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What Do Weather Disasters Cost? An Analysis of Weather Impacts in Tanzania

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Weather-related disasters negatively impact livelihoods and socioeconomic activities and often lead to the loss of lives and homes. This study uses disaster data from the Disaster Management Department (DMD) in Tanzania to describe the spatial distribution of weather-related disasters, their socioeconomic impacts and highlight opportunities to improve production and uptake of weather and climate information by climate sensitive sectors. Between 2000 and 2019, severe weather accounted for ∼69% of disasters in Tanzania. The Government spent over 20.5 million USD in response to these disasters, which destroyed over 35,700 houses and 1,000 critical infrastructures (roads, bridges, schools, and hospitals), affected over 572,600 people, caused over 240 injuries and 450 deaths. To reduce these impacts, it is important to understand the decision-making process in terms of what and how national guidelines create and enabling environment for integration of weather and climate information into disaster risk reduction strategies. For example, the National Transport Policy which is supposed to provide cross-sectorial guidelines on the use of weather and climate information addresses the use to marine industry but remains silent to other climate sensitive sectors and the public. Whilst weather warnings are available Tanzania continues to suffer from the impacts of weather-related disasters. There is a clear need to better understand the value of weather warning information at short timescales (1–5 days) and how this information can be better used in the individual decision-making processes of those receiving advisories and warnings. The review of policies to guide on cross- sectoral actions to foster the uptake of weather and climate services, decisions across climate sensitive sectors, both nationally and sub-national level is recommended.

Keywords: weather, disasters, weather warnings, climate information, policy, Africa

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INTRODUCTION

Weather events profoundly affect human well-being, health, food security, infrastructure and economic development (CRED, 2018). A changing global climate is contributing to the increase in extreme weather events and associated threats to lives and livelihoods across Africa (Bedarff and Jakobeit, 2017). Globally, 91% of all disasters during 1998–2017 were caused by floods, storms, droughts, heatwaves, and other extreme weather events (CRED, 2018). These events have led to losses in human life as well as major damage to property, infrastructure and the environment (Masson-Delmotte et al., 2018; Formetta and Feyen, 2019); disproportionately affecting people in developing countries (UNISDR CRED, 2015).

Like other countries in sub-Saharan Africa, Tanzania is particularly vulnerable to the impacts of extreme weather, including severe floods, frequent and prolonged droughts, and to coastal storm surges (Watkiss et al., 2011). These events have been linked directly to significant societal and economic impacts including declining crop yields, increased incidences of crop pests and diseases, loss of livestock, decreased water availability as well as increase in vector-borne and water-borne diseases. Both recent and historical experiences indicate that infectious disease outbreaks often follow extreme weather events, as microbes, vectors, and reservoir animal hosts exploit the disrupted social and environmental conditions of extreme weather (McMichael, 2015). Human health also suffers as a result of heat stress, weather-related changes in vector-borne diseases, higher incidence of food-related and waterborne infections, air pollutants, and conflicts driven by the depletion of natural resources (Costello et al., 2009; Ncube and Tawodzera, 2019).

Weak adaptive capacity and reliance on rainfed agriculture makes Tanzania extremely vulnerable to climate change impacts (Mkonda and He, 2018). It is projected that by 2100 Tanzania will experience increases in storm surges and sea-level rise, putting more people at risk from coastal flooding (Schaeffer et al., 2014). The Government of Tanzania has continued to spend thousands of US dollars in response to the impacts of severe weather and climate change (Shemsanga et al., 2010; WMO, 2014; UNISDR CRED, 2015), but with critiques highlighting some of the delays and institutional challenges in mainstreaming the better use of climate information (e.g., Pardoe et al., 2018). It has been recently predicted that climate change could lead to net economic costs that are equivalent to a loss of almost 2% of GDP each year by 2030 (Watkiss et al., 2011). However, to date few studies are available on the impact of severe weather events in the developing world or on the situation in Tanzania specifically. The UNISDR and CRED published a global report on economic losses, poverty, and disaster from the year 1998 to 2017 using the CRED's Emergency Events Database (EM-DAT). The EM-DAT contains the world comprehensive data on the occurrence and effects of occurrence of technological and natural disasters from 1900 to the present day (CRED, 2018). The reports classified disasters, according to the type of hazard that triggers them where hydrological, meteorological and climatological events were collectively being termed weather- or climate-related—plus geophysical disasters (CRED, 2018). The report mostly made comparisons of the impacts between high income and low-income countries with a focus on human cost rather than economic impacts.

Tanzania has kept a record of large-scale disasters since 1872. These records were established following a tropical cyclone that made landfall in Zanzibar and Bagamoyo in April 1872 (Lindström, 2019; Trove, 2020). An expert from the DMD noted that: "*Since the tropical cyclone incidence of April 1872, the government has continued keeping and improving disaster data based on national guidelines and international agreements.*" It is important to note that, the disaster risk management system in Tanzania came to major reform after the establishment of the Disaster Relief Coordination Act No. 9 of 1990. The Act established an Inter-Ministerial Committee known as the Tanzania Disaster Relief Committee (TANDREC) to oversee and coordinate the overall relief operations in the country. The TANDREC was under the Minister responsible for disaster management in the Prime Minister's Office (PMO).

The 1990 Act also established the Disaster Relief Coordination Unit, which in 1998 was elevated to Disaster Management Department (DMD). The DMD was specifically created as a secretariat to the TANDREC to coordinate and supervise all disaster management activities in the country. In 2015, Disaster Management Act No. 7 was enacted to replace Act No. 9 of 1990. The 2015 Act established an Emergency Operation and Coordination Center (EOCC) as additional section to strengthen the functions of the department. Furthermore, it established the Tanzania Disaster Management Council (TADMAC) to replace TANDREC. The TADMAC advice the minister in charge on disaster risk management activities in the country. The Act provides the overarching legal framework for DRR implementation in the country. The disaster risk management initiatives in Tanzania are supported by a number of sectoral policies, laws, strategies and plans. These sectorial collaborations has enabled the department to collect and improve its existing disaster data profile. Despite this data offering important insights into the characteristics and costs of severe weather events in Tanzania, no systematic analysis has been attempted to understand the contribution of severe weather events to the country's disaster profile and associated socioeconomic impacts. The available data cannot fully explain the cost of weather-related disasters in Tanzania, however, they can help to inform and shape management, mitigation and improve development of early warning system to save more lives in future. They can further help to strengthen disaster management plans, visions, guideline, polices, and coordination across sectors responsible for disaster risk reduction in the region.

Early warning systems are fundamental to reducing impacts of weather-related hazards (UNDP CIRDA Programme, 2016; WMO, 2017). To support the development of early warning systems for disaster risk reduction, it is important to be able to appropriately characterize extreme weather events and their impacts on society and the economy. Furthermore, it is important to understand how weather warnings are made available and how are they are used in various climate sensitive sectors and their decision-making process. It is also necessary to have policy that address the use of weather and climate information. Availability of policy allows collaboration among organization and the integration of weather and climate information to plans, actions, and setting out priorities (Pardoe et al., 2018). Tanzania Meteorological Authority (TMA) uses National Transport Policy to guide on the production and application of weather and climate information in Tanzania (URT, 2003). However, this policy emphasizes the use of climate and weather information in the marine sector predominantly. These shortcomings in this policy context contributes to the observed socioeconomic impacts of weather-related disasters.

The aim of this paper is to examine the weather—related disasters and their associated impacts in Tanzania through the following research questions:

- What are the spatial distributions and socioeconomic impacts of weather-related hazards in Tanzania and how are they associated with the rainfall?
- What is required to reduce the impacts of weather-related disasters?

RESEARCH DESIGN AND METHODS

This section presents the description of the study area, methods and data used in this study.

Climate of Tanzania

Tanzania lies within 1–12°S and 29–40°E, between the great East African lakes of Lake Victoria in the north, Lake Tanganyika in the west and Lake Nyasa to the south. To the east lies the Indian Ocean. The country includes Africa's highest and lowest elevations: Mount Kilimanjaro (5,950 m above sea level) and the floor of Lake Tanganyika (358 m below sea level), respectively. The majority of Tanzania, except the eastern coastline, lies above 200 m above mean sea level (Basalirwa et al., 2002).

The country experiences a bimodal rainfall regime in the northern parts, which includes areas around the Lake Victoria basin, Northern Coast, and Mount Kilimanjaro. The first rainfall season occurs during March, April, and May (MAM) and the second during October, November and December (OND) (Walker et al., 2019). The Central, South and Western areas are characterized by a unimodal rainfall regime from November to April. The rainfall over Tanzania is controlled by many factors, including large-scale teleconnections such as the El Nino Southern Oscillation (ENSO), the quasi-permanent systems such as the Inter Tropical Convergence Zone (ITCZ), tropical cyclones, more local-scale circulations such as sea breezes (Nicholson, 2018). Although the country exhibit bimodality rainfall characteristics over the northern sector, the rainfall analysis used for this data did not consider these variations. The recorded disaster events may not necessarily follow the rainfall regime, secondly there is a lag in reporting the impacts associated with hazards, for example for the case of slow onset disaster such as drought. Thirdly observed impacts may have been caused by a in far field severe weather events example rains over the high grounds may results to flooding in low laying areas. However, it is important future studies to explore the relationship between disaster events and the rainfall patterns to assist improvement in generation and provision early warning information.

Disaster Data

The disaster data were obtained from the Disaster Management Department [DMD—Prime Minister Office (PMO)] during field visit to assess the value of weather information to decision makers in disaster risk reduction in Tanzania between July and August 2019. The database composed of natural and man-made disasters (fires, transport accidents, mining accidents, building collapse and civil strife) from 1872 to 2019. A 20-year data period from 2000 to 2019 was used for this study. There were few events records prior to 2000 and are only reported yearly, with little information in terms of temporal distributions, scale of the impact, cost (estimated damage and money provided), which are reported from 2000 onwards. These may be due to the fact that the department (the then unity) was responsible for relief activities and not disaster management, and only disaster event that needed relief aids from government were recorded. Due to these limitations, the most recent 20-year period from 2000 to 2019 is used in this study to assess the economic impacts of weather-related disasters in Tanzania.

In this study events are classified according to the type of hazard that triggered them. All hydrological, meteorological, and climatological natural disasters in this paper are collectively termed weather-related disasters (CRED, 2018). Events such as tropical cyclones, heavy rain, drought, floods, storms, strong winds, thunderstorms, lightning, landslides, and epidemics were identified and grouped as weather-related disasters. Epidemics were included due to the substantial role that weather plays in these outbreaks (Ncube and Tawodzera, 2019). Events such as fire (both urban and bush fire events), earthquakes, accidents, vermin infestation, structural collapse, mine accidents, explosions, civil strife, locust, and other pests were grouped together and termed as "Other" disasters. The number of people and households directly (these are people who suffered injury, evacuated, displaced, died, relocated, or have suffered direct damage to their livelihoods etc.) or indirectly affected (these are in addition to direct effects, over time, due to disruption or changes in economy, critical infrastructure, basic services, work, or social, health, and psychological consequences), animals killed; and farms (acres) and houses affected (damaged and destroyed) were identified. Roads, hospital, schools, and bridges affected were identified and were termed as public infrastructure. The annual number of weather-related disasters events for the 20-year period (2000–2019) were then correlated with annual rainfall of the same period.

It is important to note that not all the weather-related disasters and associated impacts are in the profile. Until June 2018 the national dataset only includes information on the events that had a sufficiently large impact to require intervention by the central government, thus this analysis does not reflect the full cost of all severe weather but only the scale and cost of the most extreme weather events. Furthermore, the DMD keeps and maintains the country disaster data profile, events, and its associated impacts information is collected and reported by the affected sector. For example, events and impacts to the agriculture sector, the responsible ministry to assess and report is the Ministry of Agriculture and Food Security, for health-related impacts is the ministry responsible for health issues. Further research to understand the data collection processes and the criteria used may provide more comprehensive understanding of how events and its associated impacts are ranked, defined and categorized.

In June 2018, there was a step-change in reporting methodology and more local-scale events began to be reported. An expert from the DMD noted that, Tanzania has improved its reporting procedures after the inauguration of the Emergency Operations and Communication Center (EOC): "*Since the* *establishment of the EOC ......we designed and established the Situation Report (SITREP), we also strengthened communication with the disaster management focal person at the regional and district level.... this has enhanced data capturing and following up of events even at local level ....".* These comments were echoed by the Centre for Research on the Epidemiology of Disasters (CRED) who noted that the information about the occurrence and severity of disasters has greatly improved, with an upswing in data reported to CRED, encouraged by increasing international cooperation on disaster risk reduction, a growing number of national disaster loss databases and efforts to accelerate implementation of the Sendai Framework (CRED, 2018).

Rainfall Data

Daily mean rainfall from the Climate Hazards Group InfraRed Precipitation v2.0 (CHIRPS) dataset has been used to analyze rainfall over the country. CHIRPS is a processed gridded rainfall product at 0.05° x 0.05° resolution, comprising of satellite retrievals and *in-situ* station data (Funk et al., 2015). An area-weighted mean was taken over a box with the bounds between 11.77°S−1.01°S and 29.34°E−40.62°E for the years 2000–2019. The CHIRPS data are used as it has higher skill, low or no bias, and lower random errors in Tanzania compared to other operational satellite data such as the African Rainfall Climatology version 2 (ARC2) and the Tropical Applications of Meteorology using Satellite data (TAMSAT) (Dinku et al., 2018).

RESULTS

This section is divided into two parts based on the two main research questions of this study. The first part presents the analysis of secondary disaster and rainfall data which explain the characteristics of weather-related disasters, their socioeconomic impacts to the community and the livelihood and how these events correlates with rainfall. The second part looks at the available weather information and develops a set of guidelines to support the greater use of weather and climate information for Disaster Risk Reduction.

What Are the Spatial Distributions and Socioeconomic Impacts of Weather-Related Disasters in Tanzania?

A total of 498 disasters were recorded in the disaster profile from the PMO-DMD between 1872 and 2019, of which 363 occurred between 2000 and 2019 while 135 occurred between 1872 and 1999 (**Figure 1**). Weather-related disasters accounted for 250 (69%) of the 363 observed disasters in Tanzania. The period of 2000–2019 has a similar distribution of disaster type as the whole period 1872–1999 (**Figure 1**). Flooding is the most frequently occurring event, contributing ∼35% to all-natural disasters affecting Tanzania in both periods. Strong winds and drought contributed to 8.1%, and 4.4% of the total disasters, respectively, during the 2000–2019 period. With respect to events that are frequently associated with severe weather (directly or indirectly), epidemics, and marine accidents accounted for 21.2 and 16.2%, respectively, of all-natural disasters within the last 20 years (**Figure 1**). Weather impacts are viewed as a causal factor in a number of epidemics including cholera, dengue, and plague (Chersich et al., 2018; Fadda, 2020), while severe weather events and poor attention to weather conditions are among the factors contributing to marine accidents (Pike et al., 2013; Oluseye and Ogunseye, 2016).

There is a relatively high rate of occurrence of flood events over the northeastern part of the country, especially the coastal areas (**Figure 2**). A number of flood events are also observed in the Lake Victoria basin, north-eastern highlands and the central parts of Tanzania. Droughts are more prevalent over Arusha, Mara, Shinyanga, Dodoma, Tanga, and Lindi regions. Strong winds are reported to affect the coast areas of the Indian Ocean Dar es Salaam, Pwani, and Mafia Island; Lake Tanganyika, Rukwa, Njombe, Ruvuma, Mtwara; Dodoma; and the Lake Victoria basin; Mara, Mwanza, and Kagera regions (**Figure 2**). Coastal areas of the Indian Ocean have a higher number of strong wind events and are disproportionately affected by most types of disasters. This is due to a combination of various factors such as higher population density, poor infrastructure, urban development in risk-prone locations, land use changes, and poverty (CRED, 2018; Anande and Luhunga, 2019). In addition, Dar es Salaam and Zanzibar are developed business and political hubs, where reporting may be more comprehensive. Events of heavy rainfall are more frequent Dar es Salaam, Pwani, Mtwara, Mara, Mwanza, Kagera, and Singida regions. There also reports at Lindi, Shinyanga, Geita, Rukwa, Kigoma, Tabora, Dodoma, and Kilimanjaro regions (**Figure 2**). Landslides were reported over Kilimanjaro and Mwanza while few cases of lightning strikes were reported over Rukwa, Geita, and Kaskazini Unguja (Zanzibar Island). High number of epidemics (mostly cholera) were reported over Zanzibar Island and Kilimanjaro regions. Marine accidents were reported over Zanzibar Island with one case over Mwanza (Lake Victoria). This analysis provides important information in improving weather and climate forecast communications, it feeds onto vulnerability and exposures of particular regions and thus the communities. Other disasters (such as road accidents, urban and bush fire, building collapses, earthquakes, oil explosions, volcano eruptions) are more frequent in the regions of Lindi and Zanzibar Island. There also reports at the remaining parts of the country except over Tabora, Kigoma, Rukwa, Njombe, Ruvuma, Tanga, Shinyanga, and Mtwara regions.

Damage to property is one of the major causes of tangible loss due to weather-related disasters. During the 20-year period from 2000 to 2019, weather-related disasters destroyed or damaged more than 35,730 houses, affected 25,460 households and caused 450 deaths and 240 injuries. **Figure 3B** shows the total annual recorded number of people affected and the number of houses damaged and destroyed and **Figure 3A** shows the total annual number of injuries and deaths from weather-related disasters. The impact of the reported events on property and people increased in 2018 and 2019, which could be due to the change in reporting methodology in June 2018.

Apart from the direct impacts observed in **Figure 3**, communities are also impacted by indirect losses related to damage to properties, income losses linked to resultant

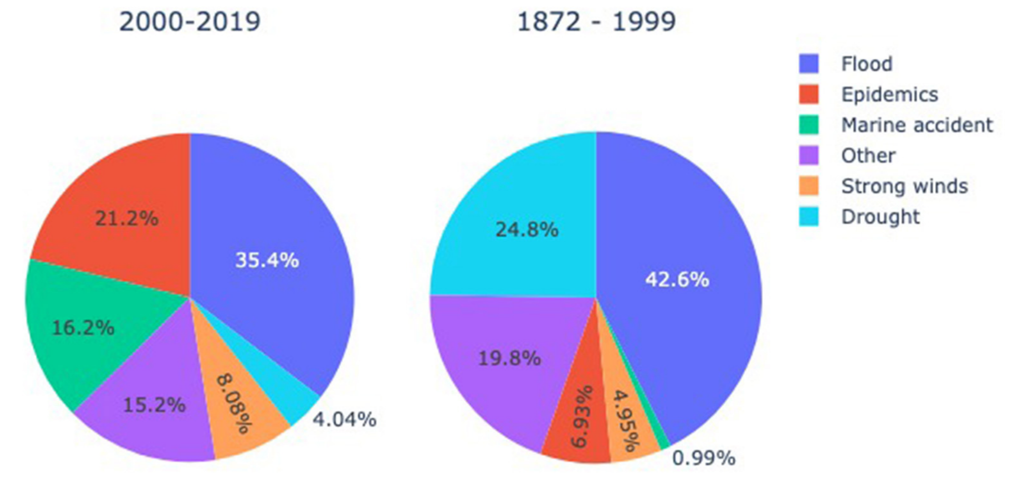

FIGURE 1 | Classification of weather-related and other non-meteorological disasters in Tanzania for the period of 2000–2019 and 1872–1999.

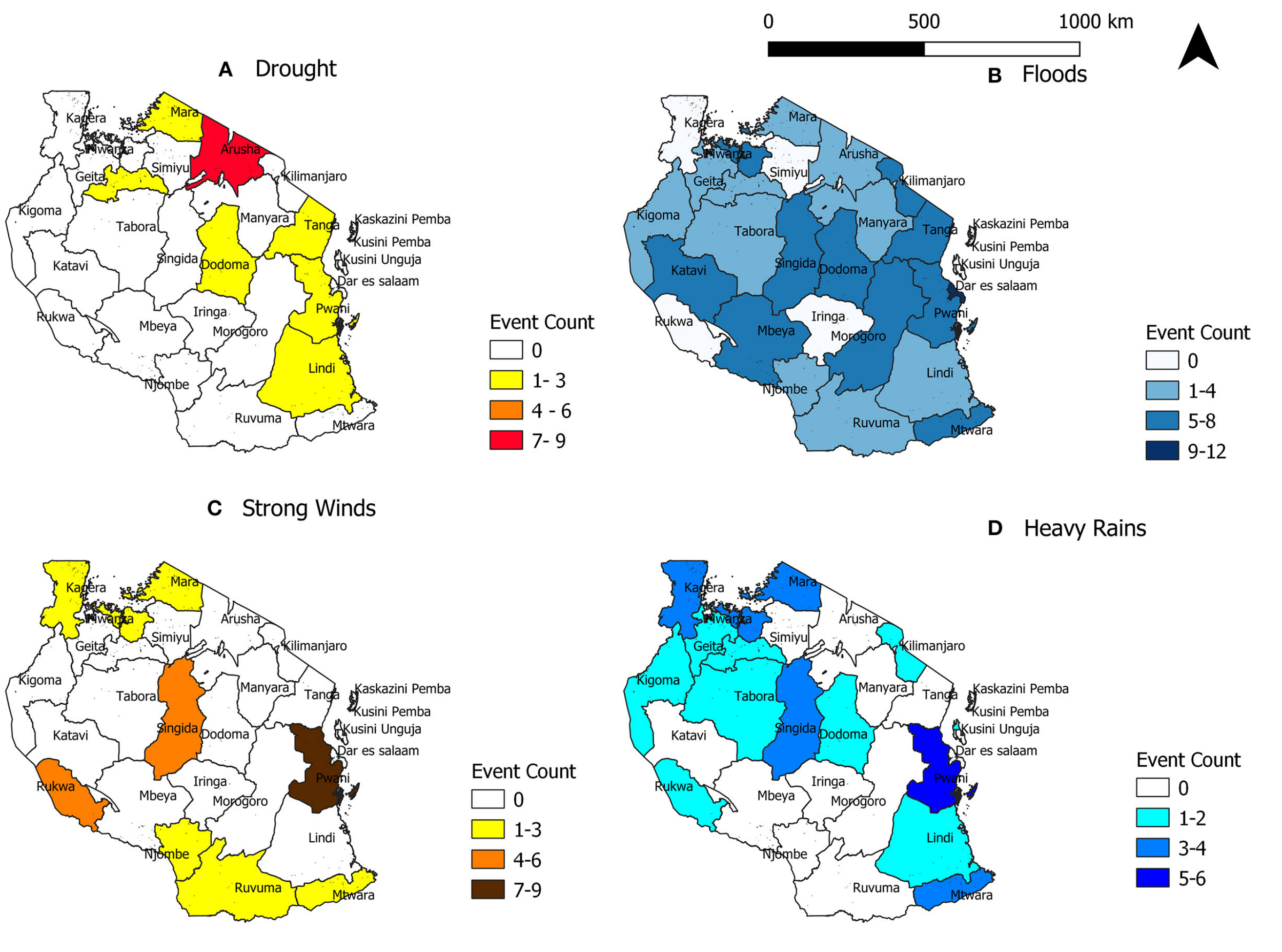

FIGURE 2 | Distribution of weather-related disasters events (drought, floods strong wind, and heavy rainfall) in Tanzania (2000–2019).

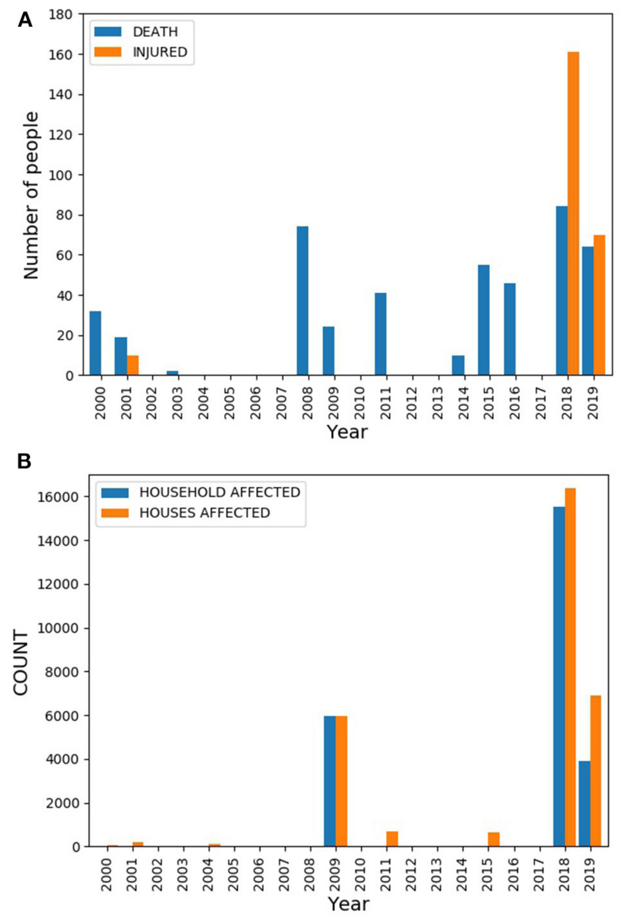

FIGURE 3 | (A) The annual number of deaths and injuries and **(B)** the annual number of people affected and houses destroyed and damaged by weather-related disasters.

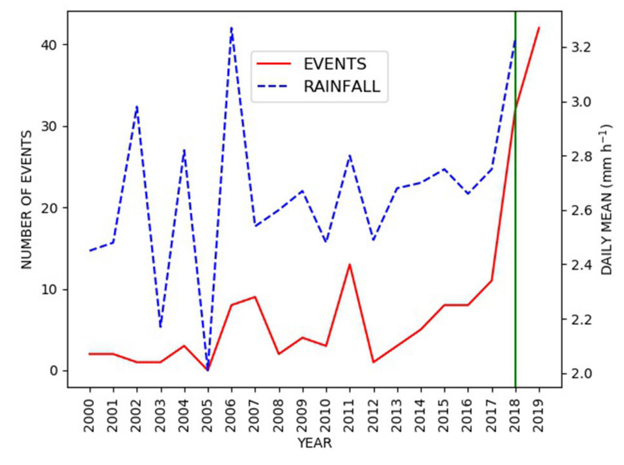

FIGURE 4 | Annual number of severe weather disaster events and mean annual rainfall over Tanzania from 2000 to 2019. The green line indicates the start of improvement in data capturing system at the DMD-PMO.

unemployment and disrupted provision of essential services. People suffer non-tangible costs such as physical, emotional, and psychological health problems, which can be challenging to measure or assign a monetary value (Chersich et al., 2018). Weather-related disasters affect way of life, culture, community, political systems, environment, health, and wellbeing (World Health Organization, 2020). Communities are forced to relocate to safer areas, which disrupts their day-to-day lives, personal and property rights and their fears and aspirations. For example, the 2011/2012 floods in Dar es Salaam left about 10,000 people homeless and the government allocated them a new location on the outskirts of the city (Anande and Luhunga, 2019).

The dataset also indicates that weather-related disasters destroyed more than 1,080 public infrastructures (bridges and railways, hospitals, schools, and roads) during the period of 2000–2019. Disruptions in the transportation system affects the functioning of socioeconomic activities, access to work places, social services and markets. Furthermore, many transport facilities and other public infrastructure are exposed and vulnerable to weather-related hazards such as floods, strong winds and heavy rains (Koks et al., 2019). More than 24,620 acres of farms for various crops were destroyed and 4,860 domestic animals (goat, sheep, cattle, donkey, chicken, and ducks) killed. These have negative impacts on food production, availability and prices thus putting many people at risk of malnutrition and increased illness due to poor health (World Health Organization, 2019). They further affect the food quality and safety; increase risks of outbreaks of animal and crop diseases and pests (Richardson et al., 2018; World Health Organization, 2019).

Figure 4 shows the total annual number of weather-related disasters and the mean annual rainfall over Tanzania from 2000 to 2019. The number of disasters is variable between 2000 and 2012, but then gradually increases from 2013 onwards, until sharp increases were recorded in 2018 and 2019 (**Figure 4**). There is a statistically significant correlation between the annual mean rainfall over Tanzania and the number of events over all 20 years (Spearman's rho $= 0.7$, $p < 0.05$) The high correlation shows that seasonal forecasts, which provide predictions of seasonal or monthly mean rainfall predictions but not extremes, could provide advance warning of periods with a large number of disasters.

The clear peak in event numbers in 2018 and 2019 could be due to the change in reporting methodology. Even with 2018 and 2019 removed, the correlation is still strong (Spearman's rho $=$ 0.54, $p < 0.05$), suggesting that in years with more rainfall, there is a higher likelihood of a large number of weather-related disasters. It is not possible to determine how much of the peak in events in 2018 and 2019 is due to changes in reporting and how much is due to the high rainfall levels recorded in these years (TMA, 2019). Tropical cyclone and sea surface temperature evolution over the Indian Ocean basin was associated with the observed above normal rainfall in 2018. Five tropical cyclones occurred over the South-Western Indian Ocean in 2018 and enhanced westerly winds, which dragged abundant moisture from the Congo forest over much part of the county (TMA, 2019). Other

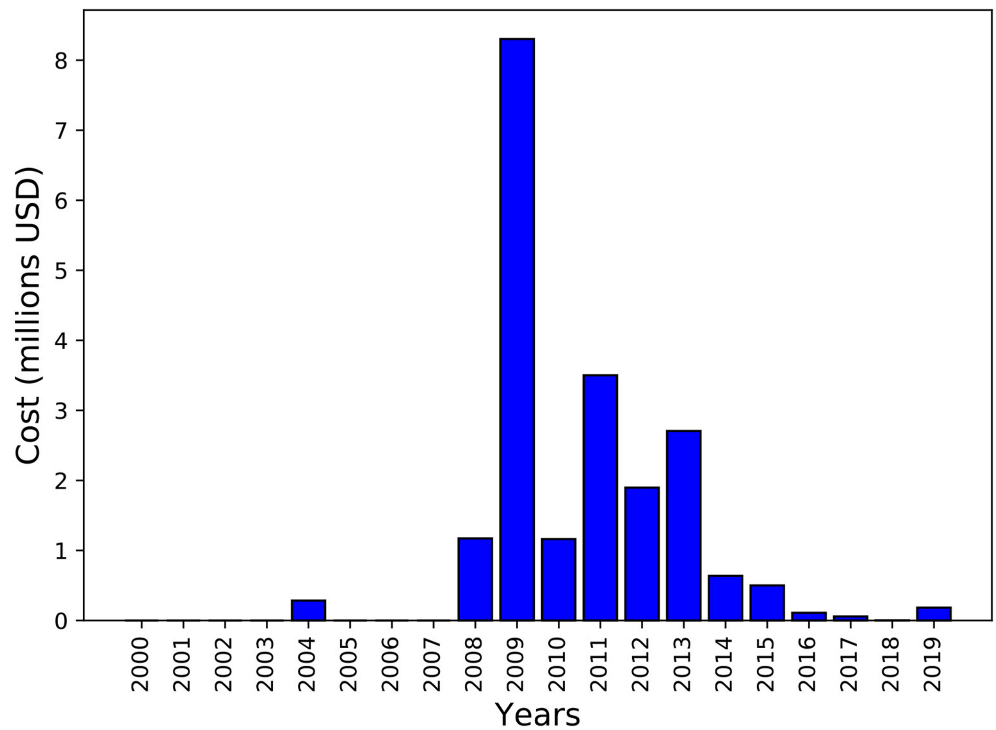

FIGURE 5 | The recorded annual amount of money spent in response to weather-related disasters.

climatic systems such ITCZ and the Near Equatorial were also associated with the observed enhanced heavy rains.

In 2019 the national mean annual rainfall was 1283.5 mm, which is equal to 125% of the long-term (1981–2010) average (TMA, 2020). The OND 2019 rainy season received above normal rainfall and is the second wettest OND on record since 1970 and October 2019 was the wettest October ever since 1970 (TMA, 2020). The heavy rainfalls were a result of positive ENSO conditions (El Niño) and Indian Ocean Dipole, Tropical Cyclone Idai deflected moist winds away from the country whereas Tropical Cyclones Desmund, Eketsang, and Kenneth induced westerly winds that dragged moisture from the Congo basin toward the country.

The government spent 25.9 billion Tanzania shillings (20.5 million USD) in response to weather-related disasters between 2000 and 2019. The annual expenditure for weather- related disasters shows no consistency across and between years (**Figure 5**) and there was no information on how much the government spent in the years 2000–2002, 2004, and 2005–2007, even though the country recorded weather-related disasters in these years (**Figure 4**). The data indicate the government provided food and non-food items, however, there was no cost attached.

Much of the cost was in 2009, which was an El Niño year, generally associated with enhanced rainfall conditions in the country (NWS, 2020). However, there is no significant peak in mean rainfall over the whole year and whole country in 2009 in **Figure 4**. The government used the money in 2009 to respond to the impacts of heavy events that resulted in floods in the Kilosa district in Morogoro region and landslides in the same district in Kilimanjaro region and for a widespread drought event in Arusha, Dodoma, Kilimanjaro, Iringa, Kagera, Lindi, and Mara regions. A total amount of 16.4 billion Tanzania Shillings (8.3 million USD) was used for the provision of humanitarian assistance for the affected population and construction of damaged infrastructure (**Figure 5**). From 2016 onwards relatively, little money has been spent, even though the number of reported events and damaged has remained constant or increased (**Figure 5**). This could be due to the increased availability of warnings and advisories (**Figures 6**, **7**), which have been issued since 2012, although further research is required to evaluate this.

The data in **Figure 5** does not reflect the cost of responding to the secondary impacts of heavy rains, floods and drought such as disease outbreaks. It has been noted that the majority of disaster reports contain no economic data and loss inequality between low and high incomes countries is much larger than reported due to a systematic under-reporting by low income countries (CRED, 2018). A disaster expert from the DMD office noted that, "*there has been less spending in humanitarian assistance in recent years [2016-2019] because most of the affected population from the past events were relocated to safer areas and in recent years the department improved its disaster reporting system so even small-scale disasters, which require no central government interventions are reported. The expenditures are mostly on public infrastructure such as roads, bridges, hospitals and others*."

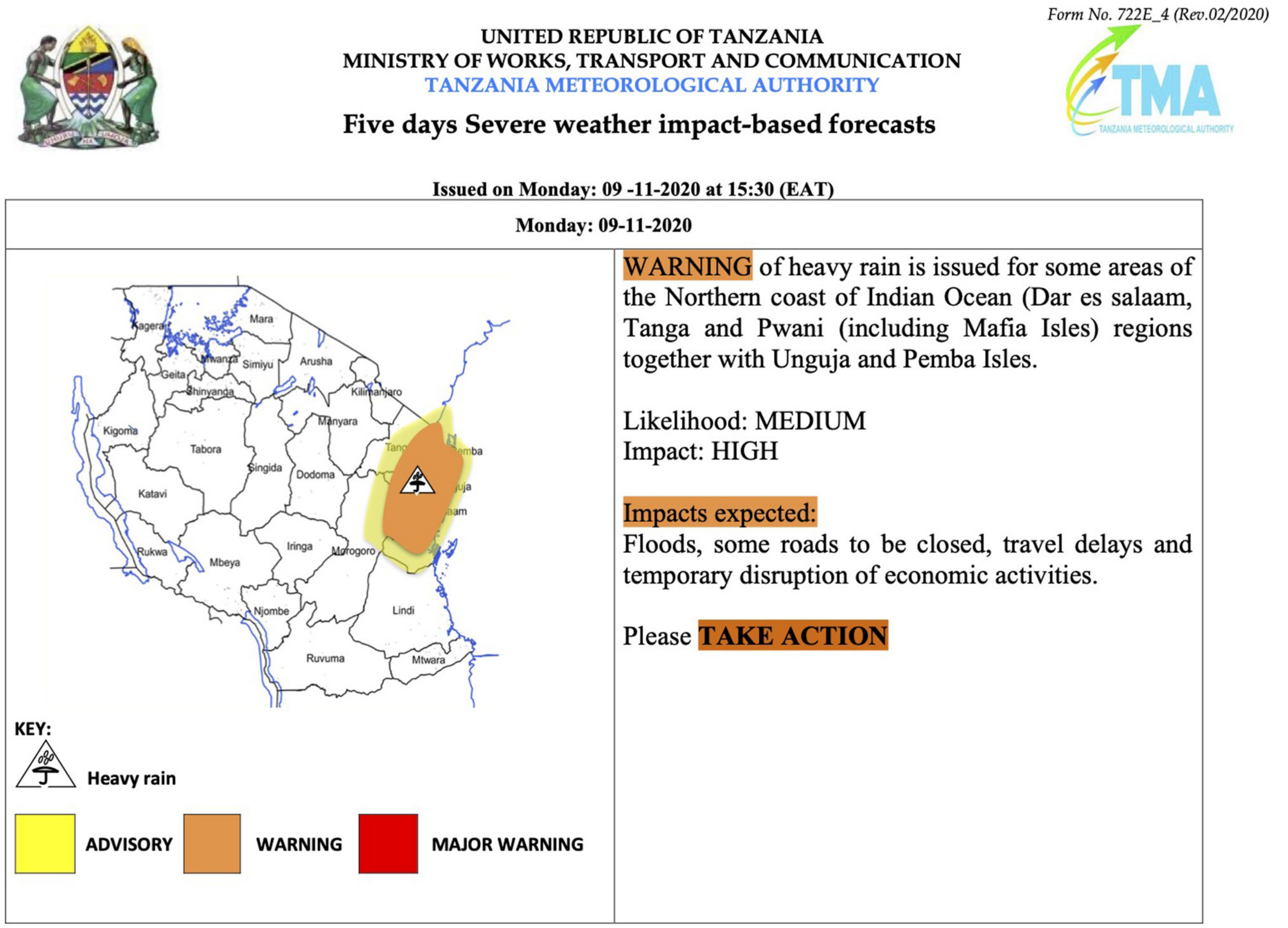

FIGURE 6 | An example of day 1 of a TMA severe weather impact-based forecast (Forecasting Division, TMA).

The amount spent on weather-related disasters including drought is about 0.04% of the Tanzania annual GDP for 2018 (WB, 2020). For example, in a study conducted by Anande and Luhunga (2019) on the assessment of socio-economic impacts of the December 2011 flood event in Dar es Salaam showed that flood events damaged properties worth 7.5 million Tanzania shillings and Tanzania Government spent a total of 1.83 billion Tanzanian shillings to rescue and relocate vulnerable communities to safer locations (high ground). These findings not only provide insight on how weather-related disasters are characterized and their cost but also calls for measures to build or strengthen community resilience to weather-related disasters.

What Is Required to Reduce the Impacts of Weather-Related Disasters?

To address this research question, we looked at the available guidelines that enables the use of weather and climate services to reduce the impacts of weather-related disasters. We found that TMA as the authoritative source of weather and climate services uses the transport sector policy from the parent ministry (Ministry of Works, Transport, and Communications) as its main framing. This policy does not provide explicit directives/guidelines on the production of weather and climate services and application to climate sensitive sectors or for Disaster Risk Reduction explicitly. Its main emphasis is on marine services to use weather information (URT, 2003). However, TMA also implements regional and global initiatives which aim to improve integration of weather and climate services into cross-sectoral planning, policy, and practice. These include the ClimDev-Africa, Global Framework for Climate Services (GFCS), and the Integrated African Strategy on Meteorology (weather and climate services of the African Ministerial Conference on Meteorology, or AMCOMET). TMA also developed and endorsed the National Framework for Climate Services (URT, 2018). Although these national, regional, and international initiatives have been taken into consideration in the generation of weather and climate information, it is necessary for the sector to have a policy instrument that enables the uptake of weather and climate services.

Secondly, we looked at the availability of weather and climate services for disaster risk reduction sector. We found that since April 2012, the TMA has issued 5-day severe weather impact-based forecasts for strong winds, heavy rainfall, tropical

Tuesday 10-11-2020	Wednesday 11-11-2020	Thursday 12-11-2020	Friday 13-11-2020
			
ADVISORY of heavy rain is issued for some areas of the Northern coast of Indian Ocean (Dar es salaam, Morogoro, Tanga and Pwani (including Mafia Isles) and Lindi regions together with Unguja and Pemba Isles. Likelihood: MEDIUM Impact: MEDIUM **Impacts expected:** localized floods, travel delays and temporary disruption of economic activities. Please **BE PREPARED**	**ADVISORY** of heavy rain is issued for some areas of the Northern coast of Indian Ocean (Dar es salaam, Morogoro, Tanga and Pwani (including Mafia Isles) and Lindi regions together with Unguja Isle. Likelihood: MEDIUM Impact: MEDIUM **Impacts expected:** localized floods, travel delays and temporary disruption of economic activities. Please **BE PREPARED**	NO WARNING	NO WARNING

FIGURE 7 | An example of day 2–5 of the TMA severe weather impact-based forecast, indicating warning of heavy rain on day 2, advisories on day 3 and 4 and no warning on day 5 (Forecasting Division, TMA).

cyclones, extreme temperatures, and high waves (**Figures 6**, **7**). The forecasts use predefined action statements, with four levels of warning: gray for no warning, yellow and amber for an advisory (be prepared and take precautions) and red for a major warning (take action). Weather advisories inform the public about the progress of a potentially dangerous weather condition while the warnings alert the public that a weather-related hazard is imminent and that immediate action should be taken to protect lives and property (WMO, 2015; Taylor et al., 2019). The forecast has a lead time of 1–5 days and includes symbols to aid visualization of expected hazards. It also has action statements with specific guidance about action to be taken, likelihood, and local impact severity. TMA also provides seasonal weather forecast with advisory to climate sensitive sectors (TMA;WAMIS, 2018).

Although this information is widely disseminated across Tanzania, the country continues to suffer disproportionally from the impact of weather-related hazards. The understanding of decision-making processes, specifically focused on how and when various types of weather and climate information are incorporated in decision making process is key to disaster risk reduction. Early warning information is a key factor in enhancing disaster preparedness for effective responses and disaster risk reduction measures (Lopez et al., 2020). Lack of policy may hinder advances or cause barriers to the identification of user needs, use of weather and climate information in decision making and impacts of climate change adaptation initiatives and climate-resilient development planning (Vincent et al., 2017). As recent research suggested that a changing climate is likely to lead to an increase in heavy rains in Tanzania (Chang'a et al., 2017) this is important information for providers of weather and climate services, as well as the disaster risk management sector. Having a sector policy will allow the use of short-term and long-term precipitation forecasts for planning, strengthen community preparedness, and implementation of actions to reduce risks during the years when enhanced rainfall is expected. These findings are important in improving the transport sector policy on enhancing the use of weather and climate services to the widest range of users.

CONCLUSION AND RECOMMENDATIONS

This paper uses disaster data from the Tanzanian Government's Disaster Management Department office to assess the cost and impacts of weather-related disasters in Tanzania from 2000 to 2019. The findings show that Tanzania continues to suffer from the impacts of severe weather events, causing injuries and deaths of people and livestock, infrastructure damage, loss of crops, and arable land for farming despite the availability of warnings for potential weather hazards. The observed association between observed rainfall and the total number of weather-related disaster events provides an opportunity for guiding decision-makers in terms of setting out mitigation measures for disaster risk reduction and preparedness planning. It also provides inputs to policy makers so set out priorities and mechanisms to attain the Sendai Seven Campaign which aims in lowering the mortality, reduce the number of people affected and direct disaster economic loss in relation to the GDP by 2030.

The current lack of an explicit meteorological policy (as found in many other African countries) limits the application and setting of priorities in wider range of use and implementation of various initiatives in climate sensitive sectors. This highlights the importance of: (i) Policy review to enhance uptake of weather and climate information to climate sensitive sectors. (ii) Assessing the entire chain of forecast generation, from an evaluation of the accuracy of the forecasts to how the end-user utilizes the forecasts for decision making. (iii) Investigating the value of the severe weather impact-based forecasts for decision making. (iv) Finding out how weather information is being used; whether the right information is being provided at each step; how much damage could be prevented with improved warning systems; how the information add value to decision-making; how weather hazards and vulnerability issues are incorporated in the warning issued to the public and other actors is key to the decision-makers, and (v) understanding the value of severe weather forecasts which are normally forecasted at a shorter time scale (1–5 days). The above needs will help to reduce the impacts of weather-related hazards will feed into the policy review process, broadens application of weather and climate services as well as setting out actions and plans at national and sub-national levels for enhancing decision making in disaster risk reduction.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

HEM collected and analyzed all the data and wrote the first draft of the paper. ALT, CEB, AJD, AH, and BJW commented on the methodology and study design. All authors have significance contributions to the manuscript.

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