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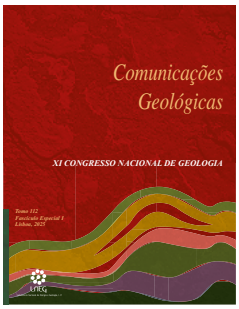
1926 – 2021 flood impacts in Mozambique from a local database incidence

Impactos associados a cheias e inundações no período de 1926 a 2021 em Moçambique a partir de uma base de dados de incidência local



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Abstract: Due to its geographical location, Mozambique has been frequently affected by climatic events, in particular depressions, storms and tropical cyclones that often cause flooding processes. In the last 10 years, the frequency of these events has increased and consequently the social and economic losses have also been amplified. This work presents results from ongoing research to create a database, using local incidence analysis, collecting and evaluating impact associated with flooding processes. The database - relying on hemerographic information and cross-checking data from official reports and international databases - shows, for the period encompassing 1926 and 2021, 996 flood occurrences, where 3237persons lost their lives, 1510 people were injured, 2.821.639 people were displaced, and 10.604.520 were only materially affected. The southern and central Mozambique have been the most exposed regions to flood process. The analysis of these outputs improve the disaster risk management system in Mozambique.

Keywords: Floods, database, disasters, Mozambique.

Resumo: Devido à sua localização geográfica, Moçambique é frequentemente afetado por eventos climáticos extremos, em particular depressões, tempestades e ciclones tropicais que, muitas vezes, causam processos de cheias e inundações. Nos últimos 10 anos, a frequência destes eventos tem aumentado e, consequentemente, as perdas sociais e económicas também têm sido ampliadas. Este trabalho apresenta resultados de uma investigação em curso, onde foi contruída uma base de dados, sustentada nos registos de incidências locais, onde foram coletados e avaliados os danos e perdas associados/as a processos de cheias e inundações. A base de dados baseia-se não só em informações hemerográficas, mas também no cruzamento de dados de relatórios oficiais com bases de dados internacionais disponíveis. Esta análise mostra, para o período compreendido entre 1926 e 2021, 996 ocorrências de cheias e inundações onde cerca de 3237 pessoas morreram, 1510 pessoas ficaram feridas, 2.821.639 pessoas foram deslocadas e 10.604.520 foram afetadas. O sul e centro de Moçambique têm sido as regiões mais expostas aos processos de cheias. A análise destes resultados permite melhorar o sistema de gestão de risco de cheias e inundações em Moçambique.

Palavras-chave: Inundações, base de dados, desastres, Moçambique.

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1. Introduction

Improving knowledge about climate variability and flood processes in Africa is a consistent way of reducing loss of lives and economic damage (Jury, 2002). In particular, flood early warning, communities sensitising and preparedness and discouraging human settlements in flood-prone areas, along with the development of local institutional capacities, are considered priorities for Africa (Di Baldassarre *et al*., 2010). The high incidence of flooding in Mozambique is explained, firstly, by the tropical cyclones that, although few in number, sometimes hit the coast with strong winds and rain; and secondly, by the large river basins that drain vast areas of south-east Africa into the coastal plains (Toté *et al*., 2015).

To mitigate the impacts of floods in Mozambique, it is important to assess the impacts of climate change, natural variability and anthropogenic activities on river hydrology and morphology (Singh, 2017). Different perspectives have emphasised the impact of flooding processes in Mozambique, whether on food supply (Jury, 2002), on a broader economic dimension (Arndt and Thurlow, 2015; Brida *et al*., 2013) or on environmental ecosystems (Fanaian *et al*., 2015).

The frequency of floods has increased considerably in recent years. Those that occur in densely populated territories cause greater human and infrastructure damages (Jongman, 2018; Vilanculos, 2021). They break the system of sustainable human development and in some urban areas (Maputo, Matola, Beira, Chimoio) there are neighbourhoods with houses submerged in standing water for more than three rainy seasons and they never return to normal.

In order to better analyse, manage and respond to extreme events caused by floods, it is essential to have reliable historical information and consistent databases, particularly from local sources, or sources reporting local information.

Databases (DBs) containing historical data provide crucial information on the probable causes, frequency and characteristics of the most affected locations (Rilo *et al*., 2017; Santos *et al*., 2014; Zêzere *et al*., 2014). The most widely used on a global scale are EM-DAT, Nat Cat Service, GRIP (Global Risk Identification Program) and DesInventar. These databases mostly use governmental data, data from UN agencies, NGOs, research centres, insurance and reinsurance companies, and media news (Tschoegl *et al*., 2006; Wirtz *et al*., 2014).

We reconstructed a database (RISCAR) based on the criteria used by the DISASTER Project (http://riskam.ul.pt/disaster/), EM-DAT (https://public.emdat.be/about) and the DesInventar (https://www.desinventar.net/methodology.html). This database records and organises losses and

damages, both spatially and temporally and allow us to quantify all the losses caused by floods for the period encompassing 1926-2021.

2. Material and methods

The methodology used to create the RISCAR database is mainly inspired in the DISASTER Project developed in Portugal 4 (Santos *et al*., 2014; Zêzere *et al*., 2014). It also included the methodologies of EM-DAT and DesInventar described by Du *et al*. (2015), Jiménez *et al*. (2012) and Wirtz *et al*. (2014).

Given its local focus, the database has more detailed information and spatiotemporal processing than other databases used for reference and validation (*e.g.* EM-DAT). All occurrences and events reported in national newspapers, in the reports of various government structures, were taken into account, whenever there were reports of evacuation of the population, damages to infrastructure, economic losses, missing persons, displaced persons and humanitarian assistance. Thus, an entry was considered in the database when one of the above conditions was recorded by the authorities and/or reported in the newspapers, independently of the number of affected people, as shown in Table 1.

Table 1. Criteria and sources that supplied the RISCAR Database.

Tabela 1. Critérios e fontes da Base de Dados RISCAR.

Registration criteria (non-cumulative)	Information Source	Coverage	Timeframe
0≥ dead people; 0≥ affected people; Evacuation reports; Impacts on residences and infrastructure; Government intervention for assistance;	1.Jornal Noticias (Daily) 2.Diário de Moçambique (Daily) 3.Jornal O País 4.Jornal Domingos (weekly) Relatórios do Governo INGD* DNGRH	National National National (With greater coverage in the Central Zone) National National	Since 1926 Since 1951 Since 2005 Since 1980 Since 1999

INGD - National Institute for Disaster Risk Reduction and Management;
DNGRH - National Direction for Water Resources

To make the spatial distribution of loss and damage, information from the RISCAR database was integrated into the ArcGIS 10.8 software and the district was defined as the minimum geographical unit, with Mozambique having 10 provinces by territorial division and 157 districts - although in the political administrative division the country's capital, Maputo City, is considered to be a province. The degreeof losses and damages was also interpolated with precipitation data at national level to see if there was any territorial correlation between areas with higher precipitation and losses and damages due to flooding, as shown in the entire methodological sequence in figure 1.

3. Results and Discussion

The data on flood events included in the RISCAR local-constructed database, as well as their impacts, are summarised in Table 2. There were 3.237 deaths, 1.510 injuries and 2.821.639 displaced persons and total of 10.604.520 people affected between 1926 and 2021. In the same period, there was a significant number of infrastructures

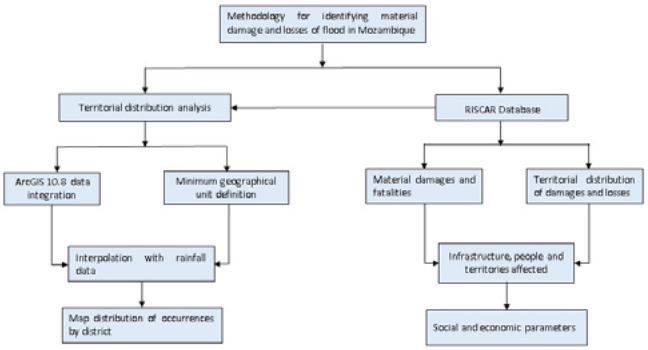

Figure 1. Methodological framework for carrying out the research.

Figura 1. Quadro metodológico da investigação.

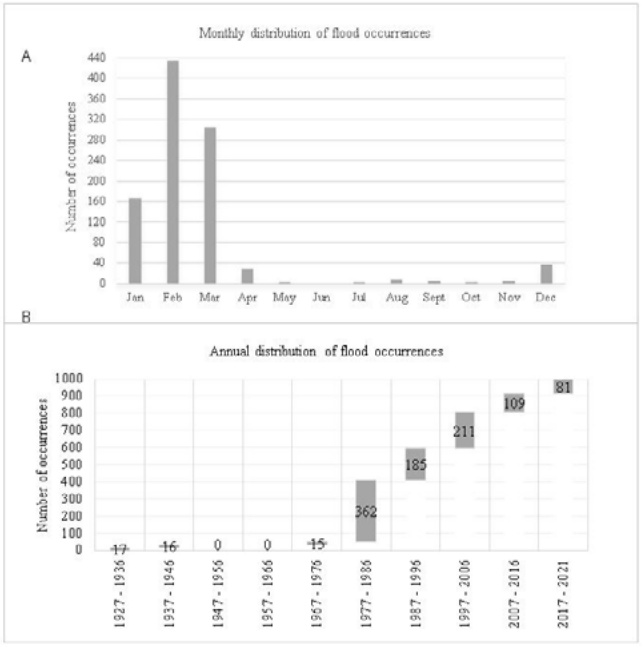

Figure 2. Monthly and annual distribution of floods from 1926 to 2021.

Figura 2. Distribuição mensal e anual das inundações de 1926 a 2021.

and social facilities affected by the floods, namely schools and health centres, as well as a large number of conventional and non-conventional houses affected. It was also possible to record damages in the agricultural sector, namely the hectares lost to various crops and livestock. Figure 2A shows the monthly frequency of floods over the period from 1926 to 2021, with most occurrences recorded between January and March, with no records in May and June.

According to the RISCAR database, the 1977-1986 and 1997 - 2006 intervals had the highest number of occurrences. The last interval, from 2017 to 2021, covering only 4 years, recorded 81 occurrences, showing an upward trend in frequency when compared to the interval from 2007 to 2016 (figure 2B).

From a territorial distribution point of view, it was found that the southern and central regions of Mozambique had the highest number of occurrences, although with lower annual rainfall records (figure 3). The districts of the coastal provinces had the highest number of occurrences of flooding, with the districts belonging to Sofala (21%), Gaza (19%) and Zambézia (18%) provinces

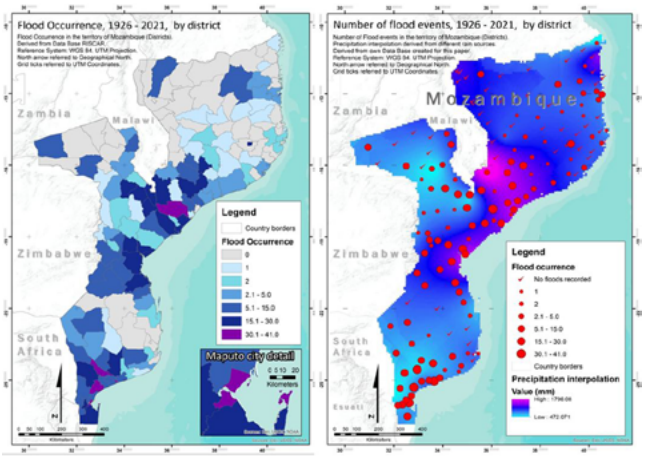

Figure 3. Map of flood occurrences by district (left) and territorial distribution of occurrences interpolated with rainfall (right).

Figura 3. Mapa de ocorrências de inundações por distrito (esquerda) e distribuição territorial das ocorrências interpoladas com a precipitação (direita).

Table 2. Flood events and their social consequences in the period 1926-2021.

Tabela 2. Inundações e suas consequências sociais no período 1926-2021.

	Damages
Number of occurrences	996
Number of affected people	10604520
Number of affected schools	691
Number of affected conventional residences	1093360
Number of affected non-conventional residences	58253
Number of fatalities	3237
Number of injured	1510
Number of displaced	2821639
Healthcare centres	319
Dead cattle	21260
Agriculture lost hectares	505836
Roads	123
Railway tracks	46
Bridges	177
Ports	2
Airports	8

standing out. The districts with the highest occurrences are Dondo (33), Beira (27), Marromeu (27) and Nhamatanda (26) in Sofala province; Mopeia (33), Marrumbala (22) and Chinde (21) in Zambézia province; Xai-Xai (41), Ckokwe (36) and Chibuto (18) in Gaza province; Maputo City (41), Manhiça (36) and Boane (26) in Maputo province.

RISCAR's flood losses and damages, when compared with EM-DAT's data, as shown in Table 3, show that there is a difference in the temporal extent: while RISCAR presents data from 1926, EM-DAT starts in 1967.

The number of fatalities and injuries in the RISCAR DB is higher than in EM-DAT. This is due to the 96-year time span of the analysis period and the methodological scope assumed, which differs from the EM-DAT DB, which only assumes as a record when at least one of the criteria is met: the event causes 10 or more deaths, 100 or more people affected, or exceeds the local response capacity, requiring national or international intervention (Guha-Sapir *et al*., 2012).

With regard to the number of people affected, EM-DAT presents higher data than RISCAR, possibly because it has also used data from international non-governmental agencies involved in humanitarian assistance missions and with some inconsistencies in the insertion and cross-checking of information that are described in the research by Jones *et al*. (2022), while RISCAR was based on data from local newspapers and official Mozambican government reports.

The floods recorded in the database were categorised according to the speed of the process, and were classified as slow-onset floods, flash floods and urban floods. Out of a total of 996 recorded occurrences, 540 correspond to slow-onset floods (54%), 269 to flash floods (27%) and 187 to urban floods (19%). It was also possible to see that the main triggering factor for floods during the period in question was heavy rainfall, with 652 occurrences. Prolonged precipitation and dam discharges accounted for 320 and 44 occurrences respectively. Percentage-wise, it can be deduced that 65.5 per cent of floods in Mozambique derive mainly from heavy rainfall.

It should be emphasised that the methodological limitations of the RISCAR database are the result of discontinuity in the publication of information, meaning that there is no record of occurrences in the intervals between 1947 and 1966. Another limitation is that RISCAR does not provide information on losses in monetary values that can be economically estimated, like EM-DAT. Unlike EM-DAT, the RISCAR database focuses on losses and damage to social infrastructure, losses in the agricultural sector and environmental impacts.

The other methodological limitations of using journalistic information and public reports to compile data are well described in

Table 3. Comparison of RISCAR versus EM-DAT data for flooding.

Tabela 3. Comparação dos dados RISCAR com os dados EM-DAT para as inundações.

	Number of fatalities		Number of injured		Number of affected	
Timeframe	**RISCAR**	**EM-DAT**	**RISCAR**	**EM-DAT**	**RISCAR**	**EM-DAT**
1927 -1937	14	sd	7	sd	1250	sd
1938 -1948	69	sd	43	sd	3781	sd
1949-1959	5	sd	13	sd	sd	sd
1960 -1970	6	sd	3	sd	sd	50000
1971-1981	755	841	195	sd	156936	1140000
1982 -1992	757	10	317	sd	156756	500000
1993 - 2003	910	975	116	3	3652636	6234829
2004 - 2014	407	252	362	88	697517	857529
2015 - 2021	313	314	194	66	2168180	712571
Total	3236	2392	1250	157	6837056	10069929

Sd- Without quantitative data

the works of Kharb *et al*. (2022), Rilo *et al*. (2017) or Zêzere *et al*. (2014), mainly in the temporal and spatial discrepancy, which for this research was reduced by cross-referencing data from various sources.

4. Conclusions

In this research, it was found that it is possible to record and characterise the level of impact of different types of flooding on the population and infrastructure, using a local incidence DB. This type of analysis is therefore important for improving the design of public prevention and emergency response policies, with a view to reducing the risk of disasters at national level. There were 996 flood events, resulting in 3,237 fatalities, 2,863,639 displaced people and various infrastructural and environmental damages**.**

The south and centre of Mozambique are the regions with the most occurrences, fatalities and damage. This may in part be associated with the way crises are managed, the definition of public policies and the social actors involved (Tavares, 2018), where knowledge of the quality of historical data and past events is a precondition for achieving a reduction in mortality and economic damage, as well as improving the capacity of organisations and decisions on the territory (Alexander, 2016; Tavares, 2018; Wehn *et al*., 2015), as well as sustainable development.

To remain consistent, the RISCAR database must be publicly available, easily accessible online and constantly fed with information on recent flood events and other locations that may not be included due to limited sources.

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