urban (yellow) has the highest number of schools that are in flood prone areas.** This area includes Freetown, Sierra Leone's most populous city. The map on the right breaks down the schools as a percentage. **This figure shows that the districts with the highest percentage of flood prone schools are Kambia, Bonthe, Western Area Urban, Western Area Rural, Moyamba, Port Loko, and Pujehun.**

Table 1.1 (below) shows the total number of schools and the percentage of total schools in flood prone areas within each district of Sierra Leone. It highlights that a significant number and percentage of schools in Western Area Urban (390), Western Area Rural (121), Port Loko (96), Kambia (88), Moyamba (57), Bonthe (47), and Pujehun (40) have experienced at least one flooding event in the last three years.

Out of the 984 schools that have experienced flooding in the past 3 years, 839 of them are in these seven districts, which accounts for 85% of all schools affected by flooding during this period[8].

[8] We have selected these districts through a combination of a high number of schools, above 50, and above 10% of total schools in the district affected.

Table 1.1. Number of schools flooded and the percentage % per district

District	Flooded for one day	Flooded for 5 days	Flooded for 10 days
Bo	24 (2.38)	8 (0.79)	0 (0.00)
Bombali	17 (2.37)	0 (0.00)	0 (0.00)
Bonthe	**47 (14.97)**	**34 (10.83)**	**7 (2.23)**
Falaba	2 (0.63)	0 (0.00)	0 (0.00)
Kailahun	11 (1.91)	1 (0.17)	0 (0.00)
Kambia	**88 (15.04)**	**27 (4.62)**	**0 (0.00)**
Karene	12 (2.78)	0 (0.00)	0 (0.00)
Kenema	36 (3.43)	9 (0.86)	0 (0.00)
Koinadugu	4 (1.22)	0 (0.00)	0 (0.00)
Kono	14 (1.62)	0 (0.00)	0 (0.00)
Moyamba	**57 (9.31)**	**12 (1.96)**	**0 (0.00)**
Port Loko	**96 (10.63)**	**12 (1.33)**	**1 (0.11)**
Pujehun	**40 (10.78)**	**7 (1.89)**	**0 (0.00)**
Tonkolili	25 (2.91)	0 (0.00)	0 (0.00)
Western Area Rural	**121 (8.39)**	**66 (4.57)**	**1 (0.07)**
Western Area Urban	**390 (21.39)**	**95 (5.21)**	**2 (0.11)**
Total	**984(8.06)**	**271 (2.22)**	**11 (0.09)**

Note: Percentages are in parentheses.

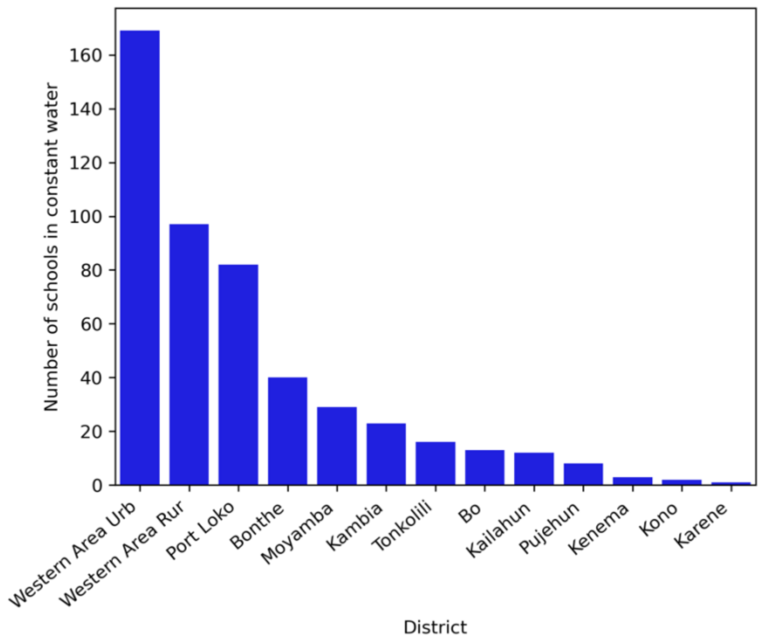
We also show the number of schools that have experienced at least one flooding event lasting five or ten days. This is to create a picture of the scale of flooding, where five- and ten-day events are used to illustrate longer and more impactful events, which increase the potential to damage infrastructure, disrupt education, and impact health. Of the schools that were flooded once (984), the flood water lasted for five days for 271, 28% of them. This falls noticeably if we extend to floods lasting 10 days, then we find that 11 schools experienced a flooding event of this length.

Taken together, looking at five- and ten-day events suggests that not only are a high number of schools in Sierra Leone at risk of flooding, but that over a quarter of them are at risk of severe and prolonged flooding events.

The seven most flood-prone districts continue to be the most impacted by longer events[9], containing 93% of all schools affected.

Graph 1.1 outlines the distribution of the 495 schools that we cannot accurately predict flooding for via district. These figures reinforce the approach of looking at the seven districts that we have drawn out as being flood prone. The graph highlights that potentially the flooding hazard facing schools in Western Area Urban is substantial with 169 schools that are close to a water source. This means that **potentially 559 schools, or 31% of schools in Western Area Urban face a flood hazard**. The potential hazard facing Western Area Rural rises to 218 schools, which is 15%. Kambia (111 /19%), Bonthe (87 /28%), Port Loko (178 /20%), Moyamba (86 /14%), and Pujehun (48/13%) still face a considerable flood hazard.

Graph 1.1 Schools in permanent inundation by district



The number of children at schools in flood prone areas

By merging the satellite and geo-referencing data with the Annual School Census (ASC), we can estimate the total number of children that are impacted by school flooding in Sierra Leone, which is shown in Table 1.2 (below). Using school enrollment data, we show that **245,794 pupils attend schools that have been impacted by flooding in the previous three years.**

Western Area Urban school children are particularly exposed to the flooding hazard with a significant number (102,979) and percentage (20.5%). Western Area Urban accounts for 42% of all children that attend flood prone schools in Sierra Leone.

When looking at schools that have been impacted by at least one event that lasted five days the figure drops to 69,575 children. 65,036 of these pupils are in the seven flood prone districts, which is 93% of pupils that have been impacted by at least one flooding event that has lasted five days.

This highlights the need to understand more about the impact on children and communities due to the significant number of schools and pupils affected by floods of varying severity. When schools flood, the consequences extend beyond the educational institutions themselves. They affect households, communities, roads, and other infrastructure. The data reveals that numerous children reside in flood-prone areas, raising concerns regarding their safety, well-being, and educational outcomes.

Table 1.2. Number of children are affected by flooded per districts (50 % land are flooded)

District	Flooded one day	Flooded 5 days	Flooded 10 days
Bo	5,622 (2.08)	1,806 (0.67)	0 (0.00)
Bombali	4,417 (2.04)	0 (0.00)	0 (0.00)
Bonthe	**10,588 (12.92)**	**7,287 (8.89)**	**1,311 (1.60)**
Falaba	372 (0.52)	0 (0.00)	0 (0.00)
Kailahun	2,455 (1.55)	154 (0.10)	0 (0.00)
Kambia	**2,7610 (14.50)**	**8,363 (4.39)**	**0 (0.00)**
Karene	3,198 (2.69)	0 (0.00)	0 (0.00)
Kenema	9,033 (2.80)	2579 (0.80)	0 (0.00)
Koinadugu	839 (0.94)	0 (0.00)	0 (0.00)
Kono	4,682 (1.81)	0 (0.00)	0 (0.00)
Moyamba	**11,821 (9.79)**	**2,492 (2.06)**	**0 (0.00)**
Port Loko	**23,540 (9.32)**	**3,997 (1.58)**	**202 (0.08)**
Pujehun	**8,369 (10.25)**	**970 (1.19)**	**0 (0.00)**
Tonkolili	4,519 (2.03)	0 (0.00)	0 (0.00)
Western Area Rural	**25,750 (7.56)**	**14,091 (4.14)**	**408 (0.12)**
Western Area Urban	**102,979 (20.54)**	**27,836 (5.55)**	**665 (0.13)**
Total	**245,794 (7.45)**	**69575 (2.11)**	**2,586 (0.08)**

Source: Annual School Census (2022).

When we add in the number of school children that attend the 495 schools that show as constant inundation to the number of children that attend a school that has "Flooded one day", the figure for **potential children impacted by flooding rises to 371,661 children. This is 11% of all school children in Sierra Leone**. **For Western Area Urban, 155,708 children have potentially experienced a flood, which is 31% of school children in that district.**

Repeat flooding incidents

We next look at repeated incidences of flooding across schools for the three-year period (see Table 1.3, below). Looking at repeat events helps to build a picture of those that are more at risk and potentially more vulnerable from being in the most flood-prone areas. Unsurprisingly, Table 1.3 highlights a drop in the number of schools that experience multiple floods over the period versus those that have one flood event.

However, the data suggests that a significant number of schools are at risk of multiple events. **Across the country, 772 schools have had two flooding events, which is 6.3% of the total schools in Sierra Leone.**

When we look at schools that have at least three flooding events, (so could be said to be roughly one per year), **we see that 468 schools have 3 flooding events**, which is 3.8% of total schools in Sierra Leone.

There are some outliers – with 330 schools having had six flooding events over the three-year period, which is 34% of schools that have one flood and 2.7% of all Sierra Leone school. This shows that as well as a significant number of schools being at risk of flooding, many schools can be classified as facing multiple flooding events in a short period of time.

Table 1.3. Number of schools flooded multiple times by district

District	Flood events - 2	flood events - 3	flood events – 6
Bo	14	5	1
Bombali	8	0	0
Bonthe	**42**	**33**	**28**
Falaba	0	0	0
Kailahun	7	3	2
Kambia	**85**	**68**	**51**
Karene	5	3	0
Kenema	26	12	9
Koinadugu	1	0	0
Kono	9	0	0
Moyamba	**47**	**26**	**11**
Port Loko	**61**	**36**	**23**
Pujehun	**29**	**15**	**5**
Tonkolili	12	4	0
Western Area Rural	**98**	**79**	**67**
Western Area Urban	**328**	**184**	**133**
Total	**772**	**468**	**330**

For schools that have been impacted by multiple flooding events, once again these are primarily clustered in the seven districts. 690 schools in those seven districts are impacted by two flooding events in the three-year period, meaning 89% of schools that have had two floods are in the seven flood-prone districts.

Of the schools which flood, we see a large share of repeated floods. The percentages that flood twice are: Kambia 97%, Bonthe 89%, Western Area Urban is 84%, Moyamba is 83%, Western Area Rural is 81%, Pujehun 73%, and Port Loko is 64%.

This means that in six of the seven districts over 80% of schools that are impacted by flooding are at risk of multiple floods over the three-year period.

Looking at repeat incidence is important and highlights a few key issues. Firstly, it reinforces the key finding that the scale of the flooding hazard on schools is high. It shows the need to use a district level lens when thinking about the problem and potential responses, as the impacts are mostly clustered within the seven flood prone districts.

In terms of resilience within the education system, repeat incidence suggests two things. Firstly, that resilience can be depleted through infrastructure degradation and the need to keep bouncing back from floods, as well as the potential stress on children and communities from having to cope with the impacts of flooding. However, conversely it also suggests that those areas that suffer repeated floods may be more skilled and experienced at coping with floods and have processes and plans in place.

In the context of climate change, more areas will become flood prone and potentially suffer repeated incidence of increasing severity. Therefore, resources are needed to support flood-prone schools, institutional capacity in the most flood-prone areas needs to be developed, and more understanding is needed of current responses and how this community expertise can be shared with other areas less experienced in dealing with floods.

What type of flood hazards do schools face?

One obvious flood hazard indicator is the distance of each school to a waterway – and this also helps us understand the possible sources of these floods. The main types of flooding in Sierra Leone are:

1. River (fluvial) floods - Occur when a river or stream overflows its banks due to heavy rainfall.
2. Coastal floods - Occur due to sharply rising sea levels during storm surges.
3. Ground (pluvial) floods - Occur due to intense, heavy rainfall over a short period of time being unable to drain away and flooding low-lying areas.
4. Urban flash floods - Occur when intense rainfall is prevented from draining into the ground as it is blocked by pavement, buildings, and other urban infrastructure. Typically, a result of poor urban drainage systems.
5. Groundwater floods - Occur as groundwater levels rise in times of intense rainfall, flooding low-lying areas.

To determine the types of flooding hazard that schools face, we categorized schools based on their proximity to constant waterways[10] (which are predominantly rivers) or the coastline (Figure 1.4). First, we calculated the shortest distance between each school and all waterways and coasts. If this distance exceeded 5km, we classified the school as 'land,' indicating that it is not near any constant water source. Schools with the nearest constant water source being a waterway were categorized as 'waterway,' while those with the nearest the coast were classified as 'coast.'

Figure 1.4. Number of schools flooded by the nearest waterway

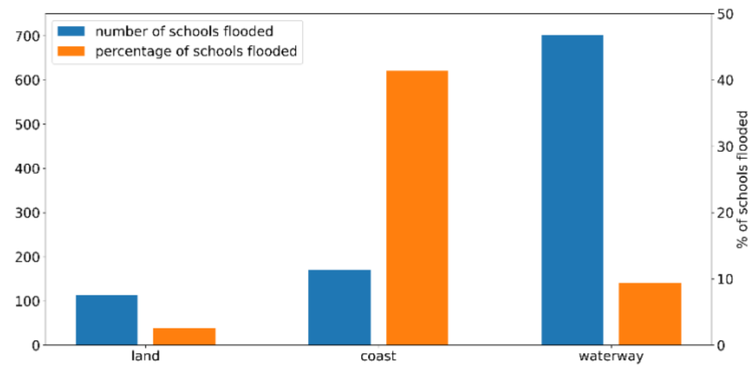


Figure 1.4 (blue bars) indicates that a higher number of schools near waterways experienced flooding compared to those near the coast or on land. Additionally, the orange bars represent all the schools in Sierra Leone and classified them as land/waterway/coast and looked at what percentage within each category experienced a flood in our time-period. The chart shows that the category with the highest percentage of flooded schools is near the coast. This is, in part, due to Freetown's proximity to the coast.

The next way that we explored the data was through looking at the question of whether schools that were exposed to flooding were in urban or rural areas. This supports the research aims to understand where flood prone schools are in two ways. Firstly, it highlights the distribution of the hazards between cities and towns versus hamlets, which has implications for vulnerability. Secondly, it has implications for the likely human and financial cost of the different flooding scenarios, as well as what interventions will be needed to fix damage and get schools open again.

The World Bank's multicity hazard and risk assessment provides information on the probable damages to buildings and infrastructure from flood events. It is estimated that across Sierra Leone's three main population centres: Freetown, Makeni, and Bo, the annual average loss from fluvial and pluvial floods is between '$3.6 to 6 million USD' [11]. The report goes further to investigate climate risks to the country's building exposure, whereby it found that 0.8% of

---

[10] Waterways as a term refers to a body of water with a directional flow. Therefore, it can relate to rivers, canals, streams, and tidal channels.

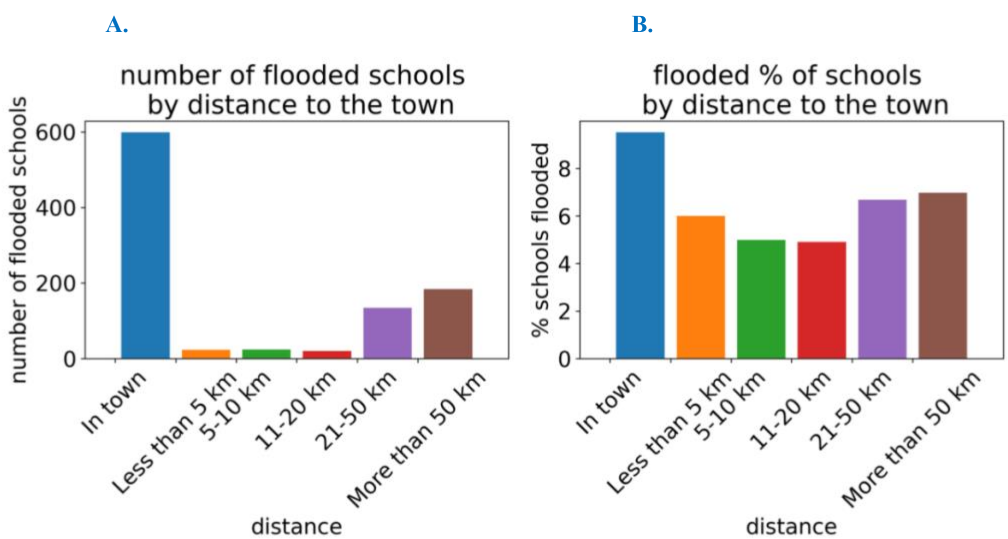
[11] World Bank. 2018. *The World Bank Sierra Leone Multi-City Hazard Review and Risk Assessment.*

buildings were exposed to fluvial flooding whereas 4.5% of building were exposed to a pluvial flood hazard[12].

Freetown, where the highest number of schools and most children are exposed to flooding, is susceptible to river, coastal and urban flash floods. In 2017, intense rainfall caused the *2017 Regent-Lumley Landslide* which resulted in significant loss of life and major damage to buildings, bridges, schools, and health facilities[13]. Whilst the most tragic loss of life and infrastructure damage came from the landslide, most people during the event were impacted by urban flash floods and rivers/streams flooding. The estimated impact of this event on the education sector amounted to $1.22 million USD in damages and losses, which compared to an education budget of $173.36 million in 2017[14]. A further impact of this event was that many schools were either permanently destroyed, used as community shelters, or had to be relocated. This meant that education was significantly disrupted as many schools were closed for over three months and other schools in the area had to absorb students.

We expanded our analysis by categorizing schools based on their proximity to urban centers. As depicted in Figure 1.5.A (left panel), the red bar in the chart demonstrates a significantly higher number of flooded schools located in towns. However, in terms of percentage (right panel), schools within towns and those situated far from urban centers (over 50km) emerge as the top two affected categories, emphasizing the impact on rural areas where resource allocation and assistance might be more challenging.

Figure 1.5. Number of schools flooded by distance to the closest urban centre



Source. Authors calculations using Annual School Census, 2022 categories.

[12] Idem

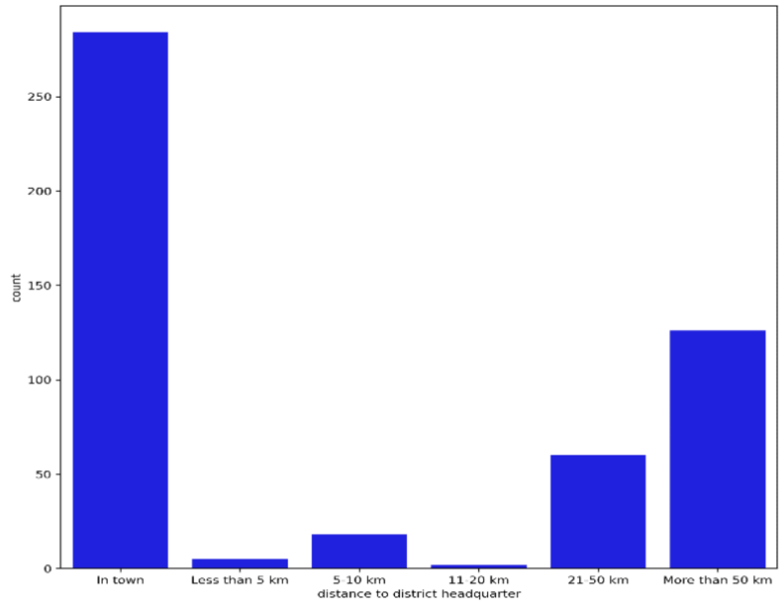
[13] World Bank. 2017. Sierra Leone Rapid Damage and Loss Assessment of August 14th, 2017 Landslides and Floods in the Western Area.

[14] UNESCO http://data.uis.unesco.org/

This additional analysis highlights the importance of considering a school's location relative to urban centers and rural areas to better understand the distribution and magnitude of the flood hazard. By incorporating these findings into the School Flood Vulnerability Index (FVI), we can develop a more comprehensive school index that accounts for social and physical components, as well as the varying impacts on urban and rural schools.

A similar pattern emerged when we look at the 495 schools that showed as consistently in water.

Figure 1.6 Schools in permanent inundation by distance to nearest urban centre



Combining an understanding of the type of flood hazard in reference to urban v rural alongside the distance to waterways shows that mitigating flood hazards requires a multi-faceted approach and needs an understanding of the school location and distance to waterway. It must deal with urban floods, which are often from inadequate drainage infrastructure, as well floods in rural areas, which are more likely to flood due to river level rises or heavy rains that cannot be absorbed into the ground.

Flood Hazard Index

Hazard refers to potential natural events that can adversely affect vulnerable and exposed elements, and it is recognized as a component of risk rather than risk itself. This understanding is the basis for the creation of a hazard index in this section.

We used the school level flood data for the last three years to create a flood hazard index. Specifically, we did a min-max transformation on the data to get them on a common scale – transforming the number of flooding events and number of flooding days onto a 0-1 scale (see Annex B). It considers the intensity (number of flooded days) and frequency (number of events). Combining these two normalized variables gives us the Flood Hazard Index, which will be used along with the flood vulnerability index (see Section Two) to assess the risk of flood damage for each school (see Section Three).

The flood hazard index confirms the exposure of the seven selected districts (see Figure 1.7). The highest index score (see Table 1.4) is in the Western Area Urban, while Bonthe ranks second. According to the index, **Bonthe has the highest number of flood events, while Western Area Urban experiences the longest duration of flooding.** In contrast, districts in the northern region, such as Falaba and Koinadugu, have significantly lower index values, ranking at the bottom compared to the other districts.

Figure 1.7 Flood hazard by district

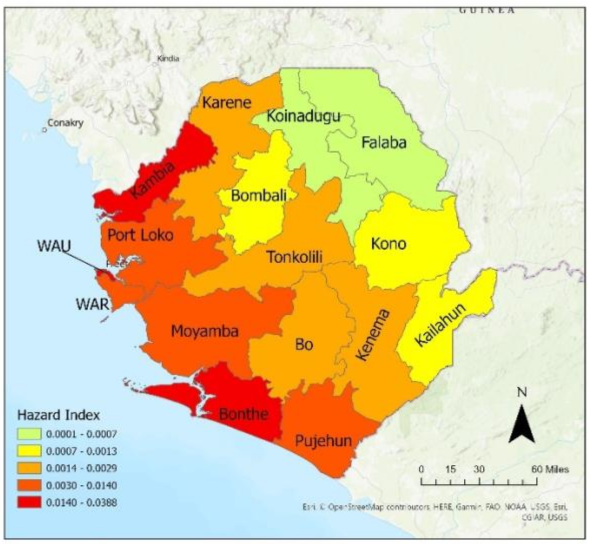


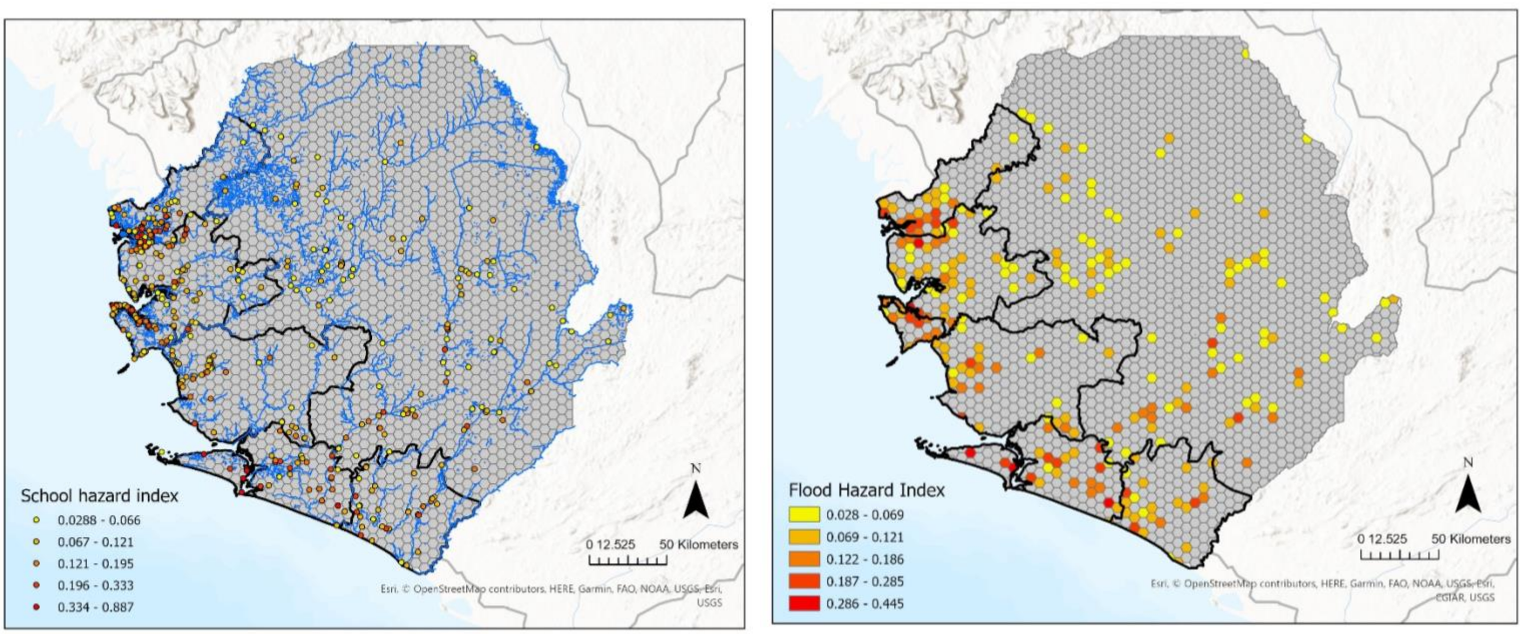
Table 1.4 – Flood Hazard Index by district

	Number of flood events			Longest flood events			Flood hazard index			
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Rank
Bo	0.000	-	0.080	0.005	-	0.474	0.00	-	0.248	9
Bombali	0.000	-	0.016	0.002	-	0.211	0.00	-	0.108	12
Bonthe	**0.027**	**-**	**0.775**	**0.051**	**-**	**1.000**	**0.04**	**-**	**0.888**	**1**
Falaba	0.000	-	0.005	0.000	-	0.105	0.00	-	0.055	16
Kailahun	0.000	-	0.043	0.002	-	0.263	0.00	-	0.137	13
Kambia	**0.015**	**-**	**0.770**	**0.030**	**-**	**0.474**	**0.02**	**-**	**0.569**	**3**
Karene	0.000	-	0.032	0.004	-	0.211	0.00	-	0.111	10
Kenema	0.001	-	0.080	0.005	-	0.421	0.00	-	0.224	8
Koinadugu	0.000	-	0.011	0.001	-	0.158	0.00	-	0.084	15
Kono	0.000	-	0.016	0.002	-	0.211	0.00	-	0.111	14
Moyamba	**0.003**	**-**	**0.246**	**0.015**	**-**	**0.421**	**0.01**	**-**	**0.285**	**7**
Port Loko	**0.005**	**-**	**0.770**	**0.016**	**-**	**0.579**	**0.01**	**-**	**0.622**	**6**
Pujehun	**0.002**	**-**	**0.134**	**0.020**	**-**	**0.474**	**0.01**	**-**	**0.256**	**5**
Tonkolili	0.000	-	0.027	0.004	-	0.211	0.00	-	0.113	11
Western Area Rural	**0.008**	**-**	**0.497**	**0.020**	**-**	**0.526**	**0.01**	**-**	**0.464**	**4**
Western Area Urban	**0.012**	**-**	**1.000**	**0.037**	**-**	**0.474**	**0.02**	**-**	**0.500**	**2**
Total	0.005		1.000	0.015		1.000	0.010		0.888	

Figure 1.8 displays the results of the flood hazard index, it shows the individual results for each school (left side) and the aggregated mean values for each hexagon, which represents areas of Sierra Leone. **As expected, the seven previously identified flood-prone districts have higher index values.** Bonthe, Kambia, and the Western Area Urban experience more frequent and intense floods, indicated by an index higher than 0.04. In comparison, Falaba and Koinadugu have a lower index value (0.01), indicating a lower flood hazard.

What the maps highlight is that alongside thinking about the flooding hazard through a district level lens, we must break it down further to look at the areas of the districts that are flood prone. As can be seen on the maps, this means looking primarily along the coastal areas, river deltas and wetlands in the northern districts of Kambia and Port Loko. For Western Area Urban it requires tackling urban and flash floods in Freetown. Bonthe, Pujehun, and Western Area Rural have more of a spread, that includes the coast, wetlands, and river-based flooding.

Figure 1.8 Flood Hazard Index at school level (Left) and mean by hexagon bin (right)[15].



Climate change and flood prone schools

Finally, in this section we place these results in the context of climate change. What we have shown is that a significant number of schools in Sierra Leone are at risk of flooding. As our data indicates, even before more extreme weather events become even more common, hundreds of thousands of children are already at risk of flooding disruption to their education, with the risks to wellbeing and safety that this also entails. Therefore,

[15] Note: The categories are five natural breaks (Jenks).

interventions are required to support schools now and to prepare them to become climate-smart in the coming years.

The story of flooding needs to be seen through a district lens, with Bonthe, Kambia, Moyamba, Port Loko, Western Area Urban, and Western Area Rural as the six districts that are most flood prone with and where the highest number and percentage of schools that experience floods. The hazard is both one-off flooding events, annual flooding, and multiple flooding events in a single year. Furthermore, there are multiple hazards from coastal flooding, urban flooding, flash floods, and river flooding.

Flooding will only be exacerbated by climate change; already 13% of its area and 35% of its population at risk to flooding, with exposure and frequency likely to worsen[16]. A 2017 report by the World Bank highlighted how due to climate change flooding events will become more common, with one in ten-year flooding events becoming one in two-year flooding events. Concerningly, a 1 in 100-year event will become a 1 in 5-year event. When this is considered alongside our analysis, it suggests that schools in Sierra Leone will become exposed to many more floods and action is needed in the seven districts that we have outlined.

As argued in the World Bank report, Disaster Risk Reduction Measures need to be developed in locations that are exposed to flooding. Our report suggests interventions should be focused at the district level, in line with the pillar system of the National Disaster Management Agency.

Due to climate change, areas that are currently not flood prone may eventually become exposed to flood hazards. Other areas will face more frequent and extreme flood events. With our evidence, it suggests that a significant percentage of schools will become flooded, those already in flood prone areas will have their resilience tested, and interventions are needed now in terms of flood planning, DRR, flood response and actions to build more climate-smart schooling. Prioritisation should be given to the seven regions that we have identified, in response to different types of flood and more work should be done to develop flood response processes in urban and rural areas.

---

[16] World Bank. 2017. *Sierra Leone Rapid Damage and Loss Assessment of August 14th, 2017 Landslides and Floods in the Western Area.* World Bank.

Section 2: Identifying which schools are vulnerable if flooded – a School Flood Vulnerability Index

There is a great deal of debate across disciplines into what constitutes vulnerability, with different sectors using different language, as discussed more in Annex A. We define vulnerability as "*the extent of harm, which can be expected under certain conditions of exposure, susceptibility and resilience*"[17], or simply the amount of harm or damage that could occur IF a school floods.

This means that to assess how vulnerable a school is, we ideally need to know:

- how likely a flooding event is (exposure),
- what level of impact can be expected from a flooding event (susceptibility)
- how able the impacted community is to cope during flooding[18], and how able they are to recover following it (resilience).

Measuring flood vulnerability is a complex process, as it is influenced by various environmental, economic, social, and political factors at the local level[19]. Flood vulnerability is affected by factors such as settlement conditions, infrastructure, policies and capacities of authorities, social inequities, and economic patterns.

In this section we begin with a brief overview of the methodology that we have used to determine a flood vulnerability index for schools (more on the methodology can be found in Annex B). Following that we look at the physical components of vulnerability and assess how physically vulnerable schools across Sierra Leone are. Then we look at how vulnerable schools in different districts are if they were to be flooded before exploring the physical vulnerability of those schools that we have defined as having had a flood event in the previous three years.

What we have done – school flood vulnerability index

Various methodologies and indexes have been developed to measure vulnerability to flooding, though only a few studies have attempted to examine the vulnerability of schools to floods. After reviewing these (see Annex A) we adapt the UNESCO-IHE Flood Vulnerability Index (FVI) to construct a school flood vulnerability index based on social and

[17] Flood Vulnerability Index, FVI (unesco-ihe-fvi.org); the Existing literature generally agrees that human systems are vulnerable to floods due to three critical aspects: exposure, susceptibility, and resilience ((Mahmood et al., 2017, Karagiorgos, et al, 2016, Balica, 2013, Rodríguez-Rosales, 2021).

[18] This leads to a question of what external support will be required to minimise the harms from the flood ahead of the flood happening, during, and in the aftermath. Emerging work in this area is looking at how can an AA system support the community to recover and be better prepared for future flooding.

[19] Jixi Gao, 2007 discusses this in detail.

physical components. The goal is to identify the locations most in need, so that interventions can be designed to reduce disruption, damage, and prevent loss through preparedness and mitigation measures. The Flood Vulnerability Index (FVI) serves as a valuable tool for policy and decision makers, enabling them to prioritize investments and enhance the transparency of the decision-making process[20]. By identifying districts and schools with significant flood vulnerability, the FVI can guide decision-makers in adopting more effective strategies for managing and mitigating floods.

As the index is adapted to the school level, vulnerability in this assessment will measure the social and physical components of vulnerability. Social variables are related to human or community aspects in schools, while physical variables are physical and structural aspects of school buildings and grounds. Each of these variables is adjusted to the conditions of the school and components that are potentially exposed to hazards. The social and physical variables in this study are composed of parameters that are crucial in disaster management in schools. Table 2.1 shows the indicators that we have used to develop the school FVI and how we have weighted them.

Table 2.1. Variables and weights by subindex

Physical subindex		**Social Index**	
Variables	Weights	Variables	Weights
Number of classrooms	25%	Total enrolment and staff	15%
Materials	25%	Distance to inundation (km)	10%
Years of construction	10%	Past experience (number of flood events)	10%
Number of latrines	10%	School feeding program (number of days)	10%
Conditions of the latrines	10%	Distance to closest school same level in a not flood-prone area	10%
Water source	10%	Network coverage	10%
Electricity	10%	Poverty	15%
		Distance to Headquarter	10%
		Population density (2km catchment)	10%

Note: See Annex A and B variable definitions and assumptions.

[20] Balica, 2009.

Physical vulnerability

Structural conditions of school buildings are measured based on several parameters consisting of the location of the school building, construction materials used, water source, number of classrooms and other facilities, whether they have electricity, toilets, and the year of construction[21]. This was possible to assess using the Annual School Census (ASC) and enabled us to estimate the physical vulnerability by weighting the variables, as shown in Table 2.1.

For the physical subindex, we made a methodological decision to assign less weight to variables such as water sanitation, electricity, and additional facilities. This is because most schools lack these services. Additionally, while the year of school foundation is important, it carries less weight than the actual materials used. Since we do not have data on whether the old schools have been renovated, we prioritise the materials and the number of classrooms in determining their weight.

Building materials is a straightforward variable in our index, as semi-solid or makeshift classroom infrastructure is more likely to be damaged or destroyed in the event of a flood. Equally, damaged buildings are more likely to be vulnerable to a flood than those that are in a good state. The type of water source and how schools get electricity can make them more or less vulnerable. The type of water source can significantly influence school vulnerability to contamination and health risks, especially if it is exposed to flood water. Certain water sources are more prone to pollution and can pose greater health hazards when used for drinking or other purposes. Being connected to the electricity grid makes a school least vulnerable, solar power is less problematic than a generator, which can become damaged in a flood or rely on fuel that may not be always available.

Improving sanitation infrastructure enhances community resilience to extreme weather events associated with climate change. However, the link between climate change, sanitation, and its impact on schools' vulnerability to flood hazards has received limited attention[22]. Insufficient sanitation or inadequate wash facilities increases the vulnerability of schools to flooding, emphasizing the need to address sanitation as a crucial aspect of climate change adaptation and disaster risk reduction[23].

As we are applying a school flood vulnerability index to Sierra Leone schools, there are some seeming paradoxes in what it suggests about the state of infrastructure in those

[21] Simonovic et al., 2007.
[22] Rodina, L. (2021).
[23] Schmuck, Hanna. 2013.

schools. For instance, having more classrooms makes a school less vulnerable, this is because if some parts become flooded or damaged there are ways that education can continue. However, it also suggests that potential costs of fixing damage could be higher in the event of a flood, as there is more infrastructure that might need repairing. If a school has more toilets and electricity, it is considered less vulnerable but the potential range of damage that the school is vulnerable to is greater, which suggests a greater financial impact from flooding. Therefore, this report highlights that a significant proportion of schools are exposed to flooding and the way to reduce vulnerability is through improving infrastructure, yet if floods become more frequent, more severe, and more schools become flooded, this will require more investment in institutional capacity, infrastructure, people, and broader financial support to maintain education infrastructure in a changing climate.

There are two reasons why we take the approach that we do, despite the seeming paradoxes in terms of the potential impacts being greater when less vulnerable schools are flooded. Firstly, small schools with limited infrastructure are potentially vulnerable as it suggests they are serving poorer communities and may be less able to resource the fixes that are needed in the event of more serious and damaging floods. Secondly, by highlighting vulnerability in schools with lower quality infrastructure, we argue that improving infrastructure is a way to reduce vulnerability in schools, rather than arguing for reducing infrastructure to make schools less vulnerable. This also means that resources, in terms of processes, financial, and human are needed to make schools in Sierra Leone less vulnerable to floods and more climate-smart.

Physical Flood Vulnerability Index Results

Table 2.2 (below) compares school infrastructure in flood-prone and non-flood-prone areas to assess their vulnerability. In Sierra Leone, there were 12,204 schools in 2022, each with an average of 5.1 classrooms. The size of schools is consistent between flood-prone and non-flood-prone areas. Schools in flood-prone areas have a higher proportion of classrooms built with solid materials (69.7% vs 57.8%). This is likely due to the high number of flood-prone schools based in urban areas, especially in Western Area Urban. The percentage of classrooms made from semi-solid materials is 3.2% in flood-prone areas and 2.9% are built using makeshift materials. However, 24% of classrooms require repair in flood-prone areas compared to 35% in non-flood-prone areas.

Interestingly, the analysis reveals that schools in flood-prone areas are on average constructed with better materials and require fewer repairs than those in non-flood-prone areas. However, it remains unclear whether the higher quality of materials is due to awareness of the risks, or if it is influenced by the relatively less impoverished districts where these schools are located.

The country's oldest school dates to 1840, with the most recent one established in 2021. The average year of establishment for schools in Sierra Leone is 1999, while in flood-prone areas, it is 1996. This variable is considered based on the assumption that newer buildings comply with safety regulations, making them more resilient. It is relevant in cities like Freetown, where schools are in areas that experience flash floods or urban flooding due to heavy rainfall that exceeds the capacity of the infrastructure. Older neighbourhoods may have outdated sewage systems that are more vulnerable to flooding.

Sanitation access is considered in flood vulnerability indexes. On average, schools have 3.5 latrines, with some schools having none and others having 51. There is no significant difference between schools in flood-prone and non-flood-prone areas regarding this. The quality of the water supply also plays a significant role in determining vulnerability. Around 20% of schools in non-flooded areas are connected to a well, while it is 15% in flood-prone areas. In flood-prone areas, 42% of schools lack water access, which is 1% less than in other areas. Therefore, regarding water supply, the situation is somewhat mixed.

Fewer schools in flood-prone areas have wells, but more have access to piped water, and there are fewer schools with no water compared to schools unaffected by floods in the past three years. This is important as floods can potentially increase the transmission of water- and vector-borne diseases, such as typhoid fever, cholera, malaria, and yellow fever, among others. When flooding occurs open water sources are at risk of contamination, which is applicable to both piped and water from wells.

Additionally, 62% of schools in flood-prone areas lack electricity, which is 14% lower compared to non-flood-prone areas. This possibly indicates that schools in flood prone areas are situated in less impoverished or more urban communities that have better access to electricity. To gain further insights, the social subindex will examine community characteristics to provide a more comprehensive understanding of socio-economic characteristics of flood prone schools. The absence of electricity and limited access to water can be indicative of a weak infrastructure.

Table 2.2 Characteristics of the schools in flood-prone and non-prone area.

			Schools in Flood Prone Area		Schools in non-Flood Prone Area	
Category	Variable		Num	Mean/Share	Num	Mean/Share
Schools	Number of schools		984		11,482	
		Pre-Primary	20%	1,804	16%	16%
		Primary	58%	6,883	60%	60%
		Junior Secondary	15%	1,929	17%	17%
		Senior Secondary	7%	866	8%	7%
	Number of classrooms		5,019	5.12	58792	5.10
Building code	Classrooms materials (share by school)					
		Solid	3,497	69.7%	33,998	57.8%
		Solid in need of repair	717	14.3%	12,463	21.2%

		Semi-solid	163	3.2%	2,806	4.8%
		Semi-solid in need of repair	303	6.0%	5,830	9.9%
		Makeshift	146	2.9%	1,535	2.6%
		Makeshift in need of repair	193	3.8%	2,160	3.7%
	Years of construction			1997		2000
Access to sanitation	Number of latrines		3,577	3.38	41,119	3.56
	Latrines conditions					
		Good	2,260	63%	23,048	56%
		Fair	875	24%	12,164	30%
		Bad	442	12%	5,907	14%
Access to water	Water source					
		Well	152	15%	2,343	20%
		Piped	231	23%	1,285	11%
		Borehole	175	18%	2,666	23%
		River	11	1%	145	1%
		No Water	415	42%	4,959	43%
		Other	0	0%	84	1%
Access to electricity	Electricity					
		Grid	305	31%	1,799	16%
		Solar	22	2%	571	5%
		Generator	38	4%	382	3%
		No Electricity	609	62%	8,669	76%
		Other	10	1%	61	1%

The level of physical vulnerability in schools across Sierra Leone is not the main focus of this paper, which is on assessing the vulnerability of schools located in flood-prone areas. Although schools in flood-prone areas appear to be less vulnerable than those in non-flood-prone areas, our index enables us to identify the schools within flood-prone areas that are more vulnerable. In the next section, we will analyse the subindex for the entire country to gain a comprehensive understanding of flood vulnerability across the country, before specifically focusing on schools that have experienced floods.

The vulnerability of physical infrastructure in the event of a flood by district

Table 2.3 (below) shows the scores of all the schools across the indicators and ranks them to generate a relative position in terms of the whole country. **Pujehun and Bonthe are flood-prone districts and in the physical subindex, they rank as the second and third most vulnerable districts in the country**. In Bonthe, it is the quality of materials that are used in school buildings that make it more vulnerable than other districts. Kambia and Moyamba are in the middle of the table and Port Loko, Western Area Rural and Urban are less vulnerable districts.

Across the seven districts identified in Section One, they all score highly on physical vulnerability in relation to classrooms, which means there are a lot of schools with a low number of classrooms and are therefore vulnerable to having to close if the school is damaged due to floods. The seven districts have high numbers of schools with low numbers of latrines, which are often not in a good condition. There is also a lack electricity in many schools. As this suggests that the schools have less resources and are more vulnerable to flooding, it also indicates that it would be relatively low cost to support them to recover in the event of a flood.

Kambia, Port Loko, Western Area Urban, and Western Area Rural fare well on building materials, which suggests that they are in a better position to cope in the event of a flood. Moyamba, Pujehun, and Bonthe score the worst of the flood prone districts in terms of materials, which suggests that their physical infrastructure is more vulnerable to flood impacts and action is needed to address this.

In terms of water, schools in Pujehun, Bonthe and Kambia are more vulnerable, suggesting low levels of access to dedicated water sources. Schools in Moyamba, Port Loko, Western Area Rural, and Western Area Urban score better on water vulnerability, which suggests that more water infrastructure is in place. However, in the event of a severe flood there may be more disruption and higher costs as interventions are required to fix this infrastructure.

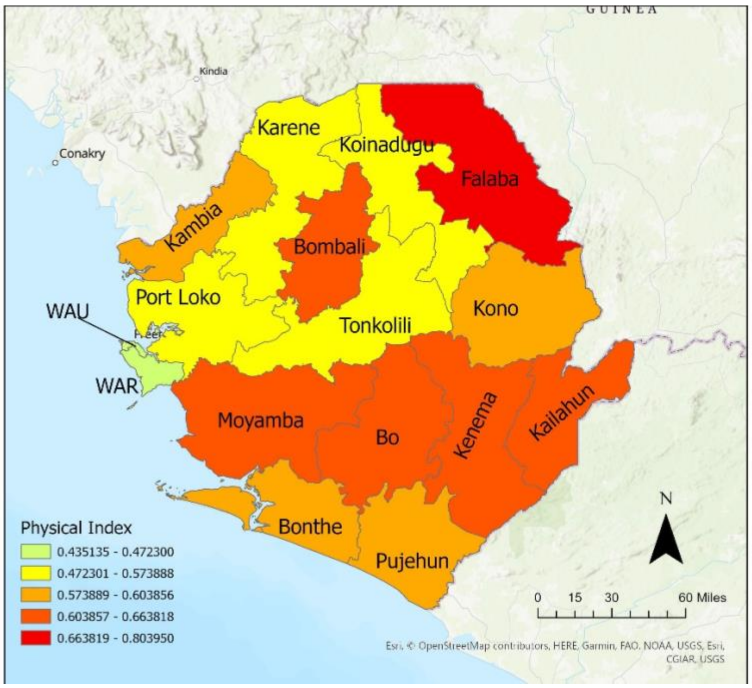
Table 2.3 Physical subindex and variables for all schools

District	Total classrooms	Materials quality	Year founded	Total latrines	Latrines conditions	Electricity	Water source	Physical	Ranking
Bo	0.857	0.241	0.142	0.938	0.413	0.844	0.607	0.569	10
Bombali	0.849	0.169	0.112	0.926	0.369	0.753	0.531	0.524	14
Bonthe	**0.884**	**0.330**	**0.155**	**0.929**	**0.435**	**0.930**	**0.612**	**0.610**	**3**
Falaba	0.876	0.376	0.086	0.939	0.547	0.984	0.671	0.636	1
Kailahun	0.862	0.267	0.157	0.927	0.459	0.895	0.715	0.598	4
Kambia	**0.868**	**0.193**	**0.118**	**0.928**	**0.486**	**0.957**	**0.654**	**0.579**	**8**
Karene	0.876	0.240	0.125	0.926	0.470	0.952	0.513	0.578	9
Kenema	0.850	0.238	0.128	0.916	0.406	0.836	0.563	0.557	11
Koinadugu	0.858	0.155	0.100	0.913	0.368	0.946	0.516	0.537	13
Kono	0.858	0.261	0.112	0.943	0.465	0.908	0.627	0.585	6
Moyamba	**0.886**	**0.292**	**0.164**	**0.923**	**0.516**	**0.935**	**0.488**	**0.597**	**5**
Port Loko	**0.857**	**0.179**	**0.116**	**0.922**	**0.380**	**0.882**	**0.483**	**0.537**	**12**
Pujehun	**0.891**	**0.296**	**0.153**	**0.914**	**0.497**	**0.939**	**0.660**	**0.613**	**2**
Tonkolili	0.870	0.245	0.128	0.935	0.447	0.908	0.635	0.584	7
Western Area Rural	**0.850**	**0.081**	**0.062**	**0.940**	**0.209**	**0.652**	**0.504**	**0.469**	**15**
Western Area Urban	**0.835**	**0.089**	**0.124**	**0.935**	**0.245**	**0.302**	**0.482**	**0.440**	**16**
Total	0.858	0.198	0.120	0.930	0.381	0.773	0.561	0.540	

Physical vulnerability of schools in flood prone areas by district

The next layer of analysis that we conducted (Table 2.4, below) was to look at how schools ranked when we analysed only those that were deemed to be in flood-prone areas, which we show through their district. We display this in Figure 2.1

Figure 2.1 Physical vulnerability by district



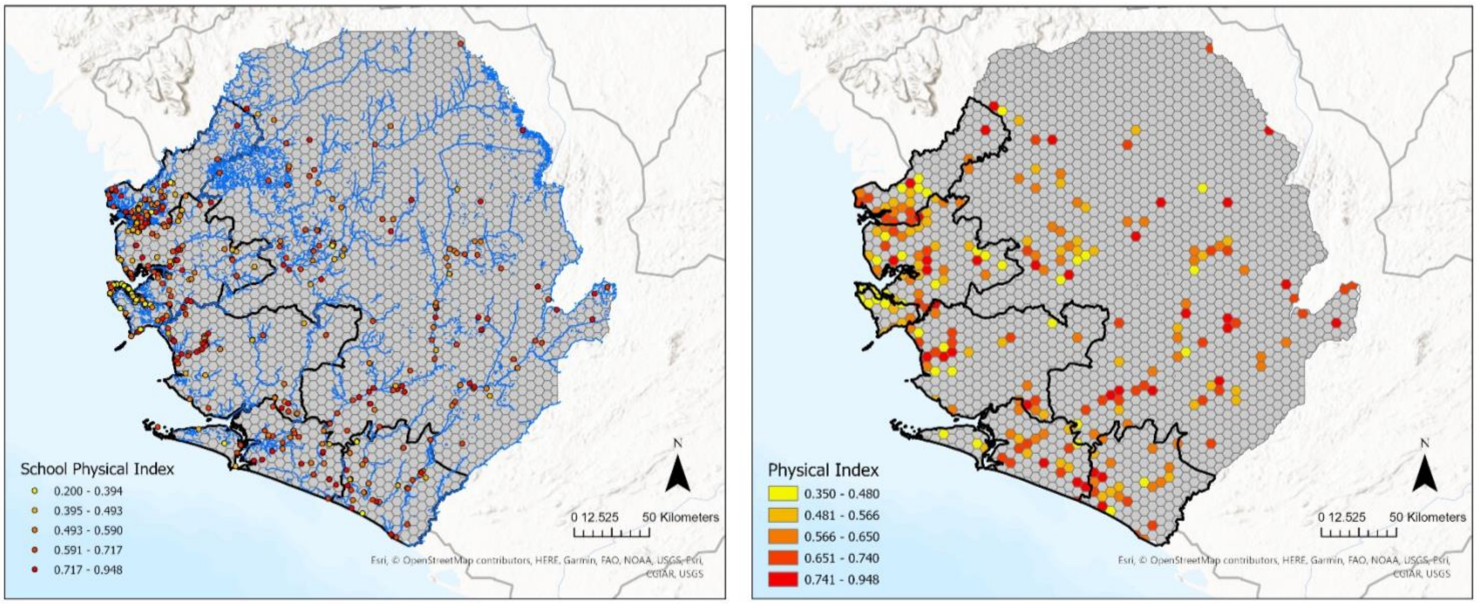
This analysis suggests that within the seven flood-prone districts, Pujehun, Moyamba and Bonthe have the most vulnerable schools, Kambia and Port Loko fare better in the ranking but the schools still score highly. Western Area Rural and Western Area Urban are the districts where schools that are prone to flooding are least vulnerable in our index. When viewing the data in this way, it also suggests that Kailahun, ranked second and Bo ranked third should be considered as districts where schools in flood-prone areas are vulnerable to disruption from flooding. However, these two districts had extremely low numbers of schools that had five-day floods or repeated floods, so would become priority areas if floods become more extreme or severe due to climate change.

Table 2.4. Physical subindex and variables for schools in flood-prone areas

District	Num of schools	Total classrooms	Materials quality	Year founded	Total latrines	Latrines conditions	Electricity	Water source	Physical	Ranking
Bo	24 (2.38%)	0.875	0.324	0.189	0.928	0.533	0.933	0.808	0.639	3
Bombali	17 (2.37%)	0.876	0.274	0.133	0.931	0.485	1.000	0.788	0.621	5
Bonthe	**47 (14.97%)**	**0.892**	**0.305**	**0.171**	**0.940**	**0.438**	**0.906**	**0.583**	**0.603**	**8**
Falaba	2 (0.63%)	0.889	0.900	0.097	0.971	0.500	1.000	1.000	0.804	1
Kailahun	11 (1.91%)	0.881	0.313	0.123	0.966	0.800	1.000	0.764	0.664	2
Kambia	**88 (15.04%)**	**0.870**	**0.207**	**0.139**	**0.945**	**0.496**	**0.968**	**0.675**	**0.592**	**10**
Karene	12 (2.78%)	0.861	0.157	0.114	0.917	0.681	0.933	0.550	0.574	11
Kenema	36 (3.46%)	0.877	0.344	0.094	0.950	0.559	0.944	0.589	0.619	6
Koinadugu	4 (1.22%)	0.868	0.179	0.052	0.907	0.267	1.000	0.400	0.524	14
Kono	14 (1.62%)	0.851	0.239	0.125	0.923	0.681	0.886	0.614	0.595	9
Moyamba	**57 (9.31%)**	**0.875**	**0.324**	**0.194**	**0.928**	**0.615**	**0.965**	**0.593**	**0.629**	**4**
Port Loko	**96 (10.63%)**	**0.870**	**0.192**	**0.118**	**0.934**	**0.478**	**0.948**	**0.588**	**0.572**	**12**
Pujehun	40 (10.78%)	0.902	0.295	0.141	0.902	0.443	0.920	0.640	0.604	7
Tonkolili	25 (2.91%)	0.900	0.191	0.133	0.938	0.492	0.840	0.520	0.565	13
Western Area Rural	**121 (8.39%)**	**0.865**	**0.058**	**0.067**	**0.948**	**0.217**	**0.620**	**0.562**	**0.472**	**15**
Western Area Urban	**390 (21.39%)**	**0.833**	**0.085**	**0.139**	**0.929**	**0.245**	**0.303**	**0.444**	**0.435**	**16**
Total	984 (8.06%)	0.858	0.165	0.131	0.934	0.373	0.649	0.547	0.519	

The results at the school level are displayed in Figure 2.2, showing the individual results for each school (left side) and the aggregated mean values for each hexagon. In Bonthe, we see that schools with higher physical vulnerability are located on the mainland, while those on the island appear to be less vulnerable. Additionally, in the Western Area Rural, schools closer to the sea exhibit higher vulnerability compared to those along the border with Western Area Urban.

Figure 2.2 Physical Vulnerability Index at school level in the flood prone area (Left) and mean by hexagon bin (right)[24].



Social Vulnerability

The social FVI provides valuable insights into the potential effects on people, which can have implications for educational outcomes. To measure social vulnerability, we consider various factors.

Firstly, we incorporate the total school population, which is calculated based on the total enrolment of students and total number of teachers. In Sierra Leone, the average school size is 275 people, with school size ranging from 3 to 3,747. Schools in non-prone areas are bigger than those in flood-prone areas, smaller schools in terms of pupils are less vulnerable in a social sense as the amount of people disrupted and the amount of intervention, both financial and scale of support, would be significantly less than for larger schools.

Population density is considered a crucial factor within the flood vulnerability assessment. Notably, schools in flood-prone areas tend to be in places with significantly higher

[24] Note: The categories are five natural breaks (Jenks).

population density compared to schools in non-prone areas. For instance, the population density in flood-prone areas averages 1,074 people per square kilometre, while the corresponding figure in non-prone areas is 473 people per square kilometre.

Including school feeding programs as an indicator of social vulnerability serves two purposes. Firstly, as an indicator of poverty, assuming schools in the program serve economically disadvantaged children. Secondly, there are more children who may suffer if the service is disrupted. The total number of schools in this program is 2,758, receiving on average 4.7 meals a week. 18% of the schools in this program are in flood prone areas, which is high considering that only around 8% of schools in total are in flood prone areas.

Poverty is included as a factor since it is closely linked to the well-being of individuals, communities, and society. This variable is estimated at the chiefdom level by the World Bank. In flood prone areas the poverty rate is 41%.

Network coverage[25] is another important consideration, as it enables communities to receive real-time information about heavy rains and potential flooding, enhancing preparedness[26]. Additionally, connectivity allows communities to communicate during a flood event, aiding emergency services in helping. In the country, 10.5% of areas around schools do not have network connectivity.

Past experience is considered, as it influences preparedness. Communities that have experienced floods are generally better equipped to cope with future floods[27]. **Twelve times was the maximum that a school was shown to be affected by floods in the past three years.** This indicator has the potential to skew the results as schools that have never been flooded, and may never be flooded, have no need to prepare flood responses. However, we have included this indicator because under climate change more schools are likely to become prone to floods and therefore it is important to acknowledge that those that have no experience currently, but may in the future, are more socially vulnerable than those with experience of responding to floods.

The final three indicators are school location in terms of whether they are urban or rural, the distance to a source of potential flooding, as well as the distance to the nearest school at the same level in a non-flood-prone area. Most flood prone schools are in towns, followed by those in the most rural locations, as outlined in Section One. **On average, the schools in flood prone areas are 0.11 kilometres away from the inundation and the distance to the closest school in a non-flood prone area is on average 1.55 km.** Having a school close by allows children to continue their education in another school in the event of their school closing due to flooding.

By incorporating these social factors into the FVI, we gain a comprehensive understanding of social vulnerability and its implications for flood-prone areas and the education system.

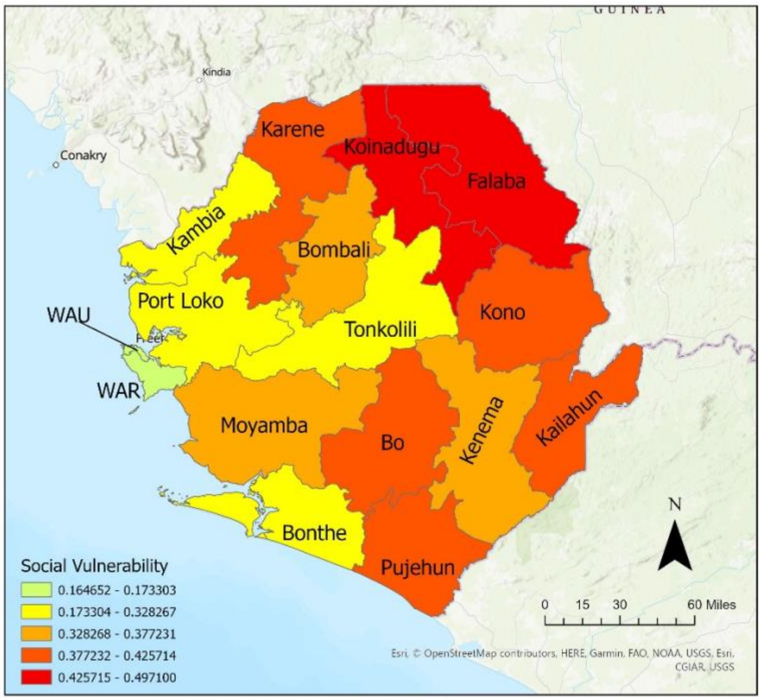
---

[25] We use network coverage data from Connected Society (GSMA) and GSMAi intelligence. This data is at the school level.
[26] Crocker, J., Saywell, D., & Bartram, J. (2020).
[27] Kapuco, 2008.

Table 2.5 Social Vulnerability Index and its variables: Mean, Minimum, and Maximum Values					
Variables		Schools in Flood Prone Area		Schools in not Flood Prone Area	
		Num	Mean/Share	Num	Mean/Share
Schools		984		11,220	
Total enrolment and staff		245,794	257.10	3,101,889	279.36
Distance to inundation (Km)		0.11		0.98	
Past experience (Number of flood events)		11.19		-	
School feeding program (number of days)					
	0	813	83%	8,643	77%
	1	8	1%	103	1%
	2	5	1%	88	1%
	5	158	16%	2,396	21%
Distance to closest school same level in a not flood-prone area		1.55			
Distance to HQ	**In town**	599	61%	5,692	51%
	Less than 5 km	23	2%	360	3%
	5-10 km	24	2%	457	4%
	11-20 km	20	2%	388	3%
	21-50 km	134	14%	1,871	17%
	More than 50 km	184	19%	2,452	22%
Network Coverage	**2G Medium**	33	3%	431	4%
	2G Strong	112	11%	1,113	10%
	2G Weak	58	6%	792	7%
	3G Medium	25	3%	286	2%
	3G Strong	119	12%	1,304	11%
	3G Weak	31	3%	382	3%
	4G Medium	8	1%	265	2%
	4G Strong	540	55%	5,076	44%
	4G Weak	13	1%	206	2%
	Absence	45	5%	1,365	12%
Poverty		40.7%		54.8%	
Population density (Catchment)		473.3		1,074.8	

When we analyse social vulnerability of flood prone schools from a district level (Table 2.6), we see that the six of the seven identified districts perform well. Only Pujehun, ranked third most vulnerable, is in the top half of the table. The other six districts are lower than average in terms of poverty rates, school feeding, have more experience of dealing with floods, and have better communications connectivity. However, Bonthe, Kambia, and Moyamba would all benefit from investment in connectivity as they still score as vulnerable in this area. Port Loko, Moyamba, and Bonthe also score highly in terms of poverty, which suggests work to reduce poverty in these districts would make them less vulnerable to the social impacts of flooding. We also show district level social vulnerability in Figure 2.3

Figure 2.3 Social vulnerability by district of flood prone schools

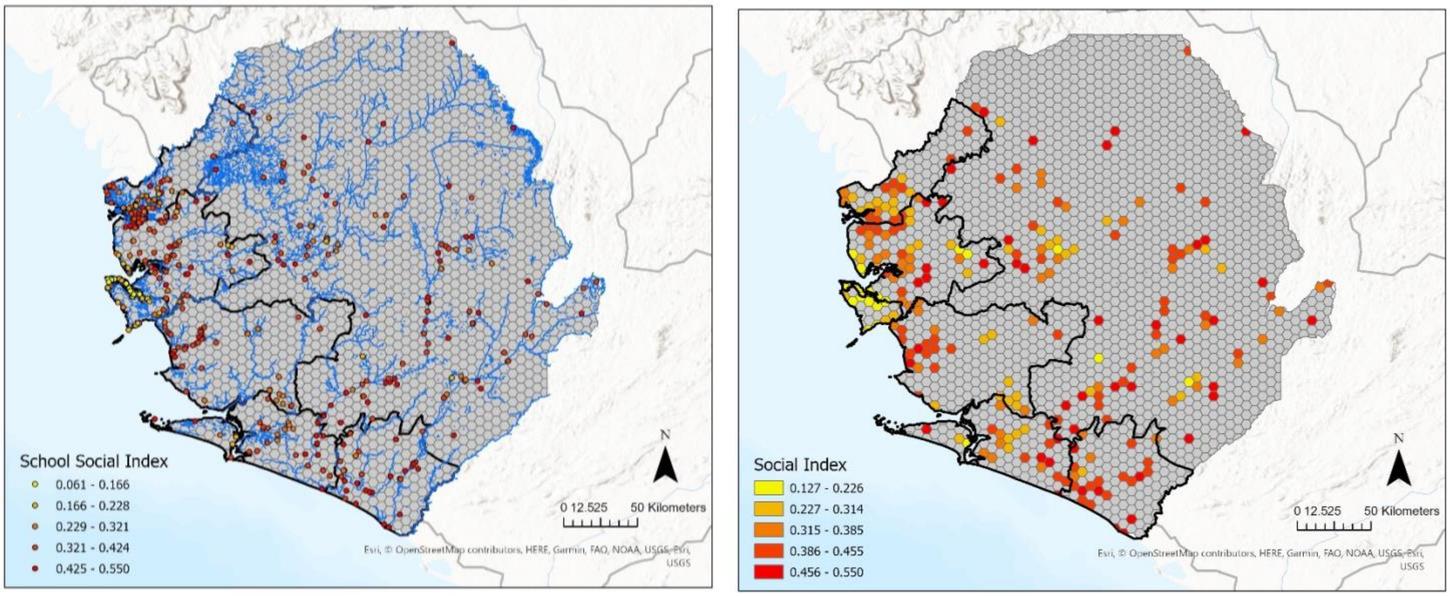


The population density is very high in the Western Area Urban, the higher the population density, the greater the vulnerability of a region to the impacts of flooding. In areas with elevated population density, the potential repercussions of flooding can be more severe. Not only does a higher population density mean more lives are at immediate risk, but it also implies a greater strain on existing infrastructure and emergency response capabilities.

Table 2.6 Social Vulnerability Subindex and components (Flood prone areas)

	Num of Schools (share)	Total population	Distance to inundation	Past experience	Feeding Program	Distance to closest schools	Connectivity	Poverty Rate	Distance to HQ	Population density	Social subindex	Ranking
Bo	24 (2.38%)	0.06	0.02	0.99	0.60	0.07	0.58	0.72	0.76	0.00	0.42	4
Bombali	17 (2.37%)	0.07	0.02	0.99	0.29	0.06	0.49	0.72	0.75	0.01	0.38	8
Bonthe	**47 (14.97%)**	**0.06**	**0.02**	**0.82**	**0.35**	**0.07**	**0.49**	**0.60**	**0.50**	**0.01**	**0.33**	**13**
Falaba	2 (0.63%)	0.05	0.01	0.99	0.60	0.10	1.00	0.79	1.00	0.00	0.50	1
Kailahun	11 (1.91%)	0.06	0.02	0.98	0.53	0.05	0.60	0.67	0.69	0.02	0.40	6
Kambia	**88 (15.04%)**	**0.08**	**0.02**	**0.90**	**0.32**	**0.09**	**0.72**	**0.40**	**0.49**	**0.01**	**0.33**	**11**
Karene	12 (2.78%)	0.07	0.01	0.99	0.33	0.07	0.68	0.80	0.77	0.01	0.42	5
Kenema	36 (3.46%)	0.07	0.02	0.98	0.33	0.07	0.52	0.71	0.61	0.04	0.37	9
Koinadugu	4 (1.22%)	0.06	0.02	0.99	0.60	0.06	0.94	0.77	0.75	0.00	0.46	2
Kono	14 (1.62%)	0.09	0.02	0.99	0.21	0.05	0.70	0.70	0.81	0.01	0.40	7
Moyamba	**57 (9.31%)**	**0.06**	**0.02**	**0.97**	**0.10**	**0.06**	**0.57**	**0.64**	**0.77**	**0.01**	**0.35**	**10**
Port Loko	**96 (10.63%)**	**0.07**	**0.02**	**0.96**	**0.33**	**0.05**	**0.30**	**0.58**	**0.57**	**0.02**	**0.32**	**14**
Pujehun	40 (10.78%)	**0.06**	**0.02**	**0.98**	**0.60**	**0.11**	**0.58**	**0.86**	**0.59**	**0.01**	**0.43**	**3**
Tonkolili	25 (2.91%)	0.05	0.01	0.99	0.13	0.05	0.57	0.67	0.41	0.02	0.33	12
Western Area Rural	**121 (8.39%)**	**0.06**	**0.01**	**0.90**	**0.00**	**0.02**	**0.10**	**0.24**	**0.19**	**0.06**	**0.17**	**15**
Western Area Urban	**390 (21.39%)**	**0.07**	**0.01**	**0.95**	**0.01**	**0.01**	**-**	**0.09**	**0.03**	**0.41**	**0.16**	**16**
Total	984 (8.06%)	0.07	0.01	0.94	0.16	0.04	0.27	0.36	0.32	0.18	0.26	

Figure 2.4 Social Vulnerability at the School Level in the flood-prone area (Left) and mean by hexagon bin (right)[28].



The results aggregated at district level in the table 2.6 can be seen in the Figure 2.2 at the school level. In Western Area Urban less vulnerable schools are shown in yellow, which highlights a large cluster of less socially vulnerable schools. In the North Western area in Kambia and Port Loko it highlights clusters of more socially vulnerable schools towards the coast and along the border between the two districts. In Moyamba, the maps show that the schools in the south are less socially vulnerable than the ones closer to Western Area Rural. Pujehun has a cluster of vulnerable school towards the South-West of the district and towards the coast.

School Vulnerability Index

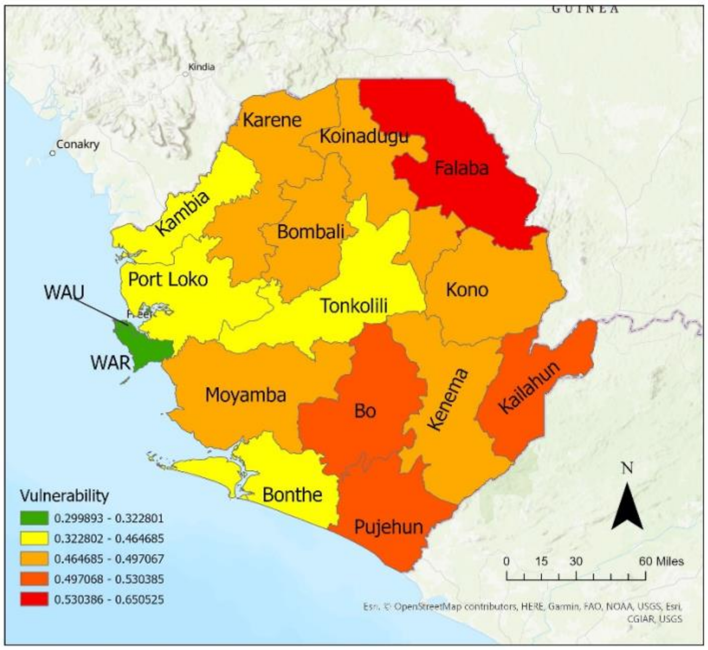
As outlined in this section, the school vulnerability index is composed of two components: the physical and social subindex. In this study, we assigned the same weight to each one, as in the literature we found that both components are equally important (see Annex A). Table 2.7 (below) shows the results when we combine the physical and social indexes to create a School Flood Vulnerability Index. We have created this index only looking at those schools that we have identified as having flooded in the previous three years[29].

[28] Note: The categories are five natural breaks (Jenks).

[29] Falaba and Koinadugu are the two most vulnerable districts. They are not particularly flood-prone, either in total schools or as a percentage of schools in the district and therefore do not figure in our analysis.

Of the seven districts that we have focused on throughout this study, Pujehun has the highest overall vulnerability, ranking seventh in the country. Moyamba is the only other district in the top ten of the vulnerability table, ranking ninth. This suggests that particular attention and investment needs to be directed to these districts to make them less vulnerable to the impacts of flooding. We show these schools in Figure 2.5.

Figure 2.5 Overall flood vulnerability by district



There is significant variation in vulnerability scores within districts. Whilst the other five identified flood-prone districts do not appear to be very vulnerable in the overall index, when we shift the analysis to within the district and looking at differences between the most and the least vulnerable schools, the gap between them is bigger than that in other districts. For example, in the Western Area Urban there is a school with a vulnerability index of 0.197 and another with 0.532. This highlights high levels of inequality in physical and social vulnerability. This trend can be observed in the physical and social subindexes, which is most prevalent in Western Area Urban. This is an example of the inequality within districts and shows the importance of doing the analysis at school level and creating specific interventions at this level in flood prone districts in Sierra Leone.

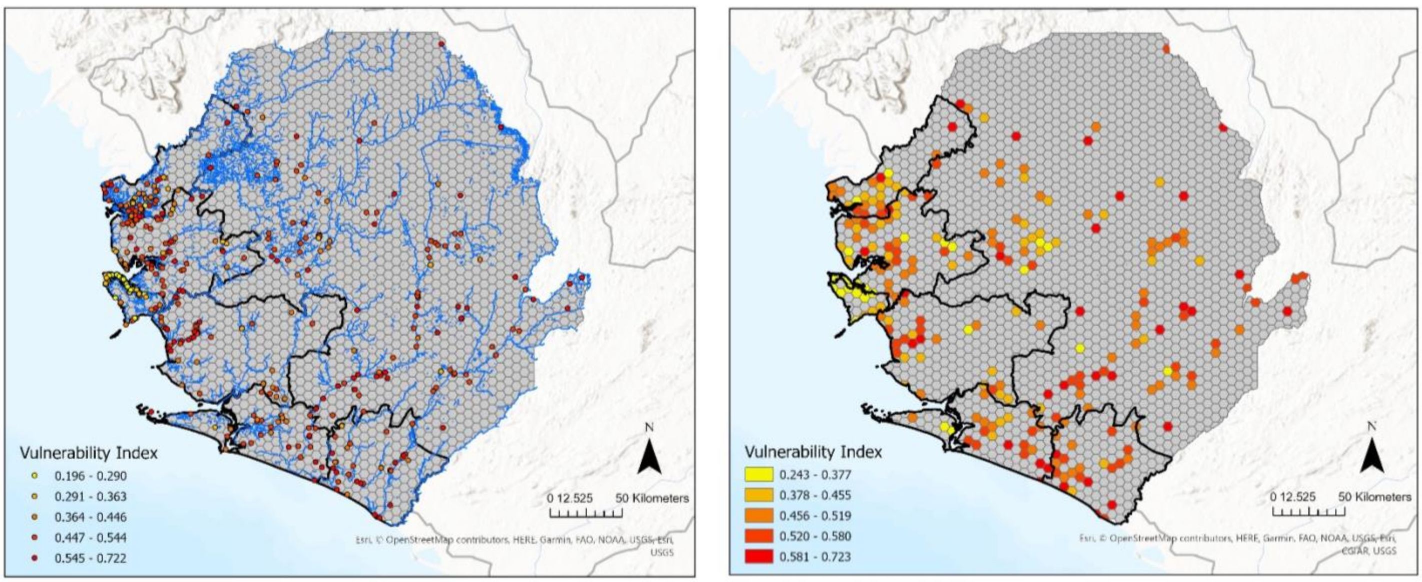
Kambia, Bonthe, Port Loko and Western Area Rural also show tremendous disparity between the least and most vulnerable schools across the sub-indexes and in the flood vulnerability index. This suggests that targeted interventions are required to support vulnerable schools within the district to make them less vulnerable to the impacts of flooding, both in terms of their physical infrastructure and in providing a social response to support vulnerable children and communities.

Table 2.7. Physical, Social and Vulnerability Index by district (schools in flood prone area)

		Physical Subindex				Social Subindex				Vulnerability Index				
District	Schools (%)	Mean	Min	Max	Gap	Mean	Min	Max	Gap	Mean	Min	Max	Gap	Rank
Bo	36 (3.57)	0.639	0.365	0.816	123%	0.420	0.187	0.524	181%	0.529	0.376	0.644	71%	3
Bombali	27 (3.77)	0.621	0.505	0.779	54%	0.377	0.283	0.511	80%	0.497	0.431	0.645	50%	5
Bonthe	**50 (15.92)**	**0.603**	**0.369**	**0.848**	**130%**	**0.326**	**0.155**	**0.513**	**231%**	**0.465**	**0.321**	**0.628**	**96%**	**11**
Falaba	4 (1.25)	0.804	0.713	0.895	26%	0.497	0.444	0.551	24%	0.651	0.578	0.723	25%	1
Kailahun	18 (3.12)	0.664	0.465	0.813	75%	0.397	0.335	0.465	39%	0.530	0.403	0.639	59%	2
Kambia	**111 (18.97)**	**0.592**	**0.338**	**0.871**	**158%**	**0.328**	**0.194**	**0.476**	**145%**	**0.460**	**0.284**	**0.655**	**130%**	**12**
Karene	17 (3.94)	0.574	0.355	0.833	135%	0.416	0.291	0.519	78%	0.495	0.372	0.624	68%	8
Kenema	43 (4.09)	0.619	0.345	0.880	155%	0.374	0.183	0.535	192%	0.496	0.272	0.625	130%	6
Koinadugu	4 (1.22)	0.524	0.438	0.674	54%	0.461	0.429	0.492	15%	0.492	0.434	0.583	34%	9
Kono	16 (1.86)	0.595	0.397	0.782	97%	0.397	0.240	0.528	121%	0.496	0.352	0.655	86%	7
Moyamba	**71 (11.60)**	**0.629**	**0.378**	**0.948**	**151%**	**0.353**	**0.193**	**0.514**	**166%**	**0.491**	**0.309**	**0.711**	**131%**	**10**
Port Loko	**125 (13.84)**	**0.572**	**0.383**	**0.881**	**130%**	**0.321**	**0.169**	**0.526**	**212%**	**0.446**	**0.293**	**0.627**	**114%**	**13**
Pujehun	**50 (13.48)**	**0.604**	**0.373**	**0.908**	**144%**	**0.426**	**0.285**	**0.530**	**86%**	**0.515**	**0.352**	**0.679**	**93%**	**4**
Tonkolili	50 (5.81)	0.565	0.340	0.883	160%	0.326	0.217	0.495	127%	0.446	0.295	0.689	134%	14
Western Area Rural	**154 (10.67)**	**0.472**	**0.321**	**0.879**	**174%**	**0.173**	**0.104**	**0.325**	**212%**	**0.323**	**0.227**	**0.545**	**141%**	**15**
Western Area Urban	**439 (24.08)**	**0.435**	**0.200**	**0.892**	**345%**	**0.165**	**0.061**	**0.305**	**398%**	**0.300**	**0.197**	**0.532**	**170%**	**16**
Total	1,215 (100%)	0.519	0.200	0.948	373%	0.257	0.061	0.551	**797%**	0.388	0.197	0.723	**267%**	

Map 2.4 illustrates flood-prone areas and schools classified by their vulnerability index score and rank. The map clearly shows that the Western Area Rural and Urban districts have schools with the lowest vulnerability levels compared to other districts, specifically Kambia and Port Loko in the northwestern region. In the southern region, where Pujehun and Bonthe are situated, the prevalence of flood-prone areas is more pronounced. However, the density of schools in these regions is relatively low compared to other flood-prone districts. This can be attributed to the regularity of flooding events in these areas, leading to a lower concentration of schools.

Map 2.4 Flood Vulnerability Index at school level in the flood-prone area (Left) and mean by hexagon bin (right)[30].



We looked at the physical and social vulnerability of the 495 schools that are shown as permanently inundated. This subset is 4.05% of the schools in Sierra Leone. Table 2.8 (below) highlights that schools in this subset do not differ greatly from the main data. The districts most affected are Western Area Urban and Bonthe, near the coast. The biggest change we see in Bonthe, where schools in this subset rank as fourth most vulnerable. Schools in Kambia, and Pujehun also rank in the top five for vulnerability whilst Western Area Rural and Western Area Urban rank as least vulnerable amongst this subset of schools.

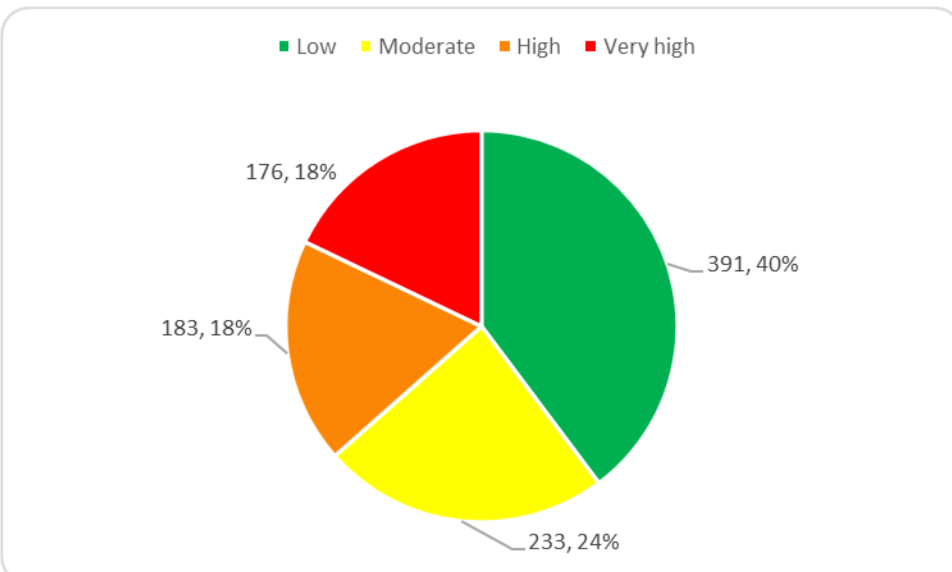
[30] Note: The categories are five natural breaks (Jenks).

Table 2.8. Physical, Social and Vulnerability Index by district for 495 schools														
		Physical Subindex				Social Subindex				Vulnerability Index				
District	Schools (%)	Mean	Min	Max	Gap	Mean	Min	Max	Gap	Mean	Min	Max	Gap	Rank
Bo	13 (1.3%)	0.664	0.524	0.789	50%	0.412	0.303	0.526	74%	0.538	0.442	0.608	38%	3
Bonthe	40 (12.6%)	0.665	0.445	0.885	99%	0.387	0.200	0.529	164%	0.526	0.349	0.665	90%	4
Kailahun	12 (2.1%)	0.609	0.443	0.782	76%	0.401	0.331	0.523	58%	0.505	0.434	0.587	35%	6
Kambia	23 (3.9%)	0.543	0.445	0.734	65%	0.328	0.230	0.508	121%	0.436	0.354	0.530	50%	9
Karene	1 (0.2%)	0.539	0.539	0.539	0%	0.496	0.496	0.496	0%	0.517	0.517	0.517	0%	5
Kenema	3 (0.3%)	0.722	0.508	0.871	71%	0.413	0.337	0.498	48%	0.568	0.423	0.685	62%	1
Kono	2 (0.23%)	0.595	0.568	0.622	9%	0.316	0.310	0.323	4%	0.456	0.445	0.466	5%	7
Moyamba	29 (4.7%)	0.559	0.392	0.793	102%	0.350	0.196	0.497	154%	0.455	0.350	0.619	77%	8
Port Loko	82 (9%)	0.526	0.290	0.831	187%	0.279	0.171	0.532	211%	0.403	0.260	0.596	129%	10
Pujehun	8 (2.1%)	0.598	0.467	0.699	50%	0.503	0.425	0.560	32%	0.551	0.497	0.590	19%	2
Tonkolili	16 (1.8%)	0.509	0.271	0.632	133%	0.283	0.221	0.379	72%	0.396	0.264	0.496	88%	11
Western Area Rural	97 (6.3%)	0.423	0.260	0.707	172%	0.205	0.137	0.309	125%	0.314	0.236	0.461	96%	12
Western Area Urban	169 (9.1%)	0.393	0.206	0.752	265%	0.170	0.116	0.254	118%	0.281	0.205	0.478	134%	13
Total	495 (4.5%)	0.482	0.206	0.885	330%	0.254	0.116	0.560	381%	0.368	0.205	0.685	235%	

Finally, by employing quartiles across all schools that have been flooded in the past three years, we have categorized vulnerabilities into four distinct groups. This approach aligns with our earlier explanation, where our index serves as a measure for ranking school vulnerabilities. As a result, our analysis of schools that have been flooded in the past three years reveals that 18% of schools exhibit a significantly high level of vulnerability, while 18% fall into the high vulnerability category. Additionally, 24% of schools demonstrate a moderate degree of vulnerability, and the remaining 40% showcase relatively low vulnerability levels (refer to graph 2.1).

This categorization not only provides a clear picture of the distribution of vulnerabilities but also offers a practical framework for targeted interventions. By identifying schools within each vulnerability category, stakeholders can efficiently allocate resources and implement strategies that address the specific needs of each group. Moreover, this comprehensive approach enhances our understanding of the diverse landscape of vulnerabilities across schools, paving the way for informed decision-making and effective support mechanisms.

Graph 2.1 Vulnerability categories of flooded schools

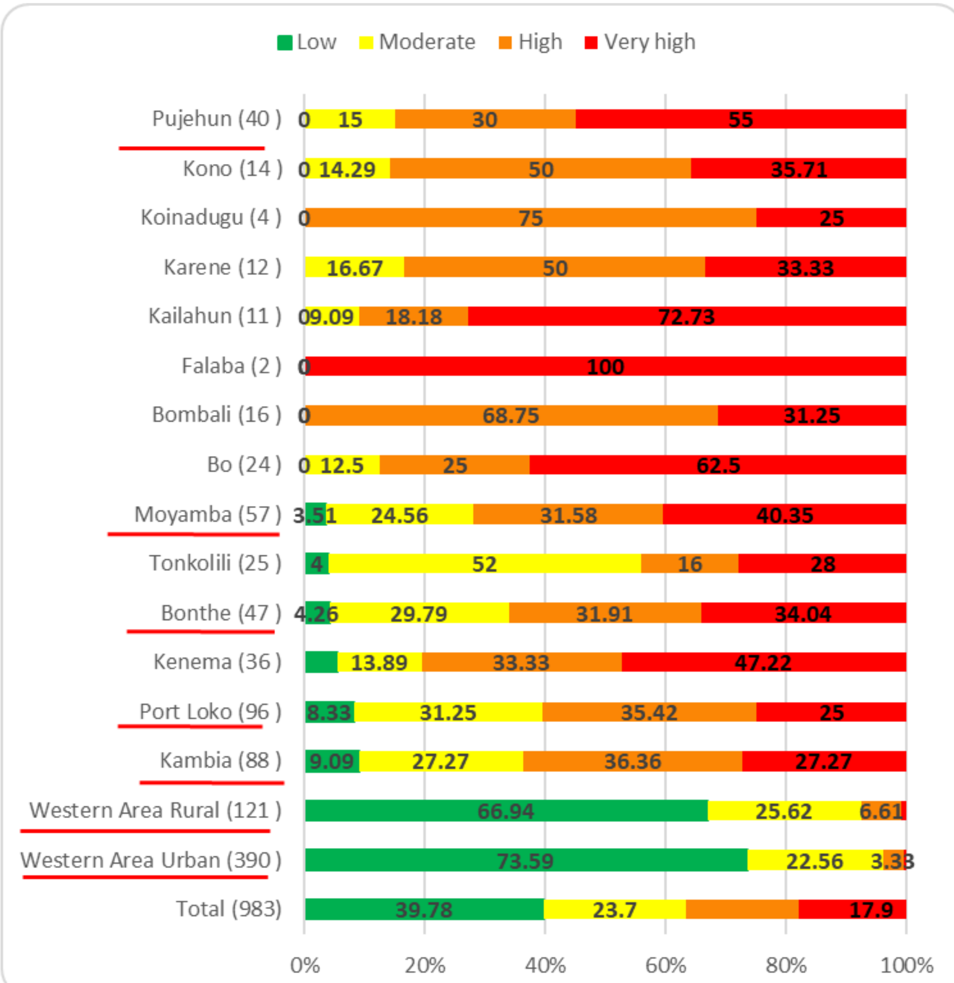


The district-level analysis of vulnerability categories highlights significant variations in school vulnerabilities. Notably, Pujehun illustrates substantially high vulnerability, with 55% of its schools falling under the "very high" category, while 30% and 15% reside in the "high" and "moderate" categories. Similarly, Moyamba and Bonthe districts exhibit similar patterns, with 40% and 34% of their schools designated as "very high" vulnerability.

An overarching trend emerges among flood-prone districts, where five out of seven districts demonstrate more than 50% of their schools categorised as

either "high" or "very high" vulnerability. In contrast, the Western Area Rural (67%) and Urban (74%) districts present a remarkably low vulnerability compared with the rest of the districts. These findings underscore the critical importance of tailored interventions, particularly within districts with heightened vulnerability. As such, these insights offer valuable guidance for targeted resource allocation and strategic planning, aiming to enhance the overall resilience of educational institutions in the face of varying degrees of vulnerability.

Graph 2.2 Vulnerability categories within districts of schools in flood prone areas



What Graph 2.2 also contributes to the analysis is to suggest that whilst the district level lens that we have highlighted is key to identifying flood-prone areas and vulnerability, other districts cannot be completely discounted, as they do have schools in flood-prone areas that are vulnerable. Bo has 24 schools in flood prone areas, around 78% of which are classed as "very" or high vulnerability. 91% of 11 flood-prone schools in Kailahun, 86% in Kono, and 81% in Kenema are classed as "very" or "high" vulnerability. Therefore, whilst district level interventions to reduce vulnerability are recommended, actions in less flood prone districts should still be considered to support individual schools.

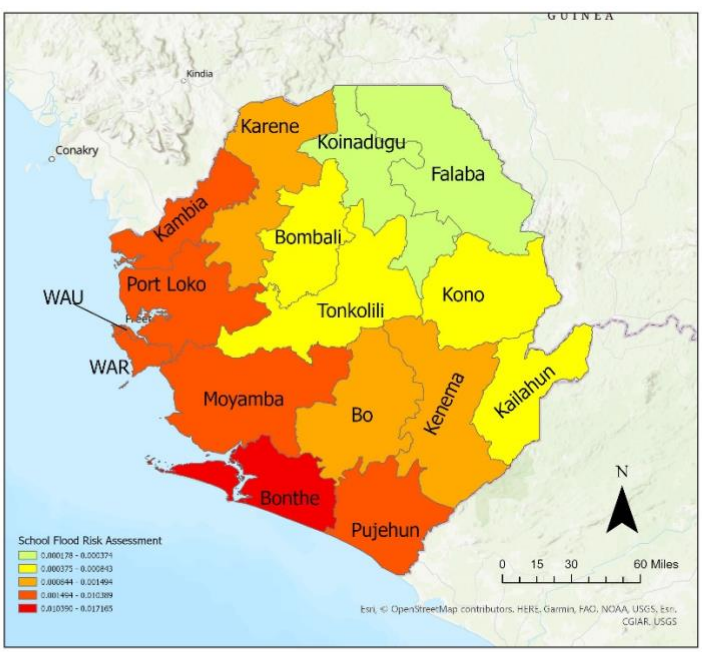
Section 3: School Flood Risk Index

Disaster risk signifies potential adverse effects resulting from the interaction of social and environmental processes. In the case of this study, we combine the physical hazards of floods with the physical and social vulnerabilities of schools. While the hazard alone does not determine risk, adverse effects are largely influenced by society's vulnerability and exposure[31].

Exposure refers to the presence of elements in areas prone to hazard events. While exposure is necessary for risk to exist, it is not sufficient on its own. Exposure alone does not guarantee vulnerability; individuals living in hazardous areas may possess the means to modify structures and behaviours to mitigate potential losses. Vulnerability, on the other hand, pertains to the susceptibility of exposed elements, including humans, livelihoods, and assets, to suffer adverse effects when impacted by hazards.

The overall flood risk for schools in Sierra Leone is determined by two factors: the likelihood of flooding (referred to as the 'hazard', see Section One) and the severity of the impact (referred to as the 'vulnerability', as explored in Section Two). Here, we present the results of the school flood risk assessment. **Among the sixteen districts, the seven districts identified as the most flood-prone have the highest levels of risk compared to the other nine districts.** This is outlined in Figure 3.1.

Figure 3.1 Risk map



---

31 UNISDR, 2004; Birkmann, 2007; Cardona, et al, 2012

Bonthe and Kambia have the highest risk scores. The highest risk school is in Port Loko, specifically a primary school situated 20 to 50 kilometers away from an urban center. It consists of three classrooms and has a total of 58 students and staff.

Table 3.1 shows that the seven districts that we have focused on are the most at risk. **Bonthe is the most 'at risk' district followed by Kambia. Interestingly, Western Area Urban, which has a significant number of schools in flood-prone areas, ranks third in the risk index.** This indicates that although the district overall is the least vulnerable in our school flood vulnerability index, the combination of flood hazards and their susceptibility to flooding elevates the risk level significantly. Districts like Falaba and Koinadugu, that scored highly in the vulnerability index, have relatively low incidence of floods, which means that these districts were ranked as the least at risk.

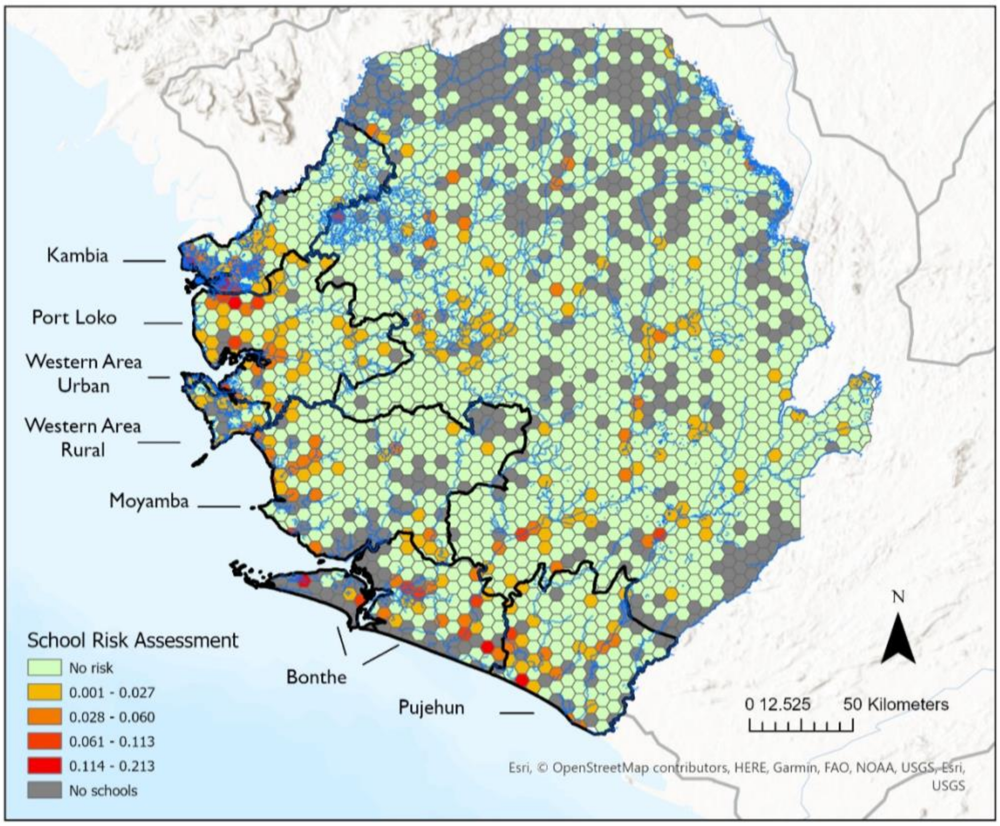
Table 3.1 School Risk Index

	Mean	Min	Max	Rank
Bo	0.001	0	0.137	9
Bombali	0.001	0	0.060	13
Bonthe	**0.017**	0	**0.285**	1
Falaba	0.000	0	0.040	16
Kailahun	0.001	0	0.072	12
Kambia	**0.010**	0	**0.265**	**2**
Karene	0.001	0	0.064	10
Kenema	0.001	0	0.111	8
Koinadugu	0.000	0	0.041	15
Kono	0.001	0	0.055	14
Moyamba	**0.005**	0	**0.139**	**6**
Port Loko	**0.005**	0	**0.296**	**5**
Pujehun	**0.006**	0	**0.170**	**4**
Tonkolili	0.001	0	0.053	11
Western Area Rural	**0.004**	0	**0.132**	**7**
Western Area Urban	**0.007**	0	**0.164**	**3**
Total	0.004	0	0.296	

We display this information in Map 3.1. The map is a summary of all the results and findings in Sections One and Two, showing all the schools in the country and their risk from floods. This map demonstrates that there are clusters of risk across the seven districts that make up the focus of this report. In the North-West and along the coast, the area around the border between Kambia and Port Loko shows clusters of schools that are at risk from flooding impacts on physical infrastructure, which can exacerbate social vulnerability. A similar story emerges in Bonthe and Pujehun where there are clusters of high-risk schools along the border between the two districts.

The blue lines and areas on the map represent different waterways and wetlands so that we can highlight that different locations are at risk from different types of flooding, either urban/flash flooding in Western Area Urban, coastal flooding, towards where rivers get close to meeting the sea, or from being near a river. Therefore, even within a district level focus the risk map highlights that certain parts of districts should be targeted for intervention, that this should be a range of physical and social support, depending on the prevailing vulnerability in the district.

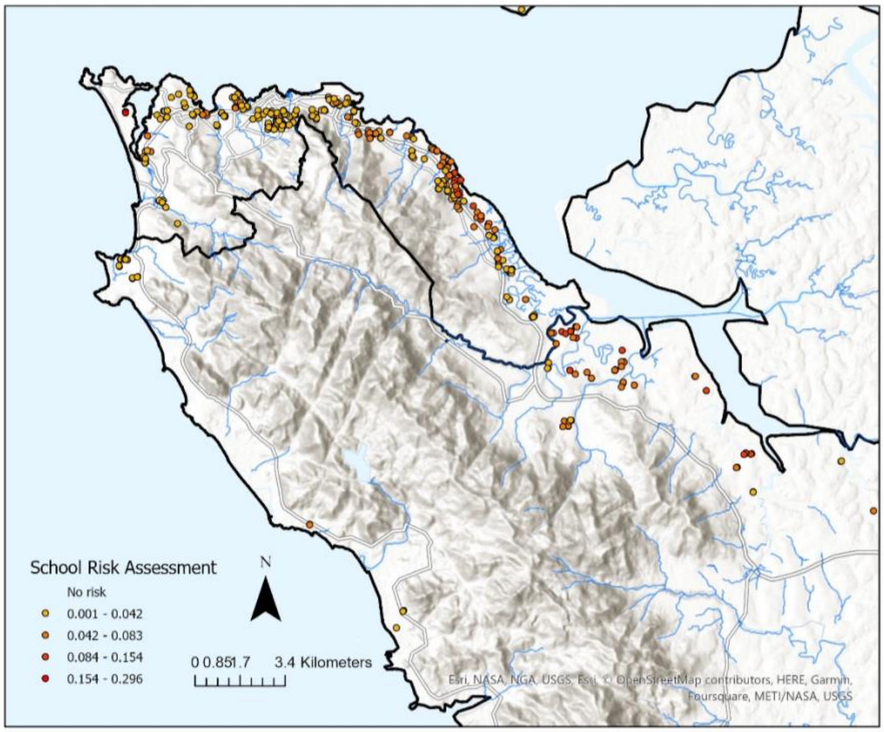
Map 3.1 School Flood Risk Assessment (total schools)[32].



To get a sense of the scale of the problem in Western Area Urban and Rural, Map 3.2 highlights the number of at-risk schools located in these areas. It shows that Freetown and the area around Freetown has a large number of at-risk schools. As these schools are at risk of urban/flash floods, as well as some from coastal flooding, it shows that a range of interventions will be needed to reduce risk. This should begin with supporting the schools through infrastructure improvement and supporting children that are socially vulnerable but must include efforts to improve broader infrastructure and drainage systems.

[32] Note: Mean by hexagon bin. The categories are five natural breaks (Jenks).

Map 3.2 School Flood Risk Assessment Western Area Urban and Rural



Finally, the risk scores vary across different school levels. As shown in Table 3.2, Senior Secondary Schools are the least vulnerable, followed by Junior Secondary Schools. This can be attributed to the fact that these levels are predominantly located in urban areas with better infrastructure and access to services. On the other hand, Primary Schools have a higher vulnerability, scoring higher in both subindexes. **The findings suggest that targeted interventions should be implemented to support primary schools in flood-prone areas.** These interventions could include improving infrastructure in primary schools, such as ensuring proper drainage systems and improving classrooms buildings materials, to reduce the risk of flood damage.

Table 3.2 Flood Risk Assessment by school level

	Physical Index	Social Index	Vulnerability Index	Hazard index	Risk index
A. Pre- Primary	0.477	0.185	0.331	0.118	0.004
B. Primary	0.554	0.299	0.426	0.122	0.004
C. Junior Secondary	0.482	0.212	0.347	0.134	0.003
D. Senior Secondary	0.425	0.204	0.315	0.112	0.003

Section 4: Conclusion and Recommendations

1. *Flooding is a real problem for Sierra Leone schools*

Flooding is a large problem for Sierra Leone schools, over the three-year period that we analyzed 984 were flooded at least once, which is approximately 8% of schools in Sierra Leone. This is a conservative estimate as 495 schools cannot be analyzed accurately due to their proximity to water. However, as these 495 schools are close to a water source it can be assumed that they are likely to flood. This means is that **up to 12.1% of schools in Sierra Leone are potentially exposed to floods.** 772 schools have had two flooding events, which is 6% of the total schools in Sierra Leone. Of the schools that were flooded once, the flood water lasted for five days for 28%. Therefore, a significant number of schools are at risk of flooding and at risk of multiple and severe flooding events.

2. *Large numbers of children are already in flood-prone schools*

Hundreds of thousands of children are at risk of flooding disrupting their education. 245,794 pupils attend schools that have been impacted by flooding in the previous three years. When we include children from the 495 schools, the **potential children impacted by flooding rises to 354,399 children, which is 11% of all school children in Sierra Leone**. Therefore, action is needed to minimize impacts on wellbeing and safety for children attending flood-prone schools entails.

3. *A district-level approach is needed to reduce physical and social vulnerability*

School flooding is most prevalent in districts across the West of the country nearest the coast. The seven most at risk districts are Bonthe, Kambia, Pujehun, Port Loko, Moyamba, Western Area Rural, and Western Area Urban. Action to reduce vulnerability to flooding should firstly focus on reducing physical and social vulnerability in these seven districts.

To create interventions to reduce vulnerability there are certain steps that will help to make interventions more successful. The first step is to look at the areas of the districts that are flood prone. Secondly, this should be combined with an understanding of the types of flood hazard they are exposed to, such as river, coastal, or urban flooding, Thirdly, this should be viewed alongside whether the schools are in urban or rural areas. This means that mitigating the flood hazard requires a multi-faceted approach that combines an understanding of the level of flooding, school location, and the type of flooding that they are exposed to.

In terms of physical and social vulnerability, there is inequality within districts about how vulnerable schools are. It is important to carry out analysis at the school level to ascertain the requirements of each to reduce vulnerability to floods. Certain parts of districts should be targeted for intervention, this should involve a range of physical and social support, depending on the prevailing vulnerability in the district.

4. *Investments are needed in infrastructure and social provision to decrease vulnerability*

Improving infrastructure in schools is a way to reduce vulnerability in schools. For instance, some schools would benefit from improvements to building materials, repairs to existing school buildings, increased latrines, or access to electricity. Other schools may require support in social areas, such as maintaining school feeding programs during disruption due to flooding. Our method of combining flood hazard and vulnerability information at the school level can be used to prioritize schools to target for interventions. A further advantage of combining satellite, geo-location and vulnerability measures is that we identify distances between high risk and low risk schools, this could be factored into planning so that pupils can continue education when their school is disrupted by floods.

Primary Schools have a higher vulnerability. The findings suggest that targeted interventions should be implemented to support primary schools in flood-prone areas, as they have higher vulnerability compared to other levels of education.

5. *Climate change will exacerbate the issue and investment is needed now to decrease vulnerability*

Interventions are required to support schools now and to prepare them to become climate-smart in the coming years. If floods become more frequent, more severe, and more schools become flooded, this will require more investment in institutional capacity, infrastructure, people, and broader financial support to maintain education infrastructure and reduce social vulnerability in a changing climate.

Recommendations for next steps

1. *Work with existing Disaster Risk Reduction Structures*

As we discuss in the literature review (Annex A), Sierra Leone has developed Disaster Risk Reduction (DRR) structures through the creation of the *National Disaster Management Agency* in 2020. Whilst still in its infancy this has created a framework for DRR in the country that draws together national government departments, district authorities, and chiefdoms. In line with our findings, further work could explore how to ensure that district level flood vulnerability within the education system is tackled through these structures. We recommend a focus on how resources in terms of money and people can be increased to focus on reducing vulnerability in schools and responding when floods occur in the most at-risk districts.

2. *Work at the school and community level to develop school-specific recommendations*

Our findings have highlighted the flood hazards that schools across Sierra Leone face and combined that with an assessment of their physical and social vulnerability, to determine risk levels. We present the data at an aggregate level, but this work could become the basis to inform community focused interventions. This should take the form of working with the most at-risk schools to understand their vulnerabilities and their current approaches to minimizing disruptions from flooding. Through this, a bottom-up response could be developed to reduce vulnerability within schools in Sierra Leone through developing school specific processes and actions to address their unique vulnerabilities.

3. *Create prioritization tools to support flood vulnerability reduction*

We know that to make schools in Sierra Leone climate-smart, whilst meeting the need for increased school places, it will require a range of investments of people, money, and institutional capacity. This will require prioritization, so that the most vulnerable schools can be helped. There are policy frameworks that this work could support and be built from as the MBSSE, as part of the Social and Environmental Management Plan, conducts assessments that encompass flooding. The MBSSE have also recently developed *The School Catchment Policy* which will incorporate building standards, including a section specifically addressing flood vulnerability. Therefore, using the approach that we have taken in this report, we recommend that the underlying data should be used to create a mechanism for decision-making that prioritizes investments in the right locations with a focus on reducing the physical and social vulnerability of schools to flooding impacts. This approach would improve the education system through prioritizing climate-smart investments and align with the aims and priorities of the Sierra Leone government.

References

Balica, S.F., Popescu, I., Beevers, L. and Wright, N.G .(2013). Parametric and physically based modelling techniques for flood risk and vulnerability assessment: A comparison. *Environmental modelling & software : with environment data news*. **41**, pp.84–92.

Balica, S. F., Wright, N. G., & van der Meulen, F. (2009). A flood vulnerability index for coastal cities and its use in assessing climate change impacts. *Water Science & Technology*, 60(5), 2581-2594.

Birkmann, J. (2007). Risk and vulnerability indicators at different scales: Applicability, usefulness and policy implications. *Environmental Hazards*, 7(1), 20-31.

Bondarenko M., Kerr D., Sorichetta A., and Tatem, A.J. 2020. Census/projection-disaggregated gridded population datasets, adjusted to match the corresponding UNPD 2020 estimates, for 51 countries across sub-Saharan Africa using building footprints. WorldPop, University of Southampton, UK. doi:10.5258/SOTON/WP00683

Cadag, J.R.D., Petal, M., Luna, E., Gaillard, J.C., Pambid, L. and Santos, G.V. (2017). Hidden disasters: Recurrent flooding impacts on educational continuity in the Philippines. *International journal of disaster risk reduction*. **25**, pp.72–81.

Chan, S.W., Abid, S.K., Sulaiman, N., Nazir, U. and Azam, K. (2022). A systematic review of the flood vulnerability using geographic information system. *Heliyon*. **8**(3), pp.e09075–e09075.

Cardona, O. D., Marulanda, M. C., & Barbat, A. H. (2012). Systemic seismic risk assessment: Application to the city of Barcelona. *Natural Hazards*, 62(2), 441-467.

Crocker, J., Saywell, D., & Bartram, J. (2020). Sustainability of Community-Led Total Sanitation Outcomes: Evidence from Ethiopia. *Water*, **12**(2), 558. MDPI AG.

David, Clarissa C.; Monterola, Sheryl Lyn C.; Paguirigan, Antonino; Legara, Erika Fille T.; Tarun, Anjali B.; Batac, Rene C.; Osorio, Jeriesa P. (2018). School hazard vulnerability and student learning. *International Journal of Educational Research*, (), S088303551830541X–. doi:10.1016/j.ijer.2018.07.005

Douglas, I., Alam, K., Maghenda, M., Mcdonnell, Y., Mclean, L., & Campbell, J. (2008). Unjust waters: climate change, flooding and the urban poor in Africa. *Environment and Urbanization*. **20**(1), pp. 187-205.

Fernandez, P., Mourato, S., Moreira, M., & Pereira, L. (2016). A new approach for computing a flood vulnerability index using cluster analysis. *Physics and Chemistry of the Earth*, 94, 47-55. https://doi.org/10.1016/j.pce.2016.04.003

Global Partnership for Education. (2023). *Towards climate-smart education systems*. https://www.globalpartnership.org/node/document/download?file=document/file/2023-04-gpe-toward-climate-smart-education-systems-rev_0.pdf

Global System for Mobile Communications (GSMA). (2023). Network Coverage.

Government of Sierra Leone. (2021). *National Adaptation Plan.*

Government of Sierra Leone. (2021). *Updated Nationally Determined Contributions (NDC)*.

IPCC. (2021): Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. In Press.

IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3-33, doi:10.1017/9781009325844.001.

Karagiorgos, K., Thaler, T., Hübl, J. *et al.* Multi-vulnerability analysis for flash flood risk management. *Nat Hazards* **82** (Suppl 1), 63–87 (2016). https://doi.org/10.1007/s11069-016-2296-y

Karmaoui, A., Balica, S. F., & Messouli, M. (2016). Analysis of applicability of flood vulnerability index in Pre-Saharan region, a pilot study to assess flood in Southern Morocco. *Natural Hazards and Earth System Sciences Discussions* [preprint]

Kapucu, N. (2008). Culture of preparedness: household disaster preparedness. *Disaster Prevention and Management*, 17(4), 526-535.

Mahmood, M.I., Elagib, N.A., Horn, F. and Saad, S.A.G. (2017). Lessons learned from Khartoum flash flood impacts: An integrated assessment. *The Science of the total environment*. **601-602**, pp.1031–1045.

Ministry of Basic and Senior Secondary Education (MBSSE), (2023). *Annual School Census 2022*.

Nasiri, H., Mohd Yusof, M.J. & Mohammad Ali, T.A. An overview to flood vulnerability assessment methods. *Sustain. Water Resour. Manag.* **2**, 331–336 (2016). https://doi.org/10.1007/s40899-016-0051-x

Papathoma-Köhle, M., Schlögl, M., & Fuchs, S. (2019). Vulnerability indicators for natural hazards: an innovative selection and weighting approach. *Scientific Reports*, *9*(1). https://doi.org/10.1038/s41598-019-50257-2

Quirós, E., & Gagnon, A. S. (2020). Validation of flood risk maps using open source optical and radar satellite imagery. *Transactions in Gis*, *24*(5), 1208-1226. https://doi.org/10.1111/tgis.12637

Rehman, S., Sahana, M., Hong, H., Sajjad, H. and Ahmed, B.B. (2019). A systematic review on approaches and methods used for flood vulnerability assessment: framework for future research. *Natural hazards (Dordrecht)*. **96**(2), pp.975–998.

Rodina, L. (2021). Sanitation Upgrading as Climate Action: A Case Study of Informal Settlements in Cape Town. *Sustainability*, 13(15), 8598. MDPI AG. https://doi.org/10.3390/su13158598

Rodríguez-Rosales, B., Abreu, D., Ortiz, R., Becerra, J., Cepero-Acán, A.E., Vázquez, M.A. and Ortiz, P. (2021). Risk and vulnerability assessment in coastal environments applied to heritage buildings in Havana (Cuba) and Cadiz (Spain). *The Science of the total environment*. **750**, pp.141617–141617.

Simonovic, S. P., McBean, G., Prodanovic, P., Burn, D. H., Wey, K., Kay, P., ... & Wood, M. (2007). *Floods: Mapping Vulnerability in the Upper Thames Watershed under a Changing Climate*. University of Waterloo, Environment Canada and Upper Thames River Conservation Authority: Waterloo, ON, Canada.

Schmuck, Hanna. (2013). "*Child-Centred Disaster Risk and Vulnerability Assessment Mozambique*." UNICEF.

Turay, B., & Gbetuwa, S. (2022). A state-of-the-art examination of disaster management in Sierra Leone: the implementation drawbacks, research gaps, advances, and prospects. *Geoenvironmental Disasters*, 9(1), 22 https://doi.org/10.1186/s40677-022-00224-3

United Nations International Strategy for Disaster Reduction (UN/ISDR), (2004). *Living with Risk. A Global Review of Disaster Reduction Initiatives*. 2004 version. UN Publications, Geneva.

World Bank. 2017. *Sierra Leone Rapid Damage and Loss Assessment of August 14th, 2017 Landslides and Floods in the Western Area.* World Bank.

World Bank. 2018. *The World Bank Sierra Leone Multi-City Hazard Review and Risk Assessment Final Report (Volume 1 of 5): Technical Methodology and Summary of Results.* World Bank

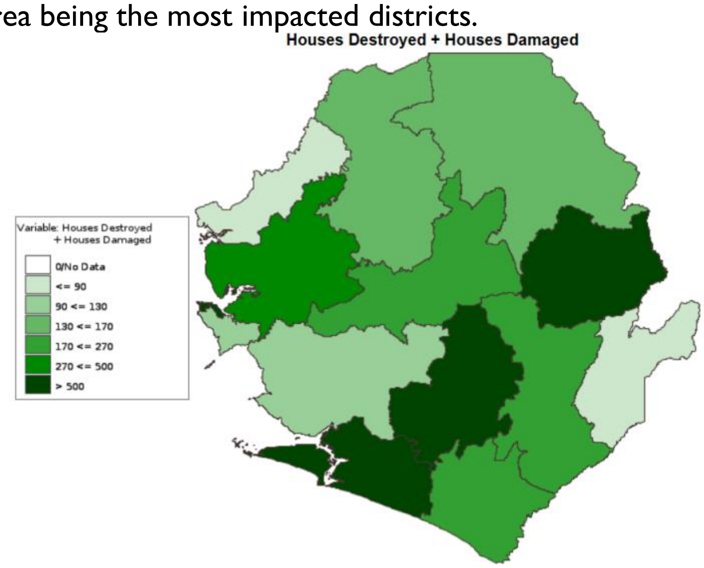
World Bank & Statistics Sierra Leone. (2020). *Subnational Poverty Estimates for Sierra Leone.* World Bank

Annexes

Annex A – Literature review. Climate change and vulnerability in Sierra Leone

The Sierra Leone government strategy is to enhance adaptation, resilience and reduce vulnerability to climate related hazards by half by 2030 and this will require considerable investment in infrastructure across the whole economy[33]. Sierra Leone's *Medium Term Development Plan* has free quality schooling as one of its flagship policies, but for this to be realised investments will be needed to build new schools, extend, and refurbish existing schools. More work is need at governmental level to align climate and development strategies, including in education. There is a focus on supporting vulnerable citizens to adapt to climate change, however, with one of the highest rates of malnutrition and child mortality in the world, alongside being ranked as one of the least developed countries in the world, Sierra Leone is one of the least able countries to adapt to the impacts of climate change[34].

In terms of weather, the country experiences a dry season from November to April, leading to incidents of bush and urban fires and water shortages. The rainy season from May to October brings challenges of flash floods, mudslides, and land slippage due to high rainfall propensity (Miles et al., 2022). Between 2006 and 2015, storms and floods accounted for 58% of house damage and affected areas, with Kailahun, Bonthe, Bo, and the Western Urban Area being the most impacted districts.



Source: Desinventar, 2022.

Floods regularly cause significant property and livelihood losses, particularly in impoverished and marginalized regions, without causing significant loss of life (Birkmann, 2007). However, many local disasters that affect a small number of individuals go unrecorded and fail to meet the global definition of a disaster (Cadag, 2017), which is applicable to most situations in Sierra Leone. Small-scale floods have notable impacts on school communities, including

---

[33] Government of Sierra Leone. 2021. *National Adaptation Plan.*

[34] Government of Sierra Leone. 2021. Updated Nationally Determined Contributions (NDC).

marginalized students, but these impacts are poorly documented and not addressed by the country's disaster risk reduction policies.

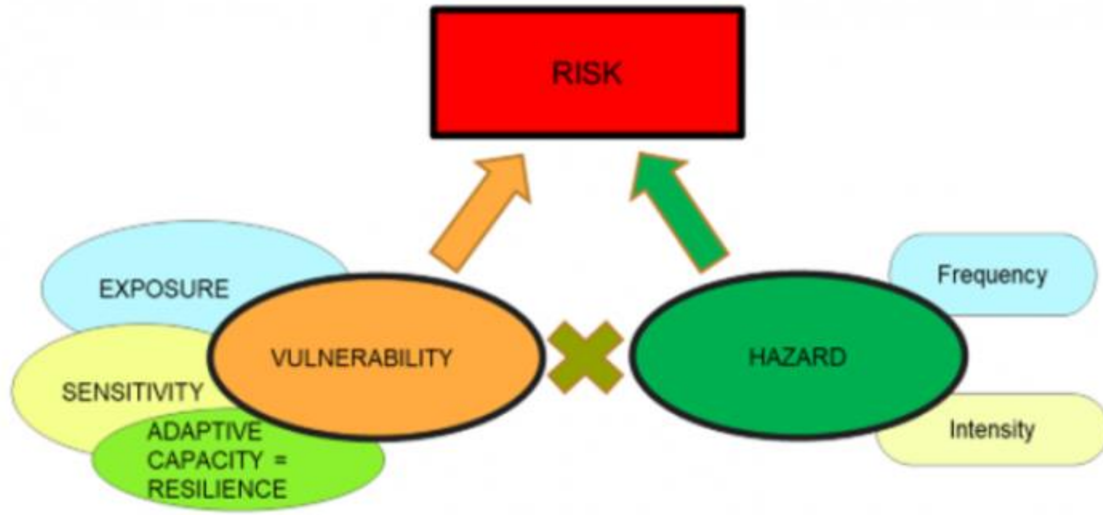
According to a World Bank report (2017), Sierra Leone faces a high mortality risk from multiple hazards, with 13% of its area and over 35% of its population at risk. Over the past 15 years, the country has experienced four major floods that affected more than 220,000 people and caused significant economic damage. Given Sierra Leone's exposure to the direct and indirect impacts of climate change, the country's vulnerability to natural disasters is expected to worsen in the future.

Urban areas in Africa, including Freetown, the largest city in Sierra Leone, are exposed to four types of flooding, as indicated by Douglas et al. (2008): localized flooding due to inadequate drainage, flooding from small streams within built-up areas, flooding from major rivers, and coastal flooding. The rapid population growth in urban areas poses a significant challenge. Freetown, with its specific topography, proximity to the coast, and presence of small streams across the city, would benefit from a flood vulnerability assessment to facilitate the implementation of effective risk reduction measures.

Sierra Leone has made progress in recent years at preparing to manage disasters, primarily through the creation of the *National Disaster Management Agency* in 2020. This has created a framework for disaster risk reduction (DRR) in Sierra Leone and is organised around a pillar system that includes coordination at national government level between ministries, regional, district and chiefdom structures created (Miles, 2021). Disasters are then designated into three levels. Level One is for minor disasters, which require a response at the local level. Level two disasters exceed the capacities of the local level and require national support. Level three are the most serious and require major national assistance, international assistance and can require military support (Turay, 2022). There have also been increased investments in Early Warning Systems, which are vital for flood responses (Miles, 2021). However, issues have been identified in terms of the current effectiveness of responses due to lack of funds, technological capability, data management, and human resources to make the system function (Miles, 2021). Conflicting mandates at national level and between the pillars, as well a lack of adequate information on which to develop appropriate action have also been identified as barriers to effectiveness (Turay, 2022).

Defining vulnerability

The concept of vulnerability is used across a range of research and policy disciplines; from engineering, land management, global environmental change, development assistance, and disaster risk reduction, amongst many others (Birkman, 2007). The central components of a definition of vulnerability entail integration of other concepts; risk, exposure, susceptibility, and the nature of the hazard in terms of frequency and duration (see Figure 1).



The UNDP (2004) defines vulnerability as, "a condition or process resulting from physical, social, economic and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard." What is useful about this definition is that the hazard is separated from the response, external structural dimensions are given prominence, and the idea that vulnerability relates to processes is introduced. Others, such as Blaikie et al. (2005) see it as an assessment of exposure to threats and the ability to recover from their impact. This approach introduces the importance of resilience within that which is exposed to a threat of some kind. Another dimension that Green (2004) introduces is the possibility of harm due to the hazard that people/communities/buildings etc are exposed to. Thus, this is a simpler idea of vulnerability, as it focuses on the risk of injury or harm from a hazard (Chan, 2022). Therefore, despite there being different ways to define vulnerability, some of which owes to the different ways that different disciplines approach this, some central components are import, most notably, risk, exposure, impacts, and resilience.

Measuring vulnerabilities

Various assessment methods for flood vulnerability have been developed in recent decades (Nasiri et al., 2016). Economic and engineering-based vulnerability assessments primarily focus on evaluating monetary damages to assets, particularly buildings and inventories (Fuchs et al., 2012). In contrast, social scientists prioritize the impacts on people, households, and communities, as well as coping and adaptation capacities, along with their underlying causes (e.g., Wisner et al., 2004). The challenge of integration lies in considering and evaluating the interdependencies and interconnectedness among different vulnerability systems and components (Karagiorgos et al., 2016).

According to Beccari (2016), from 1995 to 2014 a total of 106 different indexes were created. The main approaches employed were Hierarchical and Similar Deductive Methods, accounting for 66% of the methodologies, followed by Methods using Principal Component Analysis at 16%, among others. The primary focus was on sub-national administrative units, with the national level being the second most common target. In the majority of methodologies (85%), variables were selected through expert judgment based on literature, theoretical models, and stakeholder knowledge. The majority of methodologies (72%) utilized existing data collected by national statistical agencies and other government or non-government organizations involved in gathering socio-economic data. There was significant variation in the number of variables used in each methodology, ranging from a minimum of two to a maximum of 235. However, most methodologies used a relatively small number of variables, with two-thirds utilizing fewer than 40.

The most relevant of the indices found was the UNESCO-IHE tool which was developed to provide. policymakers and communities with detailed information about flood vulnerability, encompassing social, economic, environmental, and physical aspects. This is highly valuable as it facilitates communication and informs decision-makers, serving as a measure to prioritize adaptation efforts (Balica, 2010). The FVI is a flexible and adaptable assessment of vulnerability that can be applied to various locations, adjusting the available data to their specific components. However, a limitation of this methodology is the scarcity of available data, as highlighted by Beccari (2016): "The availability of data, rather than the conceptual model, may be a key or even the primary factor in the selection of variables for inclusion in an index."

Annex B – The methodology for creating the school hazard and vulnerability indexes

Using satellite data to determine the flood hazard

To create the hazard index, we utilize daily satellite data on flooding from the National Oceanic and Atmospheric Administration (NOAA) (https://jpssflood.gmu.edu/) for nationwide coverage in Sierra Leone. The NOAA divides the country into a series of pixels that are 375m squared. One of the issues with using daily satellite imagery is cloud cover can obscure the view, which is more prevalent during rains. To account for this, we analyse regions obscured by clouds for each day within a 5-day time window, two days forward and two days backwards. If flooding is detected during this period, we replace the cloud data with the maximum flood value recorded. If no flood value is detected, we classify the cloud-covered region as non-flooded.

As outlined in the report Section One, we determine a flooding event threshold as per the 50% water in each location and searched for flooding events across the nation during the three year period from September 2019 to September 2022. Following this, we collated flood event data with school locations to derive flooding events per school.

We were able to assess the frequency and duration of all flooding events during the period. We classify a school as being in a flood prone area if it has experienced at least one flooding event. We could supplement these findings with specific school information; this includes the school's proximity to towns, rivers, and their location within each district to categorize schools that have experienced flooding.

Creating the vulnerability index

We use an indicator-based approach, according to Nasiri et al. (2016), this approach provides a more precise understanding of overall flood vulnerability in each area compared to other approaches. Utilising indicators offers several advantages over traditional empirical loss assessment, as it allows for the summarization of complex issues and facilitates decision-making and communication among stakeholders[35]. To effectively aggregate the indicators into an index we normalise the variables using the method of minimum and maximum for the numerical variables and a categorical scale for the other variables, this method is the most used in the literature[36].

Steps to calculate the school scores for social and physical vulnerability and hazard index, and total rankings.

There are three steps to calculating the vulnerability index.

Step 1. Creating the components indices

Minimum and maximum values are set to transform the indicators expressed in different units into indices between 0 and 1. The maximum observed number will be 1, this means that has the most urgent or vulnerable result and zero when the result is the best observed. These min/max act as the "better ranked" and "worse ranked" respectively, from which component indicators are standardized:

$$Component\ Index = \frac{Observed\ value_n - Minimum\ value}{Maximum\ value - Minimum\ value}$$

Where: *n* is the school.

Step 2. Aggregating the component indices to produce the Physical and Social Index

Each of the two dimensions is estimated as a weighted arithmetic mean. This means that instead of each of the data points contributing equally to the final score, some data points contribute more than others based on the weighting given to each dimension's indicators. For the formula and the two indexes the weights are as follow:

$$SVI_n or\ PVI = \frac{(Var1_n * \mathrm{W1}) + (Var3_n * \mathrm{W2}) + (Var3_n * \mathrm{W3}) + (Var4_n * \mathrm{W4})}{W1 + W2 + W3 + W4}$$

Where:

[35] Papathoma-Köhle, 2019;
[36] Beccari, 2016.

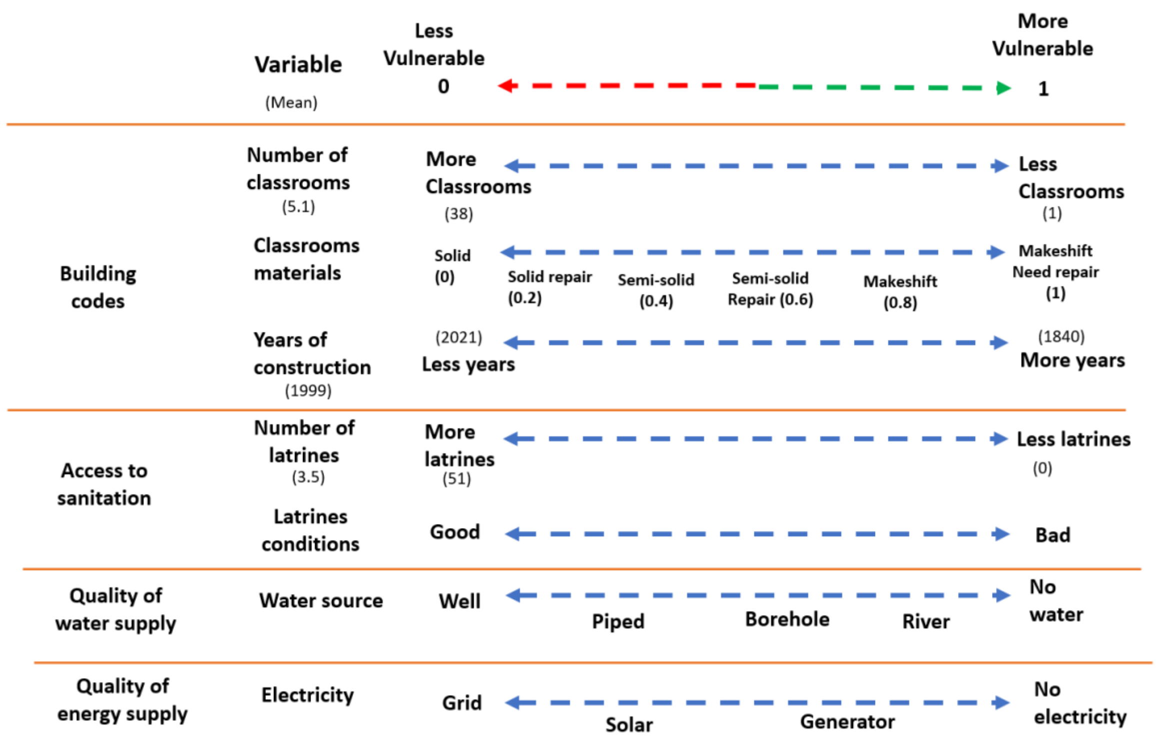
PVI=Physical Vulnerability subindex
SVI=Social Vulnerability subindex
VAR1, VAR2, VAR3, VAR4= Variables in the index
W1, W2, W3, W4= Weight for the index
n= school

Indicator	Unit	Weight	Definition	Functional relationship with vulnerability	Source
Hazard Index					
Frequency	Floods	50%	Number of flood events	Higher the number of floods, more prone to floods	NOAA
Intensity	Days	50%	Number of days flooded	Higher the number of floods, more intense, more prone to floods	NOAA
Physical Vulnerability					
Number of classrooms	Classrooms	25%	Sum of classrooms in the school	Higher the number of classrooms, lower the vulnerability	ASC, 2022.
Materials	Solid, Semi-solid, Make-shift	25%	We generate a subindex_materials=(share_solid*0)+(share_solid_rep*0.2)+(share_semi_solid*.4)+(share_makeshift*.8)+(share_semi_solid_rep*.6)+(share_makeshift_rep*1)	Higher the index of materials, higher the vulnerability	ASC, 2022.
Years of construction	Year	10%	Year of school foundation	Less years of construction, lower the vulnerability	ASC, 2022.
Number of latrines	Latrines	10%	Sum of latrines in the school	More number of latrines, lower the vulnerability	ASC, 2022.
Conditions of the latrines	Good, bad and fair latrines	10%	We gen a subindex_latrines=(good*0)+fair*0.5)+(bad*1)	Higher the index of conditions, higher the vulnerability	ASC, 2022.
Water source[37]	Well, Piped, Borehole, River and No Water	10%	If water source is Well=0, Piped=0.2, Borehole=.4, River=0.6 and No water=1	Worse water source, higher vulnerability	ASC, 2022.
Electricity	Grid, Solar, Generator, No electricity	10%	If electricity is Grid=0, Solar=0.2 as they do not need additional fuel, generator=0.4 and no electricity=1.	Worse energy source, higher vulnerability	ASC, 2022.
Social Vulnerability					
Total enrolment and staff	People	15%	Sum of enrolment and teachers	More density, higher the vulnerability	ASC, 2022.
Distance to inundation (km)	Kilometres	10%	Kilometres to closest inundation	Closer to inundation, higher vulnerability	ASC, 2022.
Past experience	Floods	10%	Number of flood events	Higher the number of floods, more prepare/aware, less vulnerable	
School feeding program (number of days)	Days	10%	Days in the school feeding program	More days in the feeding program, more vulnerable	ASC, 2022.

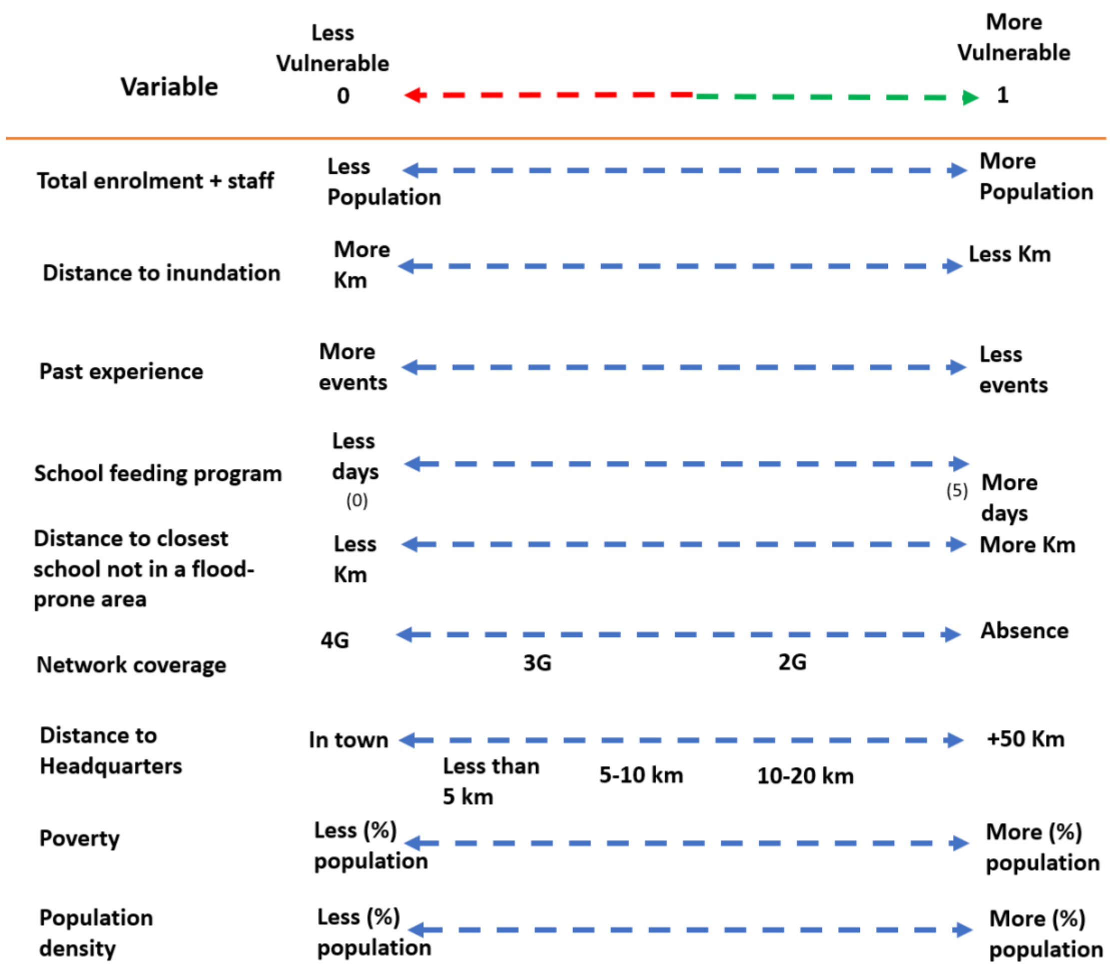
[37] Getts, M. (2018). Lack of Access to Water in Rural Malawi. Ballard Brief. https://ballardbrief.byu.edu/issue-briefs/lack-of-access-to-water-in-rural-malawi

Distance to closest school same level in a not flood-prone area	Kilometres	10%	Kilometres to closest school same level in a non-prone area	Closer to another school, students continue classes, lower the vulnerability	ASC, 2022.
Network coverage	Signal and strength	10%	4G strong is 9, 4G medium is 8, 4G weak is 7…... 2G weak is 1 and Absence is 0.	Better communication network, less vulnerable	GSMA, 2022.
Poverty	Percentage	15%	Share of population living in poor conditions	Less poverty, less vulnerable	World Bank & Statistics Sierra Leone, 2020.
Distance to Headquarter	Categorical	10%	In town, less than 5k, 5-10 km, 10-20km, 20-50km and more than 50km.	Closest to HQ, less vulnerable	ASC, 2022.
Population density	People	10%	Number of people in the 60 minutes from school by square kilometre	More density more vulnerable	Bondarenko et al, 2020.

The variables of the physical vulnerability index:



The variables of the social vulnerability index:



Step 3. Aggregating the Physical and Social subindex to produce the School Flood Vulnerability Index

The Total Score is the weighted arithmetic mean of the Physical and Social scores:

$$VUI_n = \frac{(PVI_n * \mathrm{W1}) + (SVI_n * \mathrm{W2})}{W1 + W2}$$

Where:

VUI: School Flood Vulnerability Index
n= school
PVI=Physical Vulnerability subindex
SVI=Social Vulnerability subindex
W1= Weight for the Physical subindex
W2= Weight for the Social subindex