In May-June 2022, 130 people died in landslides and floods caused by heavy rain in the Metropolitan Region of Recife, northeastern Brazil – Short report.

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1. General description

Recife (8° 04' 03'' S and 34° 55' 00'' W) is the capital of the state of Pernambuco, located in the Northeast Region of Brazil. This city is located on an alluvial plain along the Atlantic Ocean coast, with many islands, peninsulas and mangroves, and its mean altitude above sea level is 4 m. According to Leão et al. (2021), having four rivers and more than 70 artificial drainage channels, this city is known as "Brazilian Venice". Hence, the geomorphic features of the city are generally favorable to floods. During the early Portuguese colonization of Brazil, Recife was founded in 1537 and its population is 1,661,017 in 2021, which makes this city the sixth oldest city and the ninth largest city in the country. The city's Carnival is very famous both nationally and internationally. Thus, this capital of Pernambuco state plays a central role historically, culturally and economically in Brazil, especially in the northeast region. Furthermore, it should be emphasized that in Brazil Recife is one of the most vulnerable cities, precisely because of the whole geographical concerns: a very low altitude, a very high population density, and socio-economic inequality.

Nearly three weeks of heavy rainfall since the end of May 2022 caused landslide and flood disasters that left 130 dead, 9134 homeless, and 119,523 temporarily-displaced people in the Metropolitan Region of Recife. The most significant damage occurred on May 28th. This metropolitan region consists of 14 municipalities whose geographical characteristics are shown in Table 1.

Table 1 – Characteristics of 14 municipalities of the Metropolitan Region of Recife.

Municipality	Area (km²)	Population (2021)	GDP per capita (2017)
Abreu e Lima	126.193	100,698	20164
Araçoiaba	96.381	20,936	4986
Cabo de Santo Agostinho	448.735	210,796	48689
Camaragibe	51.257	159,945	11238
Igarassu	305.56	119,690	21483
Ilha de Itamaracá	66.684	27,076	9283
Ipojuca	527.107	99,101	115089
Itapissuma	74.235	27,144	53089
Jaboatão dos Guararapes	258.694	711,330	19463
Moreno	196.072	63,792	10989
Olinda	41.681	393,734	13918
Paulista	97.312	336,919	12240
Recife	218.435	1,661,017	31743
São Lourenço da Mata	262.106	114,910	9878
Total	**2,770.452**	**4,047,088**	

Obs.: Municipalities marked in red are those that have lost human lives in this disaster.

Table 2 shows the number of human deaths and monthly rainfall in May and June of the municipalities that lost human lives. The municipality of Jaboatão dos Guararapes had the highest number of human deaths followed by Recife. Therefore, it is clearly noted that the border between these two municipalities, which is characterized by hills and cliffs, was more severely affected. Figure 1 shows the locality of the Metropolitan Region of Recife and its 14 municipalities.

Table 2 – Numbers of human deaths and monthly rainfall of May and June for each municipality.

Municipality	No. death	Monthly rain in May (mm)		Monthly rain in June (mm)	
		2022	Average	2022	Average
Camaragibe	7	684.5	294.6	393.5	339.1
Jaboatão dos Guararapes	64	675.0	310.1	436.0	352.5
Olinda	6	496.1	325.8	508.9	384.7
Paulita	1	653.5	310.1	447.7	363.0
Recife	50	686.4	328.9	449.2	389.6
Bom Conselho*	1	114.0	86.0	240.8	95.6
Limoeiro*	1	316.7	135.6	190.7	186.5

* The municipalities of Bom Consello and Limoeiro are not part of the Metropolitan Region of Recife and are 233.41 km and 64.75 km respectively from Recife.

Figure 1 – Locality of the Metropolitan Region of Recife and its 14 municipalities. Five municipalities marked in pink color are those that have lost human lives in the disaster.

Based on information presented by Aguiar (2022) that examined public data from various public agencies, the breakdown of fatalities data by category is briefly demonstrated in Table 3. It is clearly observed that this disaster in Recife in 2022 was predominantly characterized with shallow landslides which caused 121 deaths. Figure 2 shows the typical scene of shallow landslide (hillslope failure) which occurred at the border between the municipalities of Recife and Jaboatão dos Guararapes and many people were buried alive.

Table 3 – Categorical characteristics of fatalities caused by the disaster.

Category	Description	
Sex	• Male	58
	• Female	72
Hazard type	• Shallow landslide	121
	• Flood	9
Age	• 0-12 years old	25
	• 13-17 years old	8
	• 18-30 years old	24
	• 31-65 years old	63
	• > 65 years old	10

Figure 2 – Shallow landslide at the border between the municipalities of Recife and Jaboatão dos Guararape, Brazil, in May 2022 (Source: Alves, 2022)

2. Rainfall characteristics

The rainy season of the Metropolitan Region of Recife usually runs from April to July, with June and July being the rainiest months in the region. Accumulation of heavy rain during this period is natural. In other words, the rainy season had already started in this region at the moment the disaster struck. In addition to the onset of the rainy season, there were three other factors contributing to the intensification of the storm.

(i) The La Niña phenomenon: The anomalous cooling of the waters of the equatorial Pacific causes the intensification of the trade winds and, consequently, intensifies the rains in the Northeast region in 2022.

(ii) Easterly Waves (EWs): They form on the African coast, reach the Brazilian Northeast coast and meet warm waters. This meeting serves as if it were fuel to intensify these rain waves which are even more charged. It is considered as one of the most important weather systems to the total rainfall over many tropical regions. They can be defined as synoptic disturbances associated with troughs and warm sea surface temperature (Machado et al., 2012; Cheng et al., 2019; Silva et al., 2020; Enyew and Mekonnen, 2022). The EWs generate Eastern Wave Disturbances that advance through the tropical region of the African continent towards the Americas, often giving rise to tropical storms and hurricanes in the North Atlantic. According to Sias (2022), however, in the case of Northeast Brazil, the EWs do not bring hurricanes, but a lot of rain. These waves form in the area of influence of the trade winds, close to the equator, especially in the autumn and winter months of the Southern Hemisphere.

(iii) The warming of the Atlantic Ocean in front of the Brazilian Northeast coast: In 2022, this warming is up to 1°C above average.

Each of these three phenomena can be said to occur naturally. However, when they occur simultaneously, they cause anomalous energy input in the physical spatial system and sometimes exceptional rainfall events.

Based on daily rainfall monitoring data as Rainfall Bulletin (*Boletim Pluviométrico*), available at the Pernambuco Water and Climate State Agency (*Agência Pernambucana de Águas e Clima* – APAC) (https://www.apac.pe.gov.br/boletins), daily rainfall values obtained in Recife during the period May 17th to June 14th, 2022, were summarized in Table 4. In case of Recife, most of May's monthly rainfall began on May 22nd. In addition, it should be emphasized that the event lasted for 22 days (May 22nd to June 12th), with a total amount of 926.4 mm and an average daily precipitation of 42.1 mm during this period. The highest amount of rainfall occurred on May 28th. For comparison, the average annual rainfall for Recife is about 2155 mm.

According to Madeiro (2022), the Brazilian Center for Monitoring and Early Warnings of Natural Disasters (*Centro Nacional de Monitoramento e Alertas de Desastres Naturais* – CEMADEN) issued a geo-hydrological bulletin on May 25th, warning of the "high risk" of heavy rains and landslides in the Metropolitan Region of Recife. Even with this alert, just on May 27th (Friday) when the APAC issued another statement informing the heavy rain forecast for the weekend, the Recife City Hall finally activated the contingency plan. After the APAC alert was issued, the Civil Defense Agency of Recife acted immediately in the late morning of May 27th,

summoning more than 3,000 municipal civil servants to work on duty from the same day. In addition, this Agency sent the alert to over 32,000 families living in at-risk areas via Short Message Service (SMS). On the other hand, Madeiro (2022) reported the comments of community leaders: Local residents were not informed that they would need to leave the area, nor were they receiving assistance, such as vehicles, to move them to safer shelters. Therefore, it will be necessary to find out what kind of communication actually occurred (or whether it did not occur) between the Civil Defense Agency and local residents.

Table 4 – Daily rainfall in Recife during the period May 17th to June 14th, 2022.

May date	Daily rainfall (mm)	June date	Daily rainfall (mm)
17th	0.0	1st	15.2
18th	0.0	2nd	18.0
19th	0.0	3rd	9.2
20th	0.0	4th	81.5
21st	0.0	5th	38.0
22nd	10.2	6th	0.3
23rd	1.8	7th	101.4
24th	69.0	8th	12.0
25th	137.4	9th	5.2
26th	33.2	10th	4.0
27th	13.2	11th	26.2
28th	190.0	12th	21.0
29th	85.2	13th	0.0
30th	19.2	14th	0.0
31st	35.2	15th	0.0

3. Historical views of disasters in Recife.

The population of Recife, one of the major cities in northeastern Brazil, has been growing rapidly (Figure 3). The current situation of the city, which plays an important role culturally and economically, encourages an influx of people to Recife from within the state, from outside the state, and even from outside the country.
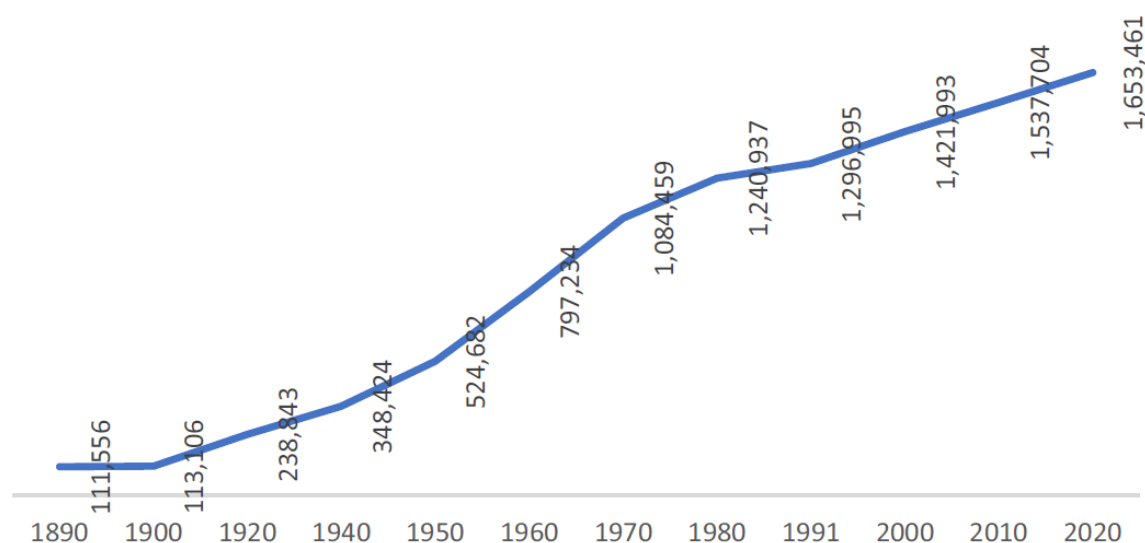

Figure 3 - Population trends in Recife during the period 1890-2020 (Source: Leão et al. 2021)

At first, poorer people generally began to live in vulnerable areas, especially in coastal, wetlands and mangrove areas. These areas are naturally susceptible to (coastal) flood. Through such a population settlement history, inhabitants in Recife frequently suffered from large and strong floods. Two largest flood disasters occurred in 1966 and 1975 (Table 5). Alves (2022) reported that, in the past, poor people lived in wetlands or floodplains and many of them were evacuated and transported to hillslopes and cliffs. Carrying out interviews with various experts in Recife, this author emphasized the housing deficit and urgent establishment of adequate housing policies. In summary, it can be said that the greater population density towards the hillslopes and cliffs of the city contributed to the social problems, i.e., sediment-related disasters.

Table 5 – Three main disasters occurred in (Metropolitan Region of) Recife

Year	Locality	Date	No. deaths	Characteristics
1966	Recife	May 30h	175	Predominantly flood. River Capibaride overflowed. In many places the water was more than 2-m deep. There was no problem with cliffs.
1975	Recife	July 17-18	107	Predominantly flood. River Capibaride overflowed. 80% of the city was flooded. 350,000 people became temporarily homeless. At one moment, more than 50% of the houses in the city lost power. There was no problem with cliffs.
2022	Metropolitan region of Recife	May 22 - June 12 (May 28)	130	Predominantly shallow landslide. More than 100 people were buried alive in slope failures and died.

Furthermore, with interviews and available data analysis, Lins et al. (2022) mentioned that 600 thousand people (about 36% of Recife's population) are living at hillslopes and cliffs which are considered as high hazard area, and concluded that the social inequality can be the principal factor for disasters in Recife.

Thus, it is easily thought that there is a growing tendency of landslide disasters in Recife. Lins et al. (2022) investigated citizens' calls for landslides, registered by the Civil Defense Agency of Recife during the period 2014 to May 2022, and reported the total of 7340 calls. Table 6 shows this data.

Table 6 – Number of calls for landslides in Recife during the period 2014 to May 2022.

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022
Calls	486	1043	1124	710	639	1064	253	1145	876

Obs.: The number of calls in 2022 is just until May 2022.

Figure 4 shows that many unstable houses were built on the top and bottom of cliffs and on steep hillslopes which are all dangerous places. This situation certainly caused the landslide disasters in May-June 2022.

Figure 4 – Several landslide-related disasters in the Metropolitan Region of Recife, Brazil (Sources: Diego Nigro/AFP/METSUL-Meteorologia in Sias (2022))

4. Final remarks

An evolution of hydrological disasters in a city, from flood disaster (water-related disaster) to mass movement disaster (sediment-related disaster) through the city's development history can be observed in various cases over the world (Figure 5). Kobiyama et al. (2010) explained that a city settlement normally starts with flood-plain occupation. Then after occupying this area, hillslope areas will be occupied. Therefore, the numbers of occurrences of flood and mass movement as natural phenomena can be constant through the city's history meanwhile those numbers as natural disasters will be probably changed, especially with a drastic increase of sediment-related disasters. Thus, people just feel that they have suffered formerly from flood and now from mass movements (landslides, debris flow, etc.). This is the hydrological disasters' evolution associated to land-occupation history in a city. Recife is not an exception and has been certainly performing such an evolution.

Investigating the inequality in Brazilian metropolis, Salata and Ribeiro (2022) concluded that the Metropolitan Region of Recife is in the worst situation in Brazil. The authors also reported that 13% of the population of the region live in extreme poverty (with an income of less than US$32/month) and that 39.7% live in poverty (US$91/month). This means that, in case of the

Metropolitan Region of Recife, more than half of the people (52.7%) live in poverty. These poor people used to live in coastal areas or swamps at altitudes near sea level. As a result of suffering from frequent flood disasters, they were relocated by public policy to cliffs or hillslopes which have another type of natural hazard.
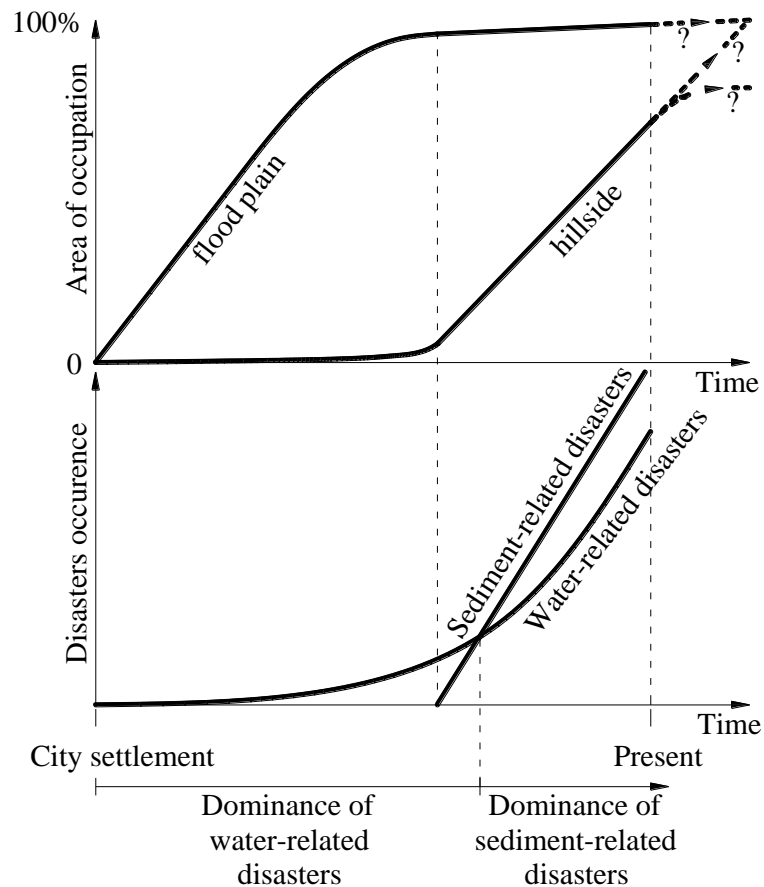

Figure 5 – Hydrological disasters evolution due to the land occupation change. (Source: Kobiyama et al., 2010).

Indeed, Recife has been playing an important role in climate change and greenhouse gas emission issues, and showing its leadership nationally and internationally (Leão et al., 2021). Though these actions are certainly useful in improving the lives of local residents and should be highly evaluated, the reality is that the results have not reached the poor people adequately.

UN (2015) presented 17 Sustainable Development Goals and 169 targets, among which the Goal 10 is "Reduce inequality within and among countries". Landslide-dominated disasters in the Metropolitan Region of Recife in 2022 gave many lessons to people and public agencies. The fact is that the achievement of the Goal 10 should be considered the best action for disaster risk reduction in this region as well as the other places in Brazil.

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