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The Value of Weather and Climate Information to the Tanzanian Disaster Risk Reduction Sector Using Nonmonetary Approaches

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ABSTRACT: This paper investigates the value of weather and climate information at different time scales for decision-making in the Tanzanian disaster risk reduction sector using nonmonetary approaches. Interviews and surveys were conducted with institutions responsible for disaster management at national, regional, and district levels. A range of values were identified, including 1) making informed decisions for disaster-preparedness-, response-, recovery-, and restoration-related activities; 2) tailoring of directives and actions based on sectoral impacts; and 3) identification of hot-spot areas for diseases outbreaks and surplus food production. However, while a number of guidelines, policies, acts, and regulations for disaster risk reduction exist, it is not clear how well they promote the use of weather and climate information across climate-sensitive sectors. Nonetheless, we find that well-structured disaster risk reduction coordination across sectors and institutions from the national to the district level exists, although there is a need for further development of integrated early warning systems and a common platform to evaluate effectiveness and usefulness of weather warnings and advisories. Key challenges to address in increasing the uptake of weather warnings and advisories include language barriers, limited dissemination to rural areas, and limited awareness of forecasts. From the findings of this study, we recommend further quantitative evaluation of the skill of the severe weather warnings issued by the Tanzania Meteorological Authority and an assessment of how decisions and actions are made by recipients of the warnings in the disaster risk reduction sector at different stages in the warning, response, and recovery process.

SIGNIFICANCE STATEMENT: Information about weather and climate information is important in making informed decisions to reduce socioeconomic losses due to severe weather. This study aims to understand the value of weather and climate information to the Tanzanian disaster risk reduction sector using nonmonetary approaches. We identify several values that could not be realized using the monetary approaches that assist in making effective and informed decision-making to reduce socioeconomic losses, improve livelihoods, and build more disaster-resilient communities. However, constraints such as formatting, accessibility and uncertainty, spatial and temporal resolution, awareness and dissemination, resource availability, and limited technical skills in the interpretation of severe weather impact-based forecasts impede their uptake. Results from this study will improve the content of the severe weather impact-based forecasts and uptake across the disaster risk reduction sector in Tanzania.

KEYWORDS: Climate services; Economic value; Emergency preparedness; Policy

1. Introduction

In recent years, Tanzania has suffered from a number of weather-related disasters leading to loss of life and property and environmental destruction. These include direct weather impacts (e.g., flooding, landslides, strong winds, and droughts) and indirect impacts such as increased frequency of disease outbreaks (e.g., malaria, cholera, dengue fever) and marine accidents (Msemo et al. 2021; Anande and Luhunga 2019; Padli et al. 2018). It is therefore critical to explore how weather and climate information can better support disaster risk reduction (DRR) in Tanzania, in line with the recognized need for improved use of climate services across the continent (Carter et al. 2019; Nkiaka et al. 2019; Vincent et al. 2020). DRR, as per United Nations Disaster Risk Reduction (UNDRR), aims at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development (UNDRR 2021).

Disaster risk reduction activities in Tanzania are governed by the Disaster Management Department (DMD) at the Prime Minister's Office (PMO) in mainland Tanzania and the Disaster

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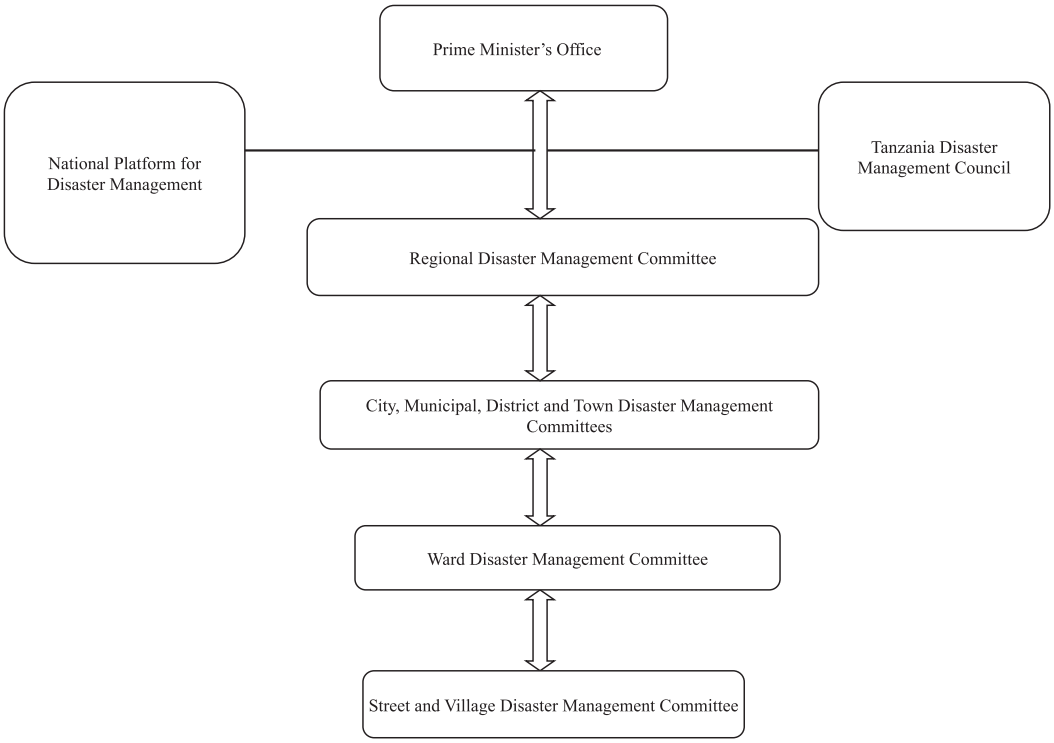

FIG. 1. DMD disaster management coordination structure. Source: Prime Minister's Office National Disaster Risk Reduction Strategy (2020–25) document.

Management Commission (DMC) under the second Vice President Office (VPO) in Zanzibar. Both the DMD and DMC work with nonstate actors from UN agencies, nongovernment organizations (NGOs), community-based organizations, the private sector, and volunteers. Roles for these actors are described in the National Disaster Management Policy of 2004 and National Operational Guidelines for Disaster Management of 2003. Roles for the DMC are stipulated in the Zanzibar Disaster Policy Management Policy and Zanzibar Disaster Communication Strategy both of 2011.

Both the DMD and DMC have national- and local-level disaster management committees (Fig. 1), appointed according to institution policy. At the national level, committees comprise permanent secretaries from government ministries and heads of institutions/organizations (as per disaster policy and act). Within each ministry, institution, region, and district there is a disaster management focal person, often referred to as a disaster focal person or disaster expert. Disaster focal persons at the ministry and institutional level form the National Disaster Platform, which provides expert advice to the national disaster management committee. Before and during severe weather events, focal persons receive weather and climate information with directives on actions to be taken from the DMD and DMC. Both the DMD and DMC have disaster communication strategies that stipulate how information should be communicated before, during and after the event. These strategies recognize and stipulate the mandate of the Tanzania Meteorological Authority (TMA), the official provider of weather and climate information in Tanzania, as an authoritative source of severe weather forecasts.

Weather and climate information, including severe weather forecasts, are provided by TMA at a range of time scales (Table 1) to the general public and other stakeholders including media, government departments and agencies, aviation, agriculture, water resource management, disaster management, health, defense, academic and research institutions, the construction industry, and other private-sector organizations.

Impact-based forecasts are issued when severe weather is expected. These are categorized as advisories, warnings, and major warnings, depending on the likelihood and the potential impact of the event. They are issued up to 5 days in advance for strong winds, heavy rainfall, tropical cyclones, extreme temperatures, and high waves. They are disseminated to both the general public and institutions responsible for disaster management in the United Republic of Tanzania (Msemo et al. 2021). Forecasts are presented using maps of affected areas, with symbols to aid visualization of expected hazards and specific guidance about action to be taken (Msemo et al. 2021; Met Office and TMA 2018).

Despite the provision of these forecasts Tanzania continues to suffer from the impacts of weather-related disasters (Msemo et al. 2021). There is therefore a need to better understand the value of weather and climate information and how this information is used by disaster experts at a national (government departments and institutions) and subnational level (region and districts).

The concept of value varies across disciplines. Value is realized by utilizing the information to improve operational and

TABLE 1. TMA weather and climate time scale (TMA 2019).

Type	Time scale	Products
Short-range forecasts	0–72 h	24-h weather forecasts (daily weather forecast); 12-h marine forecasts (issued two times per day); advisory and warnings
Severe weather impact–based forecasts	1–5 days	Advisories and warnings issued in the event of severe weather
Medium-range weather forecasts	72 h–30 days	10-day forecast (issued in every 10 days); monthly outlook
Long-range forecasts	30 days–3 months	Seasonal outlook

management processes such as planning monitoring that reduce cost and increase revenue (Williams and Williams 2007). Where information is used for decision-making, its usefulness or utilization is an important benchmark for its value (Williams and Williams 2007; Singh et al. 2016). In DRR, one may therefore take the value of information to be its usefulness in supporting decision-making for reducing harm from severe weather events and building resilience within communities at risk.

Several studies have assessed the value of weather and climate information. However, most have focused on the value of seasonal forecasts for climate-sensitive sectors such as agriculture (Bruno Soares et al. 2018) and were mainly conducted in developed countries. There has been little investigation of the value of forecasts at shorter weather time scales (1–5 days' lead time). Previously studies have mostly used monetary approaches such as the willingness to pay, cost–loss ratios, and avoided costs (Katz and Lazo 2012; Bruno Soares et al. 2018; Ouédraogo et al. 2018). However, these cannot capture nonmonetary values of weather and climate information in decision-making. Furthermore, many studies have not focused on specific decisions taken by those using weather and climate information or have used hypothetical decision scenarios (Bruno Soares et al. 2018). Consequently, much of the value of weather forecasting services may not be directly observable in the market. As weather services are provided freely to the general public, media houses, disaster management authorities, and other relevant responders—with few users having a budget to purchase weather and climate information services—the value of this information may not be realized through monetary measures such as willingness to pay. This highlights a need for alternative approaches to evaluating and realizing the value of weather and climate information in disaster risk reduction.

This paper investigates the value of weather and climate information for DRR decision-making using nonmonetary valuation approaches and addresses the following research questions:

1) How is weather and climate information currently obtained and used in decision-making in the disaster risk reduction sector in Tanzania?
2) Do policy documents exist that can assist the use of weather and climate information in decision-making?
3) What factors hinder uptake of weather and climate information in the Tanzanian disaster risk reduction sector?
4) How could providers better engage with users of weather and climate information in the disaster risk reduction sector in Tanzania?
5) What are the causes of weather-related socioeconomic losses in Tanzania?

2. Research design and methods

This research uses both qualitative and quantitative approaches to evaluate the current value of weather and climate information for decision-making within the Tanzanian DRR sector. Semistructured interviews and online surveys were undertaken between July and December 2019 with disaster focal persons in Tanzania. Sampling was initially purposive, starting with contacts in the DMD and the DMC. Government procedures, protocol, and guidelines to collect data and information were adhered to. A research permit was obtained, and official communication was made to disaster focal persons at the ministry, regions, districts, and the Tanzania Red Cross Society (TRCS) on the intent of the research and their participation in the interview and the survey. While the lead author's previous role within TMA and experience of interacting with relevant government department was critical in gaining permission to conduct the research and accessing relevant, it must be acknowledged that participants' awareness that the lead author previously worked with TMA may have had an unintended influence on some aspects of the participants' responses. Both the interviews and the survey sought to capture the value of weather information in terms of its usefulness and fitness for purpose in supporting DRR decision-making. Similar questions were used in surveys and interviews to enable comparison and assess consistency.

a. Key informant interviews

1) DESCRIPTION OF THE PROCEDURE AND PROTOCOL

Twenty-four semistructured interviews were conducted: 20 with disaster focal persons within government departments and institutions and 4 from the TRCS, which is an auxiliary to the government. The government departments and institutions included health, agriculture, disaster management, environment, transport, food reserves, cereal produce, and planning. Informed consent was obtained from each participant using an information sheet and verbal checklist, ensuring awareness of the study's aims, how data would be used, and that they were free to stop participating at any time during the interview. Interviews were conducted in English or Swahili, depending on the interviewee's preference. Interviews were recorded and later transcribed for analysis. In most cases the interview duration was approximately 1 h. Once transcribed, meaningful patterns (themes) were analyzed and identified using thematic analysis.

2) INTERVIEW PROTOCOL

The interview protocol explored the following topics: (i) the different sources of weather and climate information used to

inform different types of organizational activities, decisions, and planning; (ii) the frequency with which these are accessed and used; (iii) how losses and damage associated with weather and climate events are determined and the key institutions involved in this; (iv) the factors contributing to the socioeconomic losses due to the weather-and climate-related hazards; (v) institution budgets for disaster management activities and constraints in the use of weather and climate information for decision-making; (vi) views on charging for weather and climate information and what the implications of this might be; and (vii) opportunities for evaluating the information. The content of the interview protocol is found in the online supplemental material (first document).

b. Online survey

1) DESCRIPTION OF THE PROCEDURE AND PROTOCOL

Two hundred disaster focal persons from government department/institutions, regions, and districts were identified through discussion with disaster experts at the DMD and DMC and invited via email to take part in the survey. A response rate of 31% was achieved (62 of 200). The survey items were predominantly closed ended, although open-ended questions were included to give participants opportunity to elaborate. The open-ended questions were analyzed using thematic approaches (Kiger and Varpio 2020).

2) MEASURES

Survey questions were organized around the following areas (the content of the actual online survey can be found in the online supplemental material as the second document):

(i) Organizational and weather context

Respondents were asked about their institution/organization's role in DRR; the sources, types, and frequency of use of weather and/or climate information for decision-making and how the information is obtained; and available guidelines for integrating weather and climate information to the institution plans or policies. They identified the types of severe weather that affected their activities and the nature of these affects.

(ii) Current forecast use

Respondents were asked whether their organization currently uses weather and/or climate information to support decision-making (yes and no). Current users were asked about the types of decisions supported, and the role of weather and climate information in intuitional planning. Those responding "no" were asked why they were not used.

(iii) Losses associated with weather events

Respondents were asked how losses and damage associated with weather and climate events are determined in their sector; the key institutions involved and institutional budget for disaster management activities; and factors contributing to the socioeconomic losses associated with weather and climate hazards.

(iv) Constraints and costs

Respondents were asked about barriers and constraints in the use of weather and climate information to decision-making. We also explored current costs or charges associated with using weather and climate information and views on charging for weather and climate information and what the implications of this would be for its use, including what information it would be acceptable to charge for, and who should be charged.

(v) Evaluation of weather information

We explored the institutions' participation in the evaluation of weather warnings and potential mechanisms for strengthening the evaluation of weather warning and advisories. The evaluation aimed to understand how forecast products available to the DRR sector contribute to existing service delivery, including the extent to which warnings and advisories support decision-making related to limiting the impacts of severe weather events.

c. Data analysis

This research used a mixed-methods design, combining qualitative analysis of interview data open-ended survey responses, with a descriptive quantitative overview of closed-ended questions. For qualitative data, thematic analysis using inductive and deductive coding were used. Deductive elements were grounded in the research questions, literature review, the online survey, and a preliminary exploration of the interview data (Roberts et al. 2019; Kiger and Varpio 2020). The inductive approach followed the identification of meaningful themes emerging from the data, allowing for the identification of unexpected themes (Roberts et al. 2019; Nowell et al. 2017; Braun et al. 2019).The analysis was done using NVivo12. Closed-ended online survey questions were descriptively analyzed using the IBM Statistical Package for the Social Sciences (SPSS, version 26).

3. Results

a. How is weather and climate information currently obtained and used in decision-making in the disaster risk reduction sector in Tanzania?

1) SOURCE OF WEATHER AND CLIMATE INFORMATION IN USE WITH THE DRR SECTOR

Survey data show that TMA is the main source of weather and climate information within the Tanzania DRR sector (Fig. 2). However, both the survey and interviews indicate that other sources are used, such as the Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC), and the Famine Early Warning Systems Network (FEWSNET), and the World Meteorological Association (WMO), including WMO Regional Association 1 (RA1) responsible for issuing tropical cyclone warning over the southwestern Indian Ocean. "We get some information from an Agency based in La Reunion, most of the time is when there is Tropical Cyclone . . . they inform us." While there are benefits to accessing range of sources (e.g., examining a wider range of possible futures, gauging forecast uncertainty), without adequate training it may lead to confusion when different sources provide conflicting forecasts.

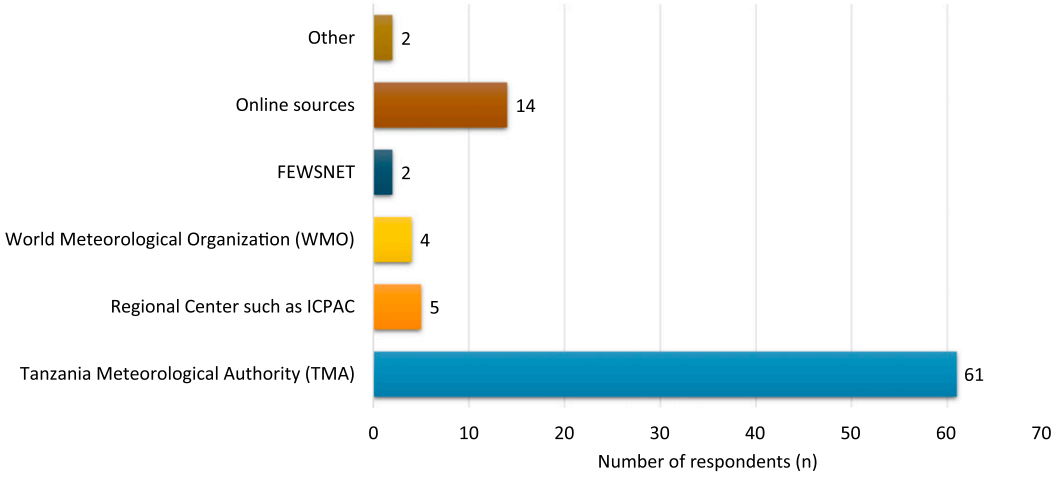

FIG. 2. Sources of weather and climate information identified by online survey respondents.

2) MOST USED WEATHER AND CLIMATE INFORMATION IN DECISION-MAKING AND WAYS IT IS OBTAINED

Survey data show that seasonal forecasts (forecasts for 1–3 months in the future) are the most widely used in institutional decision-making, followed by 1–5-day weather forecasts (including the severe weather impact-based forecasts), 10–30-day forecasts, and historical weather and climate data (e.g., historical weather observations) (Fig. 3). This information is obtained from various sources (Fig. 4) the most popular being radio and television ($n = 50$; 82%) followed by weather reports (official weather reports delivered directly to disaster focal person) ($n = 46$; 75.4%) and newspaper and press releases ($n = 35$; 57.4%).

However, some institutions use social media to both receive and further disseminate information to others. Interviewees from DMD emphasized their support for the use of social media as a means of communication, for both disseminating warnings and gathering feedback on local situations. "We have a WhatsApp group in each region, which we use to disseminate warning information and get feedback on the situation on the ground. Each group has members from the disaster management department. There are 26 groups [Tanzania Mainland]." The DMC uses the Shehia disaster management committee for disseminating information, receiving, collecting, and analyzing reports. They also produce public outreach material to highlight particular threats (e.g., through the use of short drama clips). Shehia is the lowest level of the government administrative structure and represents the community level in Zanzibar.

Survey respondents were asked to indicate whether their department/institution use weather and climate information to support decision-making. Those reporting that their organization did use weather and climate information, indicated that this information was most frequently used to support operational activities ($n = 47$; 81%), followed by planning ($n = 38$; 65.5%), resources allocation ($n = 29$; 50%), training of staff and volunteers ($n = 19$; 32.8%), and for activities ($n = 2$; 3.4%) such as directives and response measures (e.g., directing the subnational levels to take necessary preventive actions, movement from flooded areas to none flooded areas; Fig. 5). Most decisions are made when weather and climate information is received (Fig. 6).

3) FACTORS INFLUENCING DECISION-MAKING PROCESS

During the interviews, it was noted that action to be taken in response to weather warnings depends on the nature of the hazard, type of weather information and the directives attached on it. "Depending on the hazard or disaster expected, for example, if it is an outbreak of diseases . . . of human diseases we get from the Ministry of Health. If it is a livestock disease, we get from respective ministry." The DMD and DMC provide directives on action to be taken by disaster focal persons at all levels after receiving early warning information about an impending hazard with the potential to cause disaster. Interviewees noted that directives include actions and measures to be taken in response to severe weather forecasts (e.g., cleaning drainage systems, identifying of safe places to relocate people, activation of emergency operation communication centers, preparation of relief items, and alerting vulnerable communities).

The directives are disseminated through official and traditional communication channels, including letters: "The Prime Minister Office or if TMA themselves write to us." It was noted that the government repackage the weather and climate information they receive to address sector-specific impacts/concerns, which they then communicate to disaster focal persons around the country.

4) SOCIOECONOMIC BENEFITS OF WEATHER AND CLIMATE IN FORMATION TO THE DISASTER MANAGEMENT, AGRICULTURE, AND HEALTH SECTOR

During the interviews it was noted that weather and climate information plays a vital role in the relationship between the government and the public. The social and economic losses are also reduced when public take early action through government

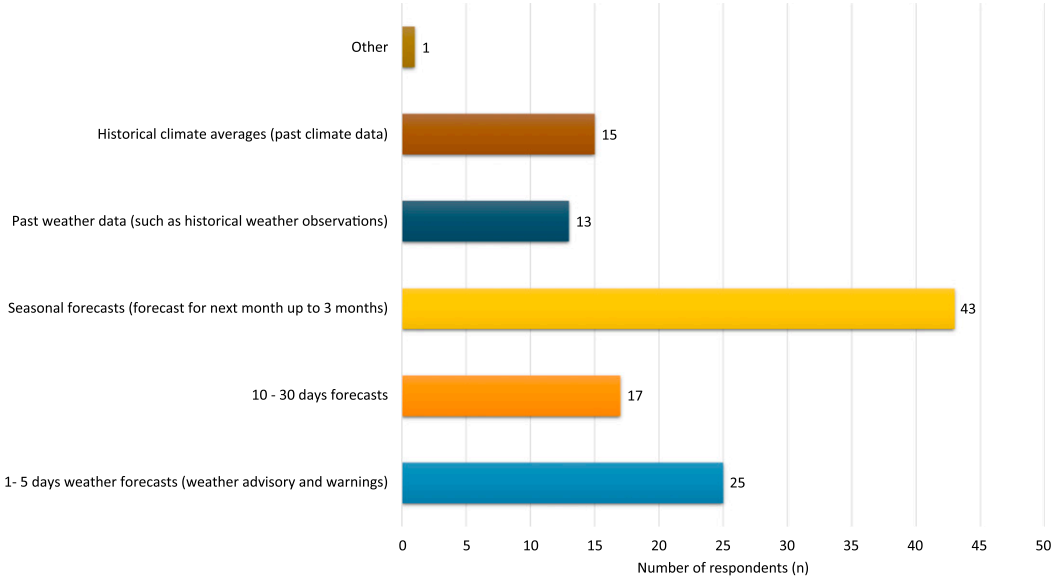

FIG. 3. Types of weather and climate information used to make decision as identified by survey respondents.

directives (e.g., people move to safer areas before a disaster occurs). Interviewees from the DMD and DMC noted that early action based on warnings and advisories may have led to a reduction in government expenditure on disaster response activities. "When it rains many people become homeless, causing the disaster commission to set up camps for the displaced community . . . we have about two years now we have not set a camp."

On the other hand, the National Food Reserves Agency (NFRA) and the Cereals and Other Produce Board of Tanzania (CPB) use the information to identify areas of surplus and reduced production of crops and incorporate the information in their operational and plan activities. The NFRA, for example, uses the information to locate camps (temporary offices) for purchasing crops in the areas with surplus production. One camp costs approximately TZS 200,000,000 for a 3-month period (equivalent to approximately USD 85,000; Oanda 2019). The NFRA further noted the risk of wrong forecasts: "So, if the information is wrong or there is an incidence of severe weather events such as flood or heavy rains it affects our plan and may lead to a big loss." The purchased food is later used by the government as relief aid to the affected communities and other countries.

The agriculture sector uses weather and climate information to inform farmers about the onset and cessation of the rains

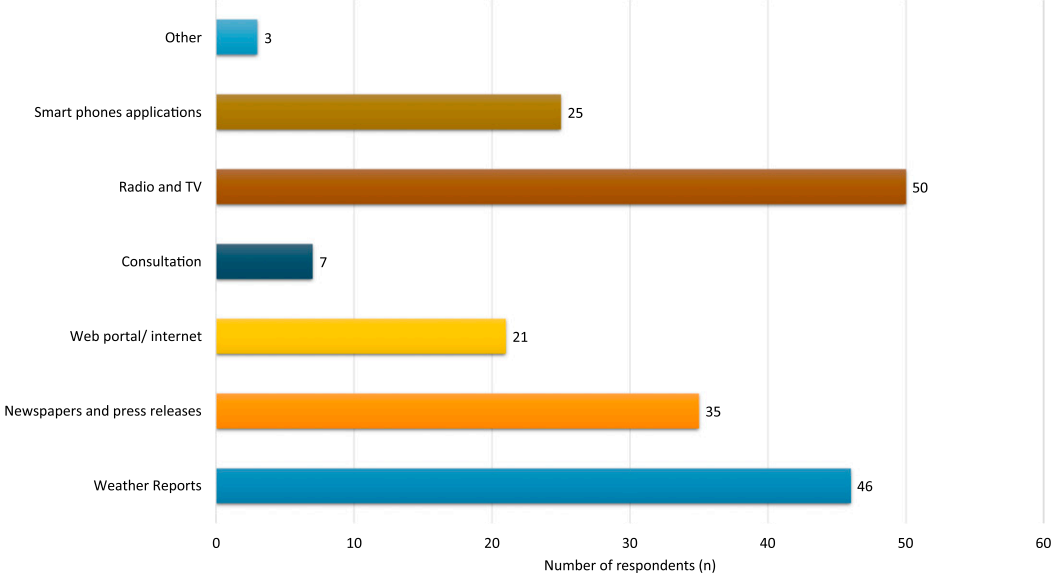

FIG. 4. How weather and climate information are obtained across the DRR sector in Tanzania.

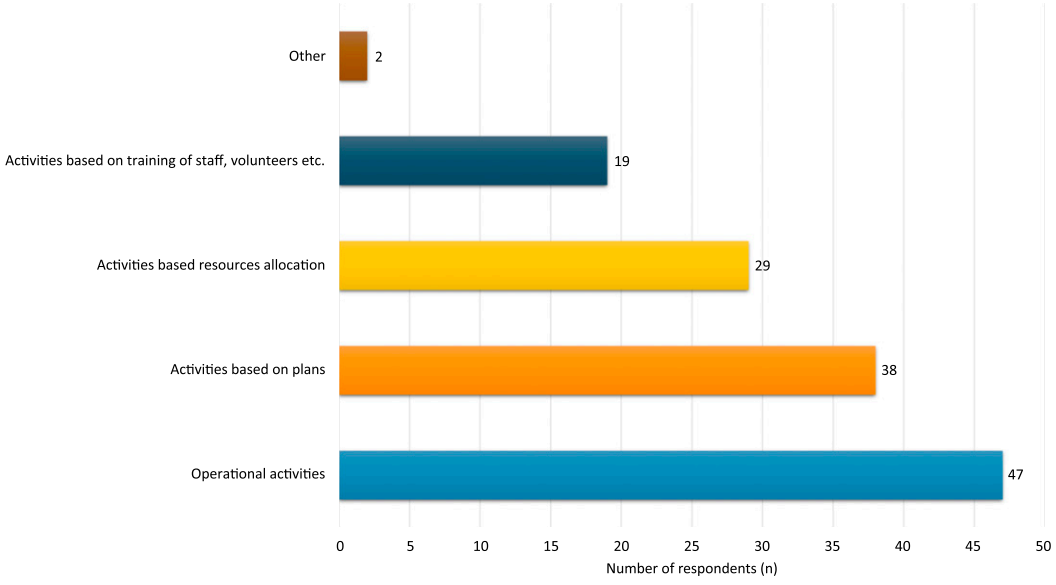

FIG. 5. Types of decisions supported by weather and climate information.

and to advise farmers on how to plan (i.e., with regard to purchasing agricultural inputs, planting, weeding, harvesting, storage, and markets). An interviewee from the Ministry of Agriculture and Food Security noted that, at the ministerial level, the information is used by the Crop Monitoring and Early Warning Unit to predict production, inform the state of food security in the country, and make plans for food security assessments: ''In food security, we use the information for food security forecast (production), conducting food assessment and post-harvest forecast.'' The report is shared with agricultural stakeholders for further action within their organizations. One interviewee indicated that they do not use weather information directly but receive a quarterly report from the Crop Monitoring and Early Warning Unit.

In the health sector, weather and climate information is used to identify hot-spot areas for disease outbreaks such as dengue, malaria, chikungunya, eye diseases, and cholera to set out intervention planning. The information is used to conduct diseases surveillance and research, training of environmental health experts, and to raise awareness within the community on practicing hygiene and use of mosquito nets. During the interviews, it was noted that needs for weather and climate information differ across units of the Ministry of Health; for instance, the Mother and Child Section will need to know how

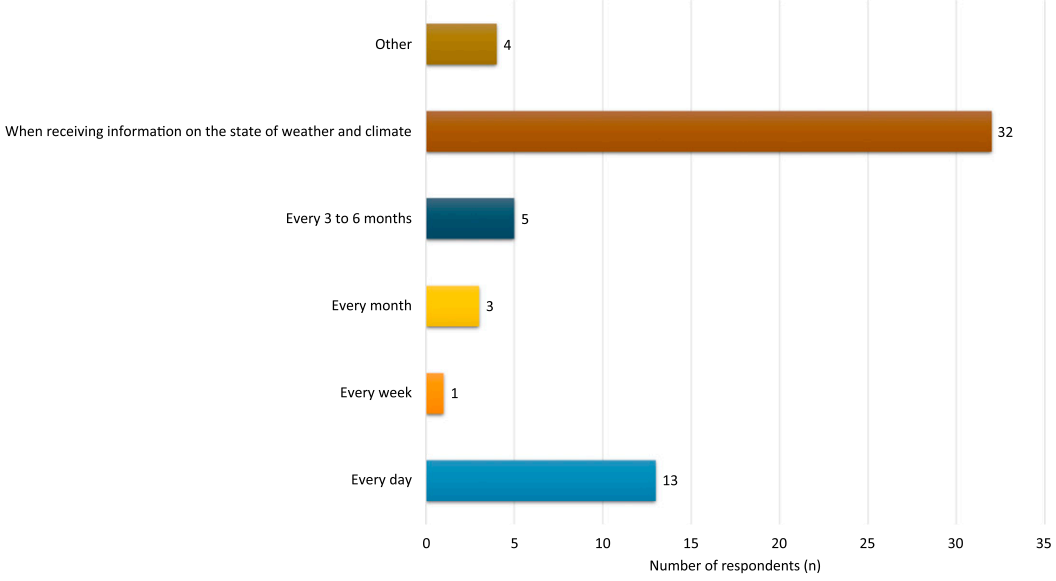

FIG. 6. Decision-making using weather and climate information at different time scales.

the expected weather condition will affect the availability of food and disease outbreaks, while the Emergency Preparedness Department will need severe weather information to anticipate direct damage to the health facilities and humans. This highlights the importance of engaging with users in climate-sensitive sectors to identify within-sector differences in climate and weather information needs, and how these can be addressed.

5) Willingness to pay for weather and climate information

In both the survey and interviews, participants were asked about charges for weather and climate information. Most survey respondents ($n = 54$; 93.1%) indicated that their institutions do not pay for weather and climate information. A small number of respondents ($n = 4$; 6.9%) indicated that they do pay for the information they get from TMA, ICPAC, WMO, and FEWSNET. TMA offers a range of weather and climate information free of charge (Table 1). It was not clear from the survey what types of information respondents pay for. However, perceived benefits of paying for weather and climate information for both users and producers that were identified include increased ownership and responsibility for the use of the information, prompting producers to increase accuracy and reliability of the services. Others are provision of an additional source of income that supports the producer organization's operations such as the maintenance of weather stations, improvement of services, procurement of modern equipment, and enhancement of the organization's performance and capacity. Several interviewees did indicate that charges should apply only for those using it for commercial purposes, construction, and consulting activities and research that "could apply for those using for commercial purpose."

Both the survey and interviews highlighted the disadvantages of paying for weather and climate information for sectors responsible for disaster risk reduction as it may limit its access and use in decision-making, resulting in an increased risk of disaster impacts including food insecurity, reduced disaster preparedness, and reduced research due to the financial constraints of individuals and institutions seeking the data. Some interviewees noted that some of the regional and district councils could find no budget to pay for such services: "we don't have even a budget for disaster, that means we cannot manage to pay."

Some interviewees indicated that charging for weather services would be detrimental to the people who are most vulnerable since they cannot afford to pay for the service. Free provision of daily weather forecasts, warnings, advisories, and seasonal forecasts for the general public and humanitarian organizations was felt to represent a critical public good in both the survey and interviews: "we save the community, and we get donations as contributions . . . information cannot be charged for by humanitarian organizations like the Red Cross."

b. Which policy documents can assist in the use of weather and climate information for decision-making?

The extent to which information can be incorporated into decision-making may depend on the regulations and guidelines in place within an organization. When asked if there were any guidelines on the use of weather and climate information in making decisions, some survey respondents ($n = 16$; 26.2%) indicated that they had guidelines, but the majority ($n = 45$; 73.8%) did not. Table 2 summarizes the specific documents identified during the interviews and survey.

It was not clear to what extent these guidelines (Table 2) actively promote the use of weather and climate information across the DRR sector. It was also not clear how they are integrated with the new Tanzania Meteorological Authority Act No. 2 of 2019, which gives TMA a mandate for management, control, provision, coordination, and regulation of meteorological services within Tanzania. While the new Act gives TMA the right to control and regulate the provision of weather and climate in Tanzania, some survey respondents felt the need for a joint forum or advisory board as independent overseers/evaluators and/or to create Technical Advisor Boards. It was also not clear as to how and to what extent the provision of weather and climate information currently supports international efforts in disaster risk reduction as stipulated in the Sendai Framework for Disaster Risk Reduction (2015–30) and Sustainable Development Goals.

c. What are the factors hindering utilization of weather and climate information in the Tanzanian disaster risk reduction sector, and are there constraints to using this in decision-making?

In the survey, 39 (67.2%) survey participants and interviewees reported constraints in the use of weather and climate information in the following areas.

1) Awareness, dissemination, and capacity building

Limited awareness of weather and climate information was identified as a key challenge. Respondents urged providers to educate and promote the benefits of using weather and climate information to households, institutions, local government authorities (LGA), and region and district disaster focal person. They also suggested private-sector involvement: "they need to work with civil society to enable the community to take part in the evaluation of weather and climate information."

In most sectors planning is done by economists who may have little or no knowledge of weather and climate, lack of knowledge affects the integration of weather and climate information in their institutional planning: "Economist they do not use weather information because they do not know its contribution/importance of it in the plan. So, there is a need to have mechanisms to sensitize the sector."

Timely dissemination of weather information through multiple channels and increased dissemination to the most affected communities, especially those in the rural areas, were identified as key issues in disaster risk reduction. Poor communication channels were noted to cause the information not to reach the community in the local areas who are the most at risk. It was further noted that most of the information are sent through radio, television, and social media, which may not reach the rural areas. Increasing access and the use of social media and text messaging [short message service (SMS)] across the whole country and the use of all media channels, including national

TABLE 2. Available documents for the DRR sector in Tanzania.

Document name and type	Nature of the document
The National Disaster Management Policy of 2004	National policy
Zanzibar Disaster Risk Reduction and Management Act	National act
The Disaster Management Act of 2015	National act
Plans and Budget Guidelines (yearly document)	National guidelines
Tanzania Emergency Preparedness and Response Plan of 2012	National guidelines
Sendai Framework for Disaster Risk Reduction 2015–30	International frameworks
Disaster Management Regulations of 2017	National guidelines
National Disaster Management Plan 2012	National guidelines
District Disaster Plan (dates vary from 2014 to present)	National guidelines
National Livestock Policy (2006)	National guidelines
National Operational Guidelines for Disaster Management (2003)	National guidelines
Rerouting of the bus route (not specified)	Local authority specific for Dar es Salaam Rapid Transport Services
National Guidelines for Prevention and Control of Cholera Outbreak (2015)	National guidelines
Crop Production Policy (not specified)	National policy
Zanzibar Disaster Management Policy (2011)	National policy
Planning and Budget Manual (not specified)	National guidelines
Zanzibar Emergency Preparedness and Response Plan (2011)	National guidelines
Zanzibar Disaster Communication Strategy (2011)	National guidelines

and local media and advisory centers for public alerts such as billboards, was advised. The establishment of a users' database and electronic platforms such as emails and WhatsApp groups to cover a wide range of information sharing was recommended. The regional and district disaster focal person requested direct, reliable communication to enhance early action and planning.

2) LANGUAGE, INTERPRETATION, AND ACCURACY OF WEATHER WARNING AND ADVISORIES

The need for more user-friendly language and interpretation of the warnings and advice currently provided to the general public was found as an important factor in the usefulness of weather information, with three interviewees identifying this as a key challenge: ''the interpretation of weather and climate information should be in a well understood medium for easy and common understanding''; ''a clear elaboration of the information to the user is very important in advancing mitigation measures.'' Generality in the information was noted to make it difficult to understand: ''it will be easy to understand the information if it is customized according to a sector's needs.''

The scientific terminology and language used in advisories and warnings were considered to be easily understood by technical experts at a national level but difficult for most users (at regional and district levels) and the general public. An expert from the disaster management department noted that the warning and advice information is key in reducing impacts associated with severe weather events. However, the information is currently presented in a way that is more suitable for technical personnel: ''We do not have challenges because we understand. But users at the district level and communities do they have the capacity to use it, I do not think they understand the warning color and symbols.'' The same concern was raised by experts from the TRCs on the probabilities used in the seasonal forecast: ''decoding of the information to be simpler is important, I still believe that the percentages that are allocated to the seasonal forecast cannot be easily comprehended by a normal person [lay person]. I wish that a normal person could be able to interpret that.''

It was noted that the current spatial and temporal resolution of forecast information is not suitable for making robust decisions. ''We do not get high-resolution information; it [TMA] provides information to big cities. Tanzania is big so we do not get information across the parts of the country.'' However, the question remains if TMA has capability and capacity to provide high-resolution products.

d. How could providers better engage with users of weather and climate information in the disaster risk reduction sector in Tanzania?

Interview questions and an open-ended survey item examined views on how best to improve the evaluation of weather and climate information in order to give feedback of effectiveness of information in decision-making.

Some participants suggested that user engagement could be enhanced through monthly, quarterly, or annual meetings in the form of workshops and focus group discussion, and that these activities need to involve key stakeholders at government departments/institutions/agencies, local government authorities and civil society organizations: ''I should probably add that, yes, it can still be done bilaterally between TMA and Tanzania Red Cross . . . to make it even more effective I would think of the forum which brings TMA and humanitarian partners together probably under the coordination of the Prime Minister's Office Disaster Management Department that will be much better.''

Some participants noted the need for a common platform in the evaluation of severe weather forecasts that involves users from various sectors and disaster focal persons at the regional and district level. It was felt that this would facilitate the sharing of views and ideas on product improvement to fit the users' needs (coproduction) and link forecast providers and

users. One interviewee noted that as the main source of weather and climate information in the country, TMA has the opportunity to use its zonal (i.e., regional) offices in designing coproduction activities and improving feedback: ''We wish we could do the co-production, for example, they are now providing the five-day forecast and they have TMA zonal offices. Those TMA zonal offices can sit with users and get feedback, and areas of improvement on the product issued. They can get the impact and understand the usefulness of the data/information provided and use the information to improve the product.'' Both the survey and interview participants highlighted a need for capacity building for users across multiple sectors involved in DRR activities. To accomplish this, TMA needs to conduct training for all media, extension officers, disaster focal person (regional and district), the general public, and private agencies.

These changes could help to increase the uptake and usefulness of weather and climate information for DRR. However, their implementation would be challenging, requiring intensive resources and collaboration with local and international organizations.

e. What are the causes of weather-related socioeconomic losses in Tanzania?

The survey and interviews revealed that most department/institution's activities are negatively affected by weather events, and they lead to economic losses. An open-ended survey item asked about the factors contributing to socioeconomic losses due to weather-related hazards in the country. The following factors were identified.

1) EXISTING VULNERABILITY AND EXPOSURE WITHIN COMMUNITIES

Vulnerability and exposure to the impact of weather-related hazard was noted to contributes to the observed socioeconomic losses. The losses were described as complex issues connected to poverty and population increase, which increases risk to weather hazards. Participants noted that poor infrastructure, geographical location, low income due to poverty, disabilities, population increase, and poor waste management systems increases the risk. It was further noted that most existing roads, bridges, and drainage systems are not able to withstand the forces of floodwater, and houses are built in exposed areas such as flood-prone locations, hillsides, or valleys. Poverty in urban areas force communities to relocate to unplanned settlements on nearby open space, especially near water bodies, which can often be floodplains: ''for the country wise is due to infrastructure which have not been prepared to be resilient in that particular event [*wise* refers to the large part of the country]. So, we need disaster risk reduction mechanisms . . . mitigation measures . . . Example floods in Dar es Salaam affect people with low economic status, because they are living in vulnerable conditions, they don't have the capacity to move/relocate to safer areas.''

Human activities along river banks cause soil erosion and the accumulation of debris, which affects river flow and depth, resulting in flooding during the rainy season. This was reinforced by several interviewees: ''open water drainage areas are invaded so water is not flowing, as a result the water accumulates and becomes a source of flooding. The presence of debris also contributes to the occurrence of flooding. Debris affects the depth of the river.'' ''Population growth is not compatible with an increase in land demand.'' In most cases, the houses are of a low standard and do not align with building codes and construction standards, and hence are not resilient enough to withstand the intensity of the floods.

2) POOR LAW ENFORCEMENT AND POLITICAL INTERFERENCE

During the interview experts from the DMD and DMC noted a challenges of law enforcement and politics. ''The by-laws are there, but fail to be realized due to political interference. A good example is the case of floods in Jangwani area at the Msimbazi Valley ''in 2013–14 we relocated affected community to Mabwepande area. We also suggested demolishing of the houses in the Msimbazi Valley but there was a lot of political interference.'' [The houses needed to be demolished because they are in flood zone. Each year when there is excess rain in the Dar es Salaam region or higher ground of Kisarawe areas, it results in flood incidences in the valley.] ''There are gaps in the implementation of various legislation, ill implementation of various existing laws and lack of control over flood-affected areas.''

3) POOR AGRICULTURAL PRACTICES

Poor agricultural practices such as cultivating the hills and overstocking of livestock (keeping a large number of animals, exceeding the carrying capacity), deforestation, burning of vegetation (bush clearance using fire), and poor farming methods were identified as contributing factors to environmental degradations thus exacerbating the impacts of weather-related hazards. A respondent noted that ''deforestation and poor agricultural practices, especially in the hill areas, increases downstream water flow, which causes floods. Overstocking of livestock, i.e., exceeding the animal carrying capacity of land has caused tremendous side effects, especially in recent decades in which prolonged drought conditions have been observed. Most livestock keepers' losses are due to lack of pasture and water.''

4) CULTURE AND TRADITIONS OF SOME COMMUNITIES

Culture and traditions have been mentioned as one of the contributing factors. An example was given by a respondent about the traditional houses in the Bahi village in the Dodoma Region. ''More than 90% of Bahi residents are from the Gogo tribe. To date, Wagogo [natives found in Dodoma] still builds and roof their famous houses by using soil [maintains the traditional building style]. The houses are commonly known as 'Matembe.' During the rainy season, most of their houses are affected easily by excessive moisture and become prone to breakage hence causes disaster to the families.'' Another issue identified was that in most communities, it is not customary to use weather and climate information.

4. Discussion

A range of weather and climate information is currently used in DRR in Tanzania, with the TMA as the main source of

information. This is in keeping with most other African countries, where weather and climate information is generated and disseminated by the national hydrological and meteorological agencies (Singh et al. 2016, 2018). Also consistent with the broader weather and climate services literature (Jones et al. 2015; Singh et al. 2018), we find that disaster risk reduction decisions in Tanzania tend to make use of short-term weather and climate information. Specifically, seasonal forecasts (for the next 1–3 months) are most frequently used for decision-making in DRR, followed by the 1–5-day severe weather impact-based forecasts. This information is mostly used in operational-based activities and is disseminated through multiple channels, such as radio and television, weather reports, newspapers and press releases, and smartphone applications.

Both surveys and interviews indicated that warning information does not reach the rural communities who are the most vulnerable. The challenge of rural communities having limited access to weather and early warning information has been observed elsewhere in sub-Saharan Africa (Mudombi and Nhamo 2014; Nkiaka et al. 2019), with a lack of timely information to user affects its uptake and integration to decisions (Singh et al. 2018). In the specific context of Tanzania, the findings of the surveys and interviews reported here identify TMA zonal offices as a bridge to achieving coproduction and timely dissemination to at risk communities and those agencies working with them, to increase accessibility, uptake, and use of short-term weather and climate information to support decision-making. They could be also used to support capacity building and the gathering of feedback with civil society organizations, local government experts, and regional and district disaster focal person, as well as community at risks.

The research identified a number of guidelines, policies, acts and regulations for disaster risk reduction used by DMD and DMC. It was not clear to what extent the acts, guidelines, regulations, and disaster policies promote the use of weather and climate information across the DRR sector. Some interviewees indicated that further work is needed to fully identify the range of current (and potential) users of weather and climate information in Tanzania and explore their specific needs. Various studies have shown that for effective provision of climate services, user engagement and knowledge are essential to promote and facilitate the uptake of weather and climate information (Bruno Soares and Buontempo 2019; Jones et al. 2015; Nkiaka et al. 2020; Carter et al. 2019; Met Office and TMA 2018; Vincent et al. 2018; Amegnaglo et al. 2017; Hansen et al. 2019; Lemos et al. 2012; Singh et al. 2018). Additionally, engagement with user communities is essential to ensure that these forecasts provide their anticipated value and to prevent misconceptions or disparities between user expectations and the available science (Robbins et al. 2019; WMO 2018).

This work identifies various benefits of using weather and climate information across the DRR space using nonmonetary approaches. For agriculture, benefits include provision of advanced information for areas of crop production surplus and shortage, and thus food security status, and the activation of operational activities across sectors. Through integrating this information into crop production forecast models, it can be used to guide planning for food security assessment and preparing and issuing the state and status of food security in the country. Studies on seasonal forecasts for crop yield modeling in Europe suggest that incorporation of climatic seasonal forecasts in crop yield modeling brings additional information to the reliable crop yield predictions therefore has valuable benefit for decision-making (Cantelaube and Terres 2005; Gardner et al. 2021). Moreover, it can be used to advise farmers on agricultural activities (e.g., harvesting, livestock carrying capacity) to avoid losses as well as helping businesses and food reserve organizations to understand which areas of the country may have surplus food.

In the health sector, weather and climate information is useful in identification of hot-spot areas for disease outbreaks (e.g., dengue, malaria, Chikungunya, eye diseases, and cholera). Both excess rainfall and drought conditions impact on the density of diseases vectors (e.g., mosquitos) and transmission of diseases depending on the characteristics of the built environment and anthropogenic water storage (Rogers et al. 2010). Furthermore, the association of meteorological parameters with African hospital admissions shows that the associations tend to be locality specific and vary by climatic region (Rogers et al. 2010). For example, warm temperatures are associated with increases in cholera epidemic and malaria admissions (Rogers et al. 2010). Other conditions include diarrhea, malnutrition (IPCC 2014; Esham et al. 2018), and respiratory syncytial virus, which is associated with increased precipitation (Rogers et al. 2010). The dry season has been associated with coughing and respiratory illness. Seasonal rainfall and temperature forecasts are useful indicators of the likelihood of malaria outbreaks and can be used to implement a program of heightened epidemic surveillance, while real-time temperature and rainfall estimates can be used to initiate selective interventions and to support the early detection of disease outbreaks (Grover-Kopec et al. 2006; Niang et al. 2014). The health sector can also use climate information effectively in epidemic early warning systems.

In the context of disaster risk reduction more broadly, we find that a key value of weather and climate information is to support informed decision for all disaster management phases (preparedness, response, recovery, and restoration), as well as the tailoring of directives and actions based on sectoral impacts. The information has been identified as a mechanism for strengthening the relationship between the government and the public. The public takes early action through government directives, thus reducing economic losses due to weather-related hazards (WMO 2018).

With respect to charging for tailored weather and climate information to institutions, we find that charges could potentially trigger ownership and responsibility for the use of information, as well as prompting producers to increase accuracy and reliability of the services and tailor them to sector-specific or institution-specific needs. It could also provide an additional source of income for support organizations, operations activities, and sustainability of provision of weather and climate information. However, the tensions between providing weather and climate information as a public good and being able to provide tailored sector-specific products has been noted

elsewhere, with concerns that reliance on less specialized free services, rather than specific, tailor-made commercial weather and climate services, may be disadvantageous for sectoral decision-making (Georgeson et al. 2017).

Although we have shown the value of the use of weather and climate information to the DRR sector in Tanzania using nonmonetary approaches, several limitations relating to its uptake and use were identified. These include lack of knowledge and awareness of usefulness of weather and climate information to decision-makers and planners, limited expertise to use and integrate the information within the institution activities and cultural barriers, scientific language, limited access, concerns about accuracy, uncertainty, and spatial distribution of weather and climate information. These limitations have been also identified by previous studies as a barrier to the uptake of climate information (Ojwang et al. 2010; Mabon 2020; Nkiaka et al. 2020; Ouédraogo 2018). For example, lack of access and knowledge to early warning information, language barriers, time lines, and spatial aspects of weather and climate information affect famers' decisions (Miuta et al. 2021; Singh et al. 2018).

A lack of budget for disaster management activities related to preparedness was also highlighted as a barrier to using weather and climate information to inform decision-making. As most disaster management funds are released during response and recovery, this may cause challenges to respond and taking early action for disaster risk reduction. These impede incorporation of weather and climate information into organization/institutional plans and policies.

Socioeconomic losses due to severe weather and climate events are increasing, which limits development activities and affect the community livelihood. We found that poverty and population increase in urban area leads to increases in risk due to high vulnerability and exposure. Studies exploring the drivers of losses from extreme weather show that increasing exposure is the most important driver through increasing population, and that there is ample evidence of increasing risk in developing countries, which calls for significant improvement in climate risk management efforts (Bouwer 2019). Increased frequent severe weather events due to climate variability and change, lack of or limited awareness and skill in the use of weather warnings and advising, and limited knowledge on existing hazards were identified as factors that contributes to losses. Other factors identified include poor law enforcement, political interference, poor land use, and town plan, which leads to the construction of buildings that are not resilient, unplanned settlements, and poor agricultural practices. Culture, traditions, and lack of disaster management capabilities were also identified. Other sources include environmental degradation, information not reaching the most vulnerable, inaccuracy of weather forecasts, and lack of an integrated early warning system (EWS). Insufficient funds allocated for disaster preparedness activities and lack of a common platform to evaluate effectiveness and usefulness of weather warnings and advisories are additional factors. Lack of user evaluation of the quality of climate services has been linked to affected provision of weather and climate services (Brasseur and Gallardo 2016; Nkiaka et al. 2020).

5. Conclusions and recommendations

This study explored the value of weather and climate information for decision-making to the DRR in Tanzania. Maximizing the benefits of these values requires close interaction between the producer and users of the information. Establishing a joint platform to link DRR sectors, decision-makers, and providers of weather and climate services will enhance collaboration between local and international organizations and use the opportunities available to enhance awareness, access, capacity building, and knowledge sharing as these activities require intensive resources.

Our findings indicate the need for further studies to understand how the existing TMA and DRR structure can cooperate at the regional and district level to improve the dissemination of weather and climate information to the communities in rural areas. There is also a need to understand how the DMD and DMC link together with the TMA to enhance and strengthen the uptake and evaluation of usefulness of weather and climate information. Engaging with a wider range of stakeholders including the nongovernmental institutions in the DRR sector will provide further opportunity for collaboration, product development (coproduction), and to reach those who are higher risk, especially the rural communities, through improved dissemination processes. The limited application of weather and climate information identified emphasizes the need for enhancing coproduction to ensure that climate information is tailored to a specific use in decisions across many sectors.

In this study participants opined that it is acceptable for TMA to charge for tailored products, climatological trends, past data, and projections. However, decision-makers in less developed countries may be more reliant on free data and services, which are not tailored to the specific problems that they face because they have limited scope to pay for providers. Thus, deciding what information should be charged for needs careful consideration. Furthermore, adapting the cost recovery mode will assist the institutions providing weather and climate information to improve their services, procure modern equipment, and enhance institutional performance and capacity.

However, assessing the capacity and capability of TMA to provide high-resolution forecasts, verifying the skill of the severe weather impact-based forecasts issued in a quantitative way, and understanding the ''forecast chain'' within TMA from production to end users are recommended. Investigating how the warning is produced and disseminated, and how decisions and actions are made by the recipients, is an important area for future research.

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Data availability statement. This study reports qualitative and quantitative data collected from disaster decision-makers

and focal persons in disaster management institutions in Tanzania. The nature of qualitative data means that they are difficult to fully anonymize. Participants were not asked to agree to their data being available for other studies, because many were well known within the disaster management organization/institutions and departments. Ethical approval for this research study was granted by the Social Sciences, Environment and LUBS (AREA) Faculty Research Ethics Committee (email address: ResearchEthics@leeds.ac.uk) on the basis that participants' data were only accessible by the researcher. Requests for access to the data may be directed to that committee and email address.

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