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Extreme heat alerts and impacts across Mozambique 2016 - 2022: gathering evidence from media articles

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Abstract. Heatwaves are increasing around the world and cause a range of devastating societal impacts. Effective communication during a heatwave enables the general public to prepare and, if possible, take the necessary actions. In many African countries, the recognition of heatwaves and appropriate action to reduce heat risk remains absent. In this study, extreme heat and heat-related impacts across Mozambique were analyzed across space and time by using text from media sources. Alerts were obtained by performing a broad word search across four popular media outlets (Club of Mozambique, Rádio Moçambique, O País, and Televisão de Moçambique). Between 2016 and 2022, 79 heat alerts and 12 posts on impacts were found. When mapped, a disproportionate number of articles were found for Southern provinces compared to Northern provinces. Communication of heat alerts were consistent across media outlets and included the maximum temperature forecasted and geographic locations affected. A majority of the messages (91%) did not include information on how to respond and the type of actions to take to reduce risk. Our findings provide spatio-temporal insights into extreme heat and impacts, and highlight the urgent need for an improved heatwave early warning system across Mozambique.

Keywords. extreme heat, media, heat-related impacts, Mozambique, GIS

1 Introduction

1.1 Heatwaves, impacts, and vulnerability

As global mean temperatures continue to rise due to climate change, nearly every region around the world is experiencing an increase in heatwave frequency, duration, and intensity (Coughlan de Perez et al., 2018). Record-breaking heatwaves are being reported every year globally which can affect nearly all sectors of society.

Most importantly, heatwaves are among the deadliest disasters and pose a serious threat to human health and well-being (McGregor et al., 2015; Watts et al., 2021). Heatwaves exacerbate pre-existing health conditions (such as cardiovascular and respiratory illnesses), can lead to kidney disease, increase the rate of transmission of food and waterborne diseases, and cause heat strokes, cramps and exhaustion (Singh et al., 2019; The World Bank, 2013; Li et al., 2015; McGregor et al., 2015). Extreme heat also impacts the productivity and work hours of outdoor and agricultural workers, leading to economic losses (International Labour Organization, 2019; Parsons et al., 2021). Damage and losses of agricultural crops and livestock may also occur, threatening livelihoods and causing food insecurity (Rogers et al., 2012). Physical infrastructure may be damaged, and essential services disrupted (e.g. electricity, food, and water supplies), which can cascade into other impacts (McGregor et al., 2015; Singh et al., 2019). Such far-reaching impacts were observed during the heatwave in India and Pakistan in the early spring of March 2022, which impacted human health, caused significant power outages, destroyed large number

of crops affecting global food markets, forced schools to close, and more (Zachariah et al., 2022).

Impacts from extreme heat are not distributed equally across countries and across different groups of people within the same community. Low-income, tropical countries suffer a disproportionate amount of economic damage due to heatwaves compared to mid-latitude regions (Callahan and Mankin, 2022). Furthermore, vulnerable groups of people that are at higher risk from extreme heat include elderly, young children, people with pre-existing medical conditions, (pregnant) women, people who are illiterate, individuals with low socioeconomic levels and/or live in informal housing, ethnic minorities, migrants, and displaced individuals (Green et al., 2019; Singh et al., 2019). Furthermore, awareness and risk perception plays an important role in determining people's likelihood to respond to warnings and impacts felt (Hass et al., 2021). Especially in countries where higher temperatures are common, people often think they are "used to" extreme heat and do not necessarily recognize when they are increasingly at risk (Pasquini et al., 2020; Amou et al., 2021). On the other hand, there is scientific knowledge on relatively simple adaptation and communication strategies that can greatly reduce impacts from heat (McGregor et al., 2015; Singh et al., 2019). Yet, in many countries, the risk of heatwaves is still not properly understood and recognized. Utilizing geospatial technologies and geo-information science methods can map risks, enhance awareness, and better understand gaps.

1.2 Research gaps across Africa

Despite the fact that research has shown nearly all regions are increasingly experiencing more intense and frequent heatwaves (IPCC, 2021), studies have been predominantly focused on mid-latitude, temperate, and high-income countries. Especially across the African continent there are significant gaps in our knowledge on heat extremes (Brimicombe et al., 2021; van der Walt and Fitchett, 2021a; Russo et al., 2016; Harrington and Otto, 2020; Campbell et al., 2018). The global reviews by Campbell et al. (2018) and Mora et al., (2017) on heat and health research summarized hundreds of studies over the past decades, and both found nearly no studies on heat and health conducted across Africa. These gaps are in part explained by existing data challenges, lack of funding and/or local researchers, as well as publishing barriers when English is not the first language (Campbell et al., 2018; Kapwata, 2020).

Over the past years, understanding of heatwaves, trends, and characteristics across some African regions has been growing. For example, studies have been done across the continent (Ceccherini et al., 2017), Northern Africa (Zittis et al. (2021), Southern Africa (Meque et al. 2022); Kenya (Amou et al., 2021); and South Africa (van der Walt and Fitchett, 2021a, b). These extreme heat events have surely led to a variety of negative impacts, yet there is little to no evidence of the impacts of heatwaves across all African countries (Wright et al., 2019). This can partially be explained by the lack of appropriate data (both weather and health data).

1.3 Case-study context: Mozambique

Over the past decades, Mozambique has been exposed to many climate disasters which have hampered much social and economic development (Bambaige et al., 2008; USAID, 2017). At present, there is limited mention of heatwaves as a climate risk, nor are heatwaves officially recorded in Mozambique. This may be due to availability of temperature data. Mozambique at present, 51 of the 154 districts of Mozambique are covered by a weather station; Club of Mozambique, 2022). With advancements in remote sensing technology, increasing evidence for the prevalence, characteristics, and trends of heatwaves across Mozambique can be determined (Meque et al., 2022; Pereira et al., 2022; Ministry of Foreign Affairs of the Netherlands, 2018). Still, knowledge about heat extremes and the communication around heat alerts and heat-related impacts remains largely non-existent across Mozambique yet is crucial to recognize the problem and take appropriate action to reduce heat risk. In this study we aimed to increase understanding of extreme heat and heat-related impacts across Mozambique by analyzing text from media sources across space and time.

Mozambique is located in southeastern Africa at the intertropical zone. The cool and dry season lasts from May to September, and the hot and humid season takes place between October and March (Ministry of Foreign Affairs of the Netherlands, 2018). Generally, Northern and Central Mozambique are tropical and subtropical, whereas the South is semi-arid (USAID, 2017).

1.4 The media as a key stakeholder and geographic text retrieval

In countries where knowledge about heatwaves and their impacts is scarce, media outlets can provide information on heatwave occurrence and their impact. In fact, the media plays an active role in communicating early warning information as well as the impacts felt across communities. Not only does the media provide insights into public awareness but also captures the perception and preparedness for reducing impacts (Singh et al. 2019).

Analyzing text from media articles or social media to identify heatwaves and impacts can have several advantages over traditional quantitative methods,

especially in data-scarce regions (Cecinati et al. 2019). First, media articles can give insight into the full range of observed impacts and highlight all affected sectors. Next, it allows for analysis on larger scales (such as national) compared to traditional impact assessments that generally use data at hospital or community level. Additionally, news outlets are often quick in reporting heat-related impacts, whereas impact data can take several weeks, months or years to be gathered, allowing for tracking impacts of heatwaves in real-time. Nevertheless, it is important to mention this type of analysis should not be seen as a replacement of traditional methods, but rather is useful where not much is recorded nor known on extreme heat. Overall, it may serve as a complement to existing data and shape research priorities. Over the past decade, progress has been made with geographic information retrieval and geographic text analysis methods, which involves analyzing text data with location-based information (Purves et al., 2018). It combines techniques from natural language processing, text mining, and geographic information systems to analyze unstructured text data, such as news articles, social media posts (Janowicz et al., 2020). The goal of geographic text retrieval is to extract information that is relevant to a specific geographic location or region, such as identifying natural disasters, monitoring disease outbreaks, or analyzing social media sentiment for a specific city or region (e.g., Tomaszewski et al. 2011; MacEachren et al., 2011). This information can be used to make informed decisions and take proactive measures to identify heatwaves or other disasters, improve preparedness, and minimize impacts. For example, social media mining has been used to identify heatwave mortality (Cecinati et al., 2019) and to analyze disaster-related information (Ponce-Lopez and Spataru, 2022; Feng et al., 2022).

Table 1. Overview of media sources, word search, number and time-period of posts found

Club of Mozambique	Website	English-language news around business, politics, and economic activities in Mozambique	"heat"	19	06/01/2016 to 14/09/2021
Rádio Moçambique (RM)	Facebook	State-owned broadcasting radio station in Mozambique	"calor" (English: "heat")	31	11/09/2017 to 13/10/2021
O País	Website	A Portuguese-language daily newspaper.	"calor"	33	13/03/2018 to 07/05/2022
Televisão de Moçambique (TVM)	Website	The national public TV broadcaster of Mozambique	"calor"	8	11/01/2019 to 23/03/2022
Extreme Temperatures Around The World (@extremetemps)	Twitter	Weather news, climatic statistics, and records	"Mozambique"	8	11/06/2020 to 09/11/2021

2 Methodology

2.1 Media analysis

There is no single, universal definition or threshold for what is considered a heatwave, as extreme heat is defined relatively to the local climate (Singh et al., 2019; Perkins and Alexander 2013; McGregor et al., 2015). Broadly, heatwaves are described as a period of unusually hot weather, which is hazardous to human and natural systems and persists for at least three consecutive days (Singh et al., 2019). In Mozambique, weather alerts on extreme heat are issued by Mozambique National Institute of Meteorology (Instituto Nacional de Meteorologia - INAM) which are then picked up by different media outlets. No archive of bulletins nor record of heat-related impacts was found for Mozambique. Therefore, a text search was done across media outlets to collect information about heat events, where these were taking place, what information was being reported, who was impacted. (Tab. 1). The variables retrieved includes: date of the post, geographic location such as the province(s) affected, maximum temperature, impacts, other weather conditions (minimum temperatures, high/low humidity, wind, intense rainfall or scarcity of rain, and strong drop in temperature), duration of the event, recommendations to reduce heat risk, the URL, and the media outlet.

First a general web search was conducted using both English and Portuguese text (as Portuguese is the official language of Mozambique), namely: "calor intenso em Mozambique" (English: "extreme heat in Mozambique") to find different media outlets that have reported on extreme heat. A variety of different types of media were identified, including English and Portuguese sources, radio, TV, and newspaper channels. Finally, four media outlets were selected which reported on extreme heat, including: "Club of Mozambique", "Rádio Moçambique", "O País", and "Televisão de Moçambique" (Tab. 1). Furthermore, record temperatures for Mozambique were

added from “Extreme Temperatures Around The World” (Twitter: @extremetemps), to retrieve and cross-compare media reports with national and international temperature records for Mozambique.

For each of the four selected media sources, a broad word search was done using “calor” in Portuguese sources and “heat” to compile all posts related to extreme heat. Posts related to either 1) extreme heat alerts or 2) impacts resulting from extreme heat across Mozambique were included. Posts were excluded if 1) they were not about Mozambique, 2) there was no indication of maximum temperature and/or location, and 3) the post contained the word “heat” but was not related to extreme heat (e.g. an article on the “heat-proof rotavirus vaccine”).

The first article found was posted on 06/01/2016 by Club of Mozambique. This search was done until 10/05/2022, thus the full extent of articles on extreme heat for 2022 was not captured. An overview and description of media outlets are provided in Tab. 1.

2.2 Weather station analysis

Next, heat alerts from each media source were cross compared with observational temperature records from weather stations across the country for that same date. Daily temperature records from weather stations were obtained for the same period as the media analysis (2016 – 10/05/2022). Daily temperature records were obtained from the National Climatic Data Center’s (NCDC) daily summaries (GHCN-Daily) archive for the same period as the media posts (2016 to 10/05/2022) (see Section 2.3 for details). 11 weather stations were selected to cover each province, mostly located in the provincial capitals: Maputo, Xai-Xai, Panda, Inhambane, Chimoio, Beira, Tete, Quelimane, Nampula, Lichinga, and Pemba.

The top three record temperatures of each weather station were summarized and compared with heat alerts in the media. Provinces with the highest and lowest number of heat alerts in the media were further analysed and included Maputo and Cabo Delgado. For these two provinces, heat alert reports were plotted over daily maximum temperature and calculated "extreme” temperatures. Extreme temperatures were calculated by taking relative thresholds based on the 90th percentile of daily maximum temperature (Pereira Marghidan, 2022). For Maputo the threshold for extreme heat was found to be 36.1 °C and for Cabo Delgado 33.2 °C. The records were matched if the observed extreme temperature coincided with a heat alert on that same day or one day in advance.

2.3 Data and Software Availability

All data used in this study are freely available in the public domain. Analysis was done using Excel and ArcGIS 10 Software. All datasets used in this study are listed in: https://github.com/carolinamarghidan/AGILE_MZ_Heat.

Spatial information from all media reports was extracted and compiled into an Excel spreadsheet and contains information on: date of the post, geographic location such as the province(s) affected, maximum temperature, impacts, other weather conditions (minimum temperatures, high/low humidity, wind, intense rainfall or scarcity of rain, and strong drop in temperature), duration of the event, recommendations to reduce heat risk, the URL, and the media outlet.

The National Climatic Data Center’s (NCDC) daily summaries (GHCN-Daily) are openly available through: https://www.ncei.noaa.gov/access/search/datasearch/daily-summaries). The parameters were filled in as follows: what: “maximum temperature” and where: “Mozambique”. Of the 17 weather stations, 11 were selected to cover each province across Mozambique, and which included records available up to May 2022. The stations selected were: Maputo, Xai-Xai, Panda, Inhambane, Chimoio, Beira, Tete, Quelimane, Nampula, Lichinga, and Pemba.

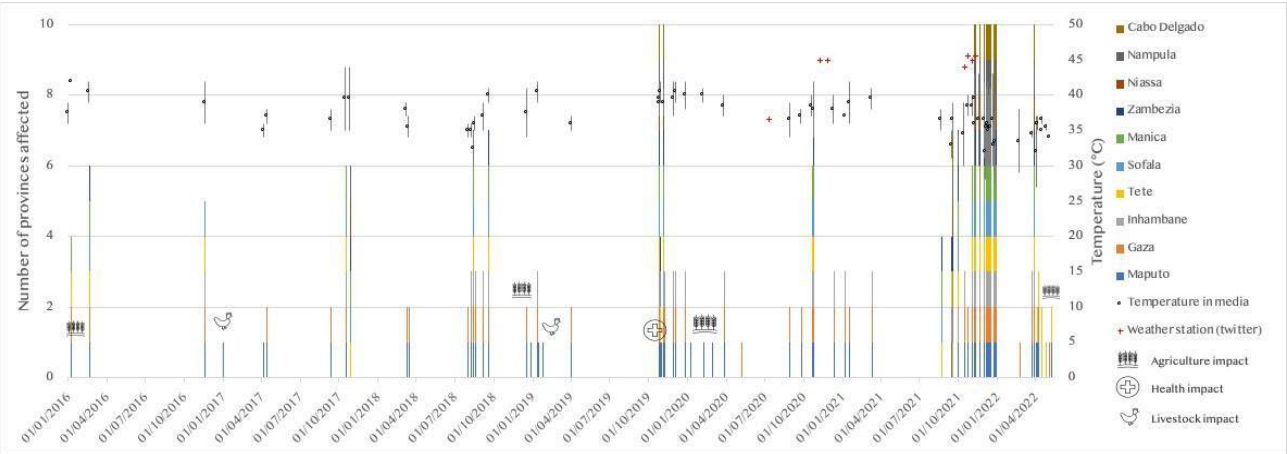

Figure 1. Heat alerts and impacts reported in media articles across Mozambique for 06/01/2016 – 10/05/2022. A total of 91 posts on extreme heat were found with various impacts recorded. Intensities posted by the media range from 27 – 43 °C, yet intensities recorded by weather stations reported on Twitter (visualized with red crosses) show temperatures up to 45.5 °C.

3 Results

3.1 Heat alerts

In total, 91 posts on extreme heat were found, 79 including heat alerts and 12 posts on impacts. Fig. 1 shows the heat alerts over time, including the number of affected provinces mentioned in each alert, range of maximum temperatures (black dots) and observed temperature records (red crosses). Reported impacts are visualized with icons and further discussed in Section 3.2.

In some cases, extreme heat was reported throughout the whole country, including on 25 October 2019, 3 November 2019, throughout November 2021, during nearly the entire month of December 2021, and 26 March 2022 (Fig. 3). The heat alert messages were found to be consistent across the media channels. In general, the information reported included 1) the area of risk (province and/or district) and 2) range of maximum temperatures to be felt. In a few cases, other weather conditions were mentioned such as minimum temperatures, high/low humidity, wind, intense rainfall or scarcity of rain, or strong drop in temperature. Furthermore, some posts included recommendations for actions to reduce risk to heat. Each are discussed in the sections below.

3.1.1 Areas at risk

Most heat alerts were found across Southern Mozambique, with fewer heat alerts covering Northern Mozambique (Figure 2). The province where most heat alerts were found was Maputo with 72 heat alerts, followed by Gaza (59) Inhambane (41), Tete (40), Sofala (32), Manica (31), Zambezia (29), Nampula (22), Niassa (20) and Cabo Delgado (20).

3.1.2. Timing of heat alerts

Across all provinces, most heat alerts were observed in 2021 (Fig. 3). In Maputo, extreme heat was reported consistently throughout the whole period of 2016 – 2022. On the other hand, only two posts covering Cabo Delgado were found before 2021, 17 posts in 2021, and one post in 2022. A similar pattern is observed for Niassa and Nampula. Most heat alerts were posted in December (18 heat alerts), followed by October (10), November (9) and April (9). No alerts were found for June, and only one for July. The only provinces where heat alerts were found in the cooler months of May and July include Tete, Gaza, and Sofala.

3.1.3. Maximum temperature and other weather conditions

Generally, maximum temperature was the only weather variable that INAM reported when alerting for extreme heat. In a few cases, other weather variables were mentioned such as minimum temperature, humidity, and other weather conditions (e.g., strong winds, sharp drop in temperature, or an upcoming storm). Across all heat alerts, maximum temperatures ranged from 27 – 44 °C. The highest intensity of 44 °C was reported on 16 and 26 October 2017, affecting Southern and Central Mozambique. Twitter posts on temperature records around the world reported maximum temperatures in Mozambique that were higher by several degrees (up to 45.5 °C) (Tab. 2; and indicated with red in Fig. 1). These temperatures did not coincide with any media posts on intense heat in Mozambique, although these included national and international temperature records.

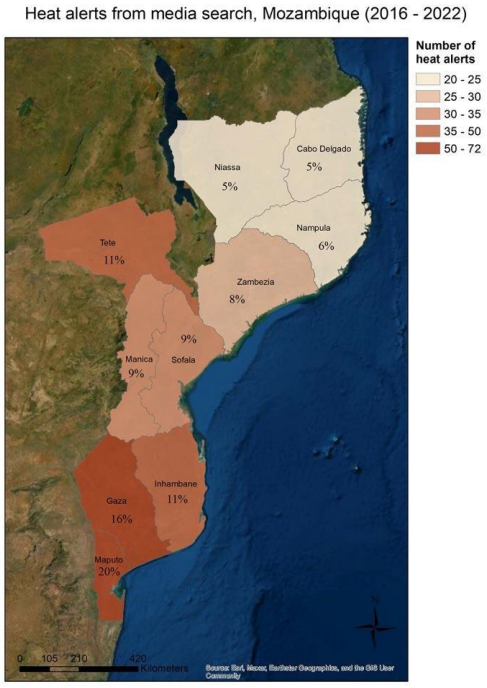

Figure 2. Number and percentage of heat alerts in media reports across Mozambique during 2016 – 2022.

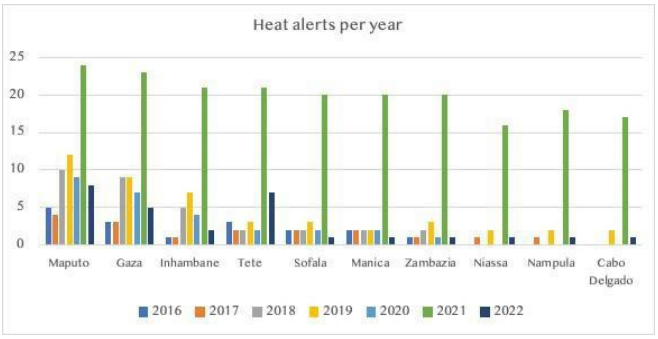

Figure 3. Number of heat alerts per year per province

Table 2. Posts on extreme temperatures in Mozambique by @extremetemps (Twitter)

Date	Location	Maximum temperature reported (°C)	Notes
11/07/2020	Massangena (Gaza district)	36.5	July temperature record for Mozambique
08/11/2020	-	45	-
25/11/2020	Northern Mozambique	45	-
14/10/2021	-	44	-
24/10/2021	Tete	45.5	Highest temperature in the Southern Hemisphere of the season
03/11/2021	-	45	-
09/11/2021	Tete	45.5	Highest temperature in the Southern Hemisphere of the season (tied with Tete on October 24st)

3.1.4. Recommendations to reduce risk

The large majority of heat alerts (91%; N=72/79) released by the media did not state any specific recommendations on what actions to take during extreme heat. Sometimes a vague recommendation was mentioned such as: "in view of the discomfort derived from the heat, INAM recommends taking precautionary and safety measures." In very few cases, specific actions to take to reduce heat risk were recommended (Tab. 3). The most common recommendations included avoiding exposure to the sun, as well as drinking water to avoid dehydration. Most recommendations were directly from INAM, with some provided by the Ministry of Health (Tab 3.).

Table 3. Summary of recommended actions to take during extreme heat reported by the media

Date	Province	Recommendation	Media outlet
11/09/2017	Maputo, Gaza	INAM recommends taking precautionary and safety measures, in view of the risk associated with high temperatures, such as: not being exposed to the sun, drinking plenty of liquids without alcohol, resting in cool places, avoiding physical exercise especially during peak hours, and not using tight clothing that may inhibit breathing.	RM; Club of Mozambique
25/10/2019	Maputo, Gaza, Inhambane	INAM warns about the possible worsening of chronic diseases due to high temperatures, health risk for children and adults, dehydration, and development of cardiovascular diseases, which is why people cannot expose themselves to the sun and should drink a lot of water.	TVM
28/10/2019	Manica, Tete, Zambezia, Sofala	INAM recommends the population to drink plenty of fluids to avoid dehydration, suspend physical exercises in the open air, between 10 am and 4 pm, rest in cool environments and wear loose, lightcolored clothes.	RM
06/11/2019	Maputo, Gaza, Inhambane	It is recommended to avoid excessive exposure to the sun's rays.	RM
28/11/2019	Maputo, Gaza, Inhambane	It is recommended to avoid excessive exposure to the sun's rays.	RM
26/12/2019	Maputo, Gaza, Inhambane	INAM recommends taking precautionary measures, avoiding excessive exposure to sunlight and drinking plenty of fluids to avoid dehydration.	RM
16/12/2020	-	To counter the effects of the heat, the Ministry of Health recommends drinking at least two liters of water a day, and consuming food rich in water, vitamins, and mineral salts to avoid dehydration. It suggests avoiding fatty foods and keeping children in a cool environment.	Club of Mozambique

3.2 Heat-related impacts in the media

In total, 12 reports on heat-related impacts were found from 2016 to May 2022 (Tab 4.).

Most heat-related impacts reported related to the agricultural sector, including the large number of losses of crops (e.g. maize, beans, horticultural products, cabbage, lettuce) and livestock (mainly laying hens and their eggs) (Tab. 4). The extreme heat, sometimes in combination with existing water scarcity, was reported to cause food insecurity in Gaza, where 3,500 families were affected by hunger. In response to these agricultural losses, the government has supported farmers with seeds. In addition, the provincial government of Maputo has been trying to establish a resilient form of agriculture through the development and use of greenhouses (Club of Mozambique, 2020). Over the past two years, a total of 96 greenhouses have been set up in Maputo province (Club of Mozambique, 26 February 2020). This allows for

permanent production regardless of weather conditions. Furthermore, many areas in Mozambique contain open food markets that do not have adequate storage spaces for produce, and extreme heat has resulted in spoilage of produce, affecting market prices and the livelihoods of farmers and traders.

Two posts were found on heat-related impacts on human health. During the weekend of 26-27 October 2019, Hospital Central de Maputo (HCM) reported over 950 people to be admitted with heat-related illnesses. No details of the people admitted nor responses by the hospital or government were mentioned. Maximum temperatures of up to 42 °C were reported by the media during this weekend (Fig. 1). Next, during that same heatwave, 8 children drowned in Beira City (Tab 4.). Other posts did not mention any specific impacts but stated the increasing risk of extreme heat on human health: "the rise in average temperature levels in Mozambique, particularly in the provinces of Tete, Manica and Niassa, could lead to an increase in cases of malaria and diarrhea." (TVM, 2017). Lastly, as the analysed time-period coincided with the COVID-19 pandemic, one article mentioned that residents refused to wear masks due to the intense heat felt in Tete, highlighting the interaction between heat and other crises (Carlos, 2020).

Similar to the spatial distribution of heat alerts, a disproportionate number of reports were found for Maputo province (75%; N=9/12), in addition to two reports on Gaza and one on Sofala. No impacts were reported for all other provinces, including Inhambane, Manica, Tete, Zambezia, Nampula, Niassa, and Cabo Delgado.

3.3 Weather station analysis

3.3.1. Weather station records (2016 – 2022)

The top 3 records of maximum temperature were summarized per weather station (Tab. 5). From these records, only 40% were found to be reported by the media.

Table 4. Impacts from extreme heat recorded in media articles across Mozambique (2016 – May 2022)

Sector impacted	Date of post	Province affected	Heat-related impacts recorded	Source
Agriculture	6 January 2016	Maputo	Price of food products falls due to weak demand and extreme heat. The intense heat together with a lack of adequate storage spaces at the market in Maputo caused **produce to be lost**, affecting traders.	Club of Mozambique
Livestock	30 December 2016	Maputo (Boane district)	**Over 30,100 laying hens and 78,000 eggs were lost** in three days in the district of Boane, Maputo province, due to the combination of extreme heat and power cuts that were not communicated.	Club of Mozambique
Agriculture	27 December 2018	Maputo	**Over 35,000 crops were destroyed.**	RM
Agriculture	22 January 2019	Maputo (Manhica, Boane, and Marracuene districts)	Heatwave **destroys in total 40,000 hectares of crops** (of a total of 63,000 hectares sown in the first season) consisting of mostly maize, beans, and horticultural products. The provincial government responded by distributing 100 tons of seeds to producers to replace the lost crops.	RM
Health	29 October 2019	Maputo	During the weekend proceeding 29th of October (26-27 October), o**ver 950 people were admitted to Hospital Central de Maputo, "with illnesses resulting from the heat wave"**. The chief physician of the hospital said that cardiovascular diseases are the main cause of hospitalizations. The spokeswoman from National Public Safety Service mentioned that drownings tend to increase during the bathing season.	RM

Health	29 October 2019	Sofala (Beira City)	Eight children died of drowning on the beaches of Sofala in the last two weeks, following the heatwave that is felt "practically throughout the entire country".	RM
Agriculture	6 January 2020	Maputo (Maputo & Matola districts)	Heatwave affects crop production in Matola City, where **over 400 hectares of crops have been destroyed**, affecting the livelihoods of farmers and production and sale of crops. Cabbage and lettuce crops have been highlighted as most affected by the heat. The president of the Association of Farmers and Breeders of Green Areas, Ernesto Manhiça said: "We are very bad. The heat is intense and leaves nothing to live for. When we sow, it burns, and there is no water in the ditches."	RM
Agriculture	26 February 2020	Maputo & Matola and Southern Mozambique	**Loss of 17,000 hectares of crops**, which includes 5% of the cultivated area in this agricultural campaign. (Club of Mozambique) Government allocates 48 tons of seeds to Maputo Province to support producers affected by heat (TVM)	Club of Mozambique; TVM
Agriculture / food insecurity	7 May 2020	Gaza (Mapai district)	**Hunger affects 3,500 families** in Mapai district in Northern Gaza. *"Because of the intense heat that was felt, all crops were lost"*	RM
Livestock	13 January 2022	Maputo (Marracuene district)	**Over 3000 chickens dead** due to extreme heat and failures in the ventilation system.	TVM
Agriculture / food security	21 February 2022	Gaza (Mabalane district)	Scarcity of rain and extreme heat combined threaten food production of approximately **900 hectares are considered lost** due to water stress, causing food insecurity in the region.	RM

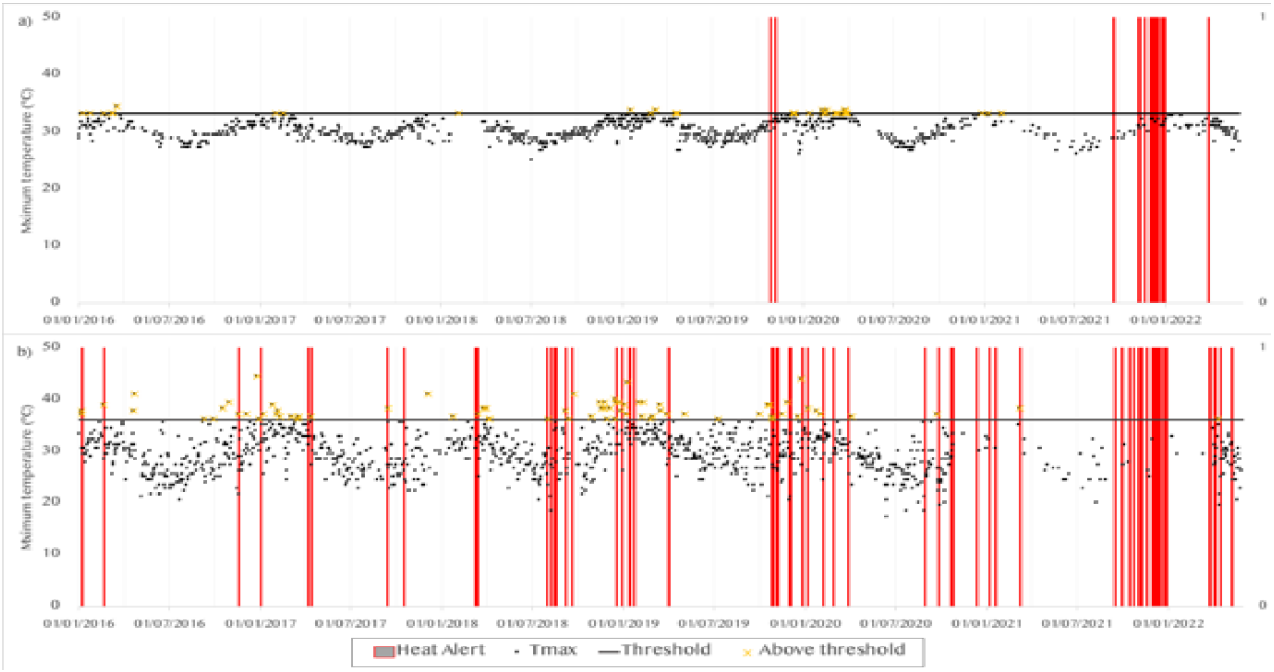

Figure 4. Daily maximum temperatures and heat alerts reported by the media for a) Cabo Delgado and b) Maputo for (06/01/2016 – 10/05/2022).

Table 5. Top 3 maximum temperatures from weather stations in each province during 2016 - 2022

Province, City	Date	Tmax weather station (°C)	Media post	Tmax in media (°C)
Maputo, Maputo City	24/12/2016	44.4 43.9	-	
	26/12/2019	43.3	✓	38 – 42
	12/01/2019		✓	39 – 42
Gaza, XaiXai	28/10/2019	42.8	~* (26 Oct)	37 – 42
	03/12/2019	41.7	✓	39 – 42
	25/10/2019	40.6	✓	38 – 42
Inhambane, Panda	28/10/2019	44.4 42.2	-	
	26/10/2019	41.7	✓	37 – 40
	26/12/2019		✓	38 – 42
Inhambane, Inhambane	23/12/2016	36.7	-	
	28/03/2016	35.6	-	
	18/01/2020	35	-	
Manica, Chimoio	17/10/2017	40.6 38.9	~ (16 Oct)	35 – 44
	26/10/2017	38.3	✓	35 – 44
	21/02/2016		~ (19 Feb)	39 – 42
Sofala, Beira	26/03/2020	37.2	-	
	14/12/2017	36.1	-	
	06/11/2020	35.6	-	
Tete, Tete	09/11/2021	45.6	~ (8 Nov)	30 – 43
	28/10/2019	44.4	✓	39 – 42
	24/11/2020	43.9	-	
Zambezia, Quelimane	29/10/2019	43.9	~ (28 Oct)	39 – 42
	16/11/2017	43.3	-	
	17/10/2017	42.2	-	
Nampula, Nampula	16/11/2019	39.4 38.3	-	
	20/11/2019	37.8	-	
	19/11/2019		-	
Niassa, Lichinga	18/10/2017	34.4	-	
	26/11/2020	32.8	-	
	16/11/2020	32.2	-	
Cabo Delgado, Pemba	18/03/2016	34.4 33.9	-	
	27/03/2020	33.3	-	
	04/02/2021		-	

* [~] indicates a post by the media within a range of 1-2 days from the observational record

3.3.2. Comparing provinces: Maputo and Cabo Delgado

The provinces of Maputo and Cabo Delgado were observed to have the highest and lowest number of heat alerts, respectively. Therefore, these provinces were analyzed in more detail with regards to their heat alerts and daily temperature records. Overall, the weather stations were found to contain a large number of missing values (Fig. 4). Across the time-period analyzed (01/012016 – 31/05/2022), Cabo Delgado contained 58.3% and Maputo 49.7% missing maximum temperature values.

From the 72 media posts on extreme heat in Maputo province, 11 matching temperature records (15.3%) were found. From the 20 posts in Cabo Delgado, zero were found to match with the observational record (0%). In addition, from the 75 extreme temperatures measured for Maputo (Tmax > above 36.1 °C), 12 contained a corresponding media alert (16%). From the 39 extreme temperatures measures in Cabo Delgado (Tmax > above 33.2 °C), zero were reported by the media.

4 Discussion

Heat is a hazard that has been greatly underexplored across Mozambique as well as other African countries. This research presents one of the first studies on extreme heat alerts and heat-related impacts across Mozambique. However, it is important to note that these results do not represent the full extent of episodes of extreme heat and impacts, due to the limited number of media outlets analysed as well as the common underreporting of heat in the media. Nevertheless, these findings are important considering the limited knowledge around heat in Mozambique.

4.1 Towards the development of a heatwave early warning system

Currently, the warnings on extreme heat released by INAM are based on one day of extreme heat and generally only include the range of maximum temperature forecasted and the area(s) affected. It is not clear what temperature threshold is used by INAM, its rationale for this threshold, and if the same threshold is used across the entire country. Furthermore, no specific heatwave definition could be found (e.g., extreme heat that last for at least three consecutive days).

Overall, INAM's current warnings and bulletins on extreme heat could be improved by expanding on its heatwave definition as well as the information disseminated. Different climates and regions of Mozambique may require different temperature thresholds and/or weather variables to define heatwaves. For example, tropical regions in Northern Mozambique experience less variation in temperature and might not reach extremely "high" temperatures. Still, "apparent" heatwave intensities may be higher due to higher levels of humidity. Research has shown that tropical regions experience heat-related impacts at lower temperature thresholds (Gasparrini et al., 2015; Strathearn et al., 2022). Also depending on the population and local context, impacts may be observed at lower thresholds that might not be seen as climatologically extreme (Pasquini et al., 2020). To establish operational and effective early warning systems, it is therefore important to combine weather information with observed impacts (Nissan et al., 2017).

Information disseminated during heat warnings could be improved by communicating about vulnerable groups of people and specific actions to take during heatwaves. Recently, the Sahel region has developed such an improved heat-health early warning system and bulletins (Ndiaye et al., 2022). On the other hand, even with a good forecast and improved warning message, these might not reach the full population. In fact, only 40% of the African population has access to early warning systems at present (UN News, 2022). Therefore, it is also crucial to collaborate between stakeholders and make efforts to make warning systems as inclusive and accessible as possible. For example, warning information can be disseminated through voice messages to include illiterate people.

4.2 Spatial patterns of heat alerts

Our results reveal a much higher level of reporting for the southern provinces such as Maputo, Gaza compared to northern provinces such as Cabo Delgado, Niassa, and Nampula. In contrast, recent research using relative heatwave thresholds to calculate heatwaves across Mozambique reveal the opposite: over the past decades, a higher number of heatwaves in Northern Mozambique compared to Southern Mozambique (Pereira et al., 2022; Meque et al., 2022). The lower levels of reporting on heatwaves in Northern Mozambique might therefore relate to the threshold for extreme heat employed by INAM, which might be "too high" for tropical regions. As emphasized in the previous section, humidity may be an important factor to consider in tropical regions of Mozambique. In addition, most journalists and media outlets are based in the capital city of Maputo, which might create a reporting bias towards Southern provinces.

4.3 Gathering evidence for heat-related impacts & data challenges

Although heatwaves are among the deadliest extreme weather event, impacts are consistently underestimated and underreported. The findings from this study provided initial evidence for heat-related impacts reported in Mozambique and highlight a need for additional efforts in improved health surveillance to validate and understand these impacts. Similar to the spatial patterns of the heat alerts, all reported impacts found were for Southern Mozambique. It is likely that other provinces also experienced impacts due to the extreme heat felt, yet currently there is no understanding at all of these.

Many heat-related impacts reported by the media related Mozambique's agricultural sector. Agriculture is one of the most important sectors in Mozambique, contributing greatly to the national economy and livelihoods of people (Maure et al., 2010). Extreme heat was reported to have caused large losses of crops, affected sales and livelihoods of farmers, leading to food insecurity and hunger (Tab. 4). In addition, one heatwave in October 2019 caused an increase of 950 hospital admissions in Maputo City. Still, additional research is required to uncover the locally dominating factors contributing to the vulnerability and impacts (e.g., what were the characteristics/demographics of the people admitted). This can help target solutions to reduce risk of the most vulnerable.

However, heat as the cause of illness/death is often masked as extreme heat compounds pre-existing health risks. On top of this, a lack of appropriate data (both weather and health data) makes it especially complicated to quantify and understand the full extent and characteristics heat impacts. Such data challenges are not exclusively for Mozambique but are common for many other African countries. When common health variables such as total or cause-specific mortality/morbidity due to non-communicable diseases (Green et al. 2019) are not readily available, proxy variables such as 911 calls, text from social media or expert knowledge from local health practitioners might be used to estimate the impact (Cecinati et al. 2019).

4.4 Conclusion

Knowledge around heatwaves and impacts is urgently needed across Mozambique and other African countries. The current lack of knowledge is worrying, especially considering temperatures over Africa are rising at twice the rate compared to global averages (Engelbrecht et al., 2015), and there is little to no understanding of the heat-related impacts. Advances in (AI-based) geo-information methods can fill data gaps and help identify heatwaves and impacts, particularly in areas where traditional data is not available (Cecinati et al. 2019; Janowicz et al., 2020; Feng et al., 2022). Furthermore, efforts should be made to increase the knowledge and awareness of local governments, meteorologists, health professionals, community organizers, and the general population on heatwaves and its risks. This will enhance the effectiveness of heat early warning systems, increase preparedness, and minimize impacts. Future priority areas for research on heatwaves across Mozambique include research into operational heatwave forecasts, heat-related impacts, and effective local adaptation and communication solutions.

4.5 Summary

This study concludes:

- Heatwaves are greatly under-reported and under researched across Mozambique. From 2016 until May 2022, 91 extreme heat alerts and 12 reports on heat-

related impacts were found with a disproportionate number of articles for Southern Mozambique.

- A variety of heat-related impacts have been reported, including extreme losses of agricultural crops and livestock, and increased hospital admissions.
- Mozambique would benefit from an improved heatwave early warning system, that include consistent reporting, provides recommendations for actions to take during heatwaves and the impacts of the heatwave (e.g. losses of agricultural crops and livestock, and hospital admissions).
- In data-scarce countries such as Mozambique, geo-information science and geographic text analysis plays a crucial role in filling data gaps thereby increasing recognition and awareness of the problem, as well as analyzing and advocating for certain solutions to reduce extreme heat.

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CPM, MvA, JB conceived the paper; CPM performed the analysis; Mva, JB, GM, TM advised. All authors wrote the paper.

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