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The ‘triple dividend’ of early warning systems

Evidence from Tanzania’s coastal areas

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Key messages

- Improving the communication of extreme weather information in Tanzania through the Multi Hazard Early Warning Service (MHEWS) project has helped to reduce mortality and property damage when storms and floods hit.
- Evidence from a study in the coastal region of Tanga suggests that there are other ‘co-benefits’ from investment in early warning systems. Fishermen and seaweed farmers are better able to plan their economic activities, and some have seen a rise in income.
- However, lower levels of risk from better preparedness do not appear to have encouraged higher levels of saving and investment because of other limiting factors – fishermen are poor with little capacity to save without access to microfinance.
- The Triple Dividend of Resilience framework used in this study can help to identify the full range of benefits associated with functioning early warning systems, strengthening the business case for making these and associated investments.

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Acronyms

ACPC	African Climate Policy Centre
BCR	benefit–cost ratio
BMU	Beach Management Unit
CAROT	Climate Adaptation, Risk and Opportunities in Tanzania
DarMAERT	Dar es Salaam Multi-Agency Emergency Response Team
DFID	Department for International Development
DFO	District Fisheries Officer
DMD	Disaster Management Department
DRM	disaster risk management
EBRD	European Bank for Reconstruction and Development
EWS	early warning system
FAO	Food and Agriculture Organization of the United Nations
FGD	focus group discussion
GEF	Global Environmental Finance
GFDRR	Global Facility for Disaster Reduction and Recovery
IASS	Institute for Advanced Sustainability Studies
KII	key informant interview
MALF	Ministry of Agriculture, Livestock and Fisheries
MHEWS	Multi Hazard Early Warning Service
SUMATRA	Surface and Marine Transport Regulatory Authority
TDR	Triple Dividend of Resilience
TMA	Tanzania Meteorological Agency
TPA	Tanzania Port Authority
TURP	Tanzania Urban Urban Resilience Programme
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
WISER	Weather and Climate Information Services for Africa
ZM	Zonal Manager

Executive summary

Early warning systems (EWSs) have been effective in reducing loss of life and injury associated with extreme weather events, but it is less clear what influence they have on other household decisions, and whether having greater certainty about the weather prompts small business and households to make different economic and personal choices. Some research has identified increased productivity in rainfed farming from using weather and climate information, but much less is known about fishing communities, where livelihoods also depend heavily on the weather.

This paper begins to fill this gap by examining the range of socioeconomic benefits associated with improvements in EWSs in coastal areas of Tanzania, including for fishing communities and the marine sector. It uses the Triple Dividend of Resilience (TDR) framework, developed by ODI, the World Bank and the London School of Economics (Tanner et al., 2015) to capture the direct, indirect and co-benefits of investments in disaster risk reduction.

The focus is on the Multi Hazard Early Warning Service (MHEWS) project, which established an impact-based five-day weather forecast service for coastal areas in Tanzania, as well as a series of alerts. The project improved the communication of warnings of extreme events by using pictorial symbols and colour-coding, and by providing information on the potential impacts of adverse weather – all co-produced with community members and other national and local stakeholders.

Based on interviews and focus group discussions (FGDs), our findings suggest that the understanding and use of short-term weather information has significantly improved as a result of this initiative. Receiving early warnings has reportedly led to a reduction in mortality and property damage from extreme weather events (the first resilience dividend) and an increase in household incomes (the third resilience dividend), where people engaged in fishing and related activities have been able to better plan their economic activities.

Receiving early warning information does not, however, appear to have encouraged higher levels of saving and investment in these coastal communities (the second resilience dividend). The most likely explanation is that disaster risk is only one obstacle preventing people from investing in more financially risky and potentially profitable activities. Poor people's ability to save and invest is constrained, and so the second resilience dividend is less likely to arise than the other two dividends from investment in EWSs.

Capacity development and training for users, the media and staff of the Tanzania Meteorological Agency (TMA) has been effective but needs refinement, as problems of interpretation persist. One major challenge is reaching users in remote areas. Suggestions for improving coverage and use of the EWS include collecting phone numbers and registering them so that more users can receive information via SMS message; distributing mobile phones where necessary; and investing in infrastructure to increase electricity and internet access. It is important to have tailored, targeted information in EWSs, and to ensure that weather information is accompanied by practical advice on how to act.

Further exploration and quantification of these resilience dividends is required to better understand the scale of change (how many people have benefited) and sustainability (whether positive changes can be sustained over time).

1 Introduction

EWSs are critical for avoiding loss of life due to natural hazards.[1] Globally, the number of reported events, fatalities and economic impacts of disasters significantly increased from 1980–2016[2] (Formetta and Feyen, 2019), yet average mortality and loss rates (reported fatalities as a percentage of exposed population and reported losses as a percentage of exposed GDP) fell 6.5 times and nearly five times respectively. Better monitoring and forecasting of hydro-meteorological hazards and more effective emergency preparedness measures have played a major role in reducing these loss rates (see WMO, 2019).

It is less clear what role EWSs play in reducing economic losses, however. In 2017, the cost of disasters globally reached $314 billion, more than double the average cost of 2007–2016 (UNISDR, 2018). This is partly due to increasing exposure (increasing populations and greater capital at risk) but also better reporting (Visser et al., 2014). Evidence is also growing of the increasing intensity and/or frequency of some weather and climate extremes (e.g. Donat et al., 2016).

A number of studies have attempted to quantify the benefits of EWS, although these are mostly in developed country contexts. Studies in developing countries have centred on the avoided damage and loss of life that can be attributed to EWSs. A few studies also look at the broader benefits of hydro-met services (not only related to disaster risk reduction (DRR)) for different sectors – for example, increased profits due to incorporating weather information in decision-making – and for society at large. However, these studies rarely capture the intangible costs and benefits, such as improvements in wellbeing or a reduction in delays (WMO, 2015). To our knowledge, no study so far has explored or attempted to quantify the full set of benefits or 'dividends' associated with having a strong functioning EWS, including the effect this can have on economic growth.

To cover this knowledge gap and explore the potential contribution that EWSs can make to building resilience at different scales, this qualitative study examines the broader socioeconomic benefits associated with an EWS using the TDR framework. This assesses direct benefits in terms of avoided losses, indirect benefits associated with a lower risk environment, and co-benefits related to specific interventions (Tanner et al., 2015). The study focuses on Tanzania, and in particular coastal areas which are highly exposed to and regularly affected by flooding, strong winds and high waves, all of which in turn affect fishing and related livelihood activities. The paper explores the effects on resilience in this climate-vulnerable context of having better early warnings, brought about through the MHEWS project.

The MHEWS project closed in early 2018 with the formal launch of the service, but without sufficient time or budget to carry out any monitoring, evaluation or learning activities post-launch. As noted in the Project Completion Report, it would still be beneficial to determine user confidence in – and understanding and interpretation of – the warnings received.

1 An effective EWS refers to the implementation of four components: detection, monitoring and forecasting the hazards; analyses of risks involved; dissemination of timely warnings – which should carry the authority of government; and suggestions on and activation of emergency plans to prepare and respond.

2 In this case, trends are deflated but not normalised with respect to exposed wealth of the year of the event. Natural hazards considered include general floods, flash floods, coastal floods, cold related hazard, heatwaves, droughts, and wind related hazards.

This report partially addresses this knowledge gap. It is part of the WISER Transform project, an initiative of the Weather and Climate Information Services for Africa (WISER) programme which aims to enhance learning and sharing of knowledge and information between WISER projects and, more broadly, between Africa's national meteorological services. The results of this research will be of interest to those involved in implementing the MHEWS project, most critically TMA, and can be used to inform the design of future early warning services.

In the next chapter, the paper summarises previous efforts to assess the benefits of EWSs and then sets out the framework that will be used to explore these benefits in the context of coastal Tanzania: the 'Triple Dividend of Resilience'. Chapter 3 then describes the impact of climate-related hazards in Tanzania, as well as recent investments in improving the communication of early warnings of extreme weather events, including through the MHEWS project, implemented between 2016 and 2018. Chapter 4 assesses outcomes of these improvements in EWSs, using the Triple Dividend framework to distinguish between direct benefits, in terms of avoided losses when disaster strikes, wider benefits stemming from a reduction in 'background risk' (in the absence of a disaster actually taking place), and economic, social and environmental 'co-benefits' associated with having an effective EWS in place. Key conclusions from the study are set out in the final chapter.

2 Evaluating the benefits of early warning systems

Costs and benefits are quantified in order to assess the viability of planned investments in climate and weather services. For EWSs, the benefits outweigh the costs in both developed and developing countries (Hallegatte, 2012; WMO, 2015). However, studies vary widely with respect to the methods and measures used, the type of services evaluated, and the beneficiaries concerned (individuals, households and/or economic sectors) (WMO, 2015). Hence, very different benefit–cost ratios (BCRs) have been produced by these studies (see Table 1). One notable evaluation of a new five-day forecast warning message service in Bangladesh looked at the effects of the service after flooding in 2014 (Flood Forecasting and Warning Centre, 2014). It found that, on average, households receiving the warning were about $430 (BDT 37,000) better off than those that did not because they were able to prepare for the upcoming threat. The largest savings were found in the fishery sector.

The Global Commission on Adaptation similarly has produced a 'best-guess' benefit estimate of upgrading EWSs in developing countries of $9 billion, and an annual cost of $1 billion, suggesting a best-guess BCR of around 9:1, with low and high estimates of 3:1 and 16:1 respectively (WRI, 2019). They note that while the financial cost is low, establishing effective EWSs nonetheless remains a challenging task in many countries, involving, for example, the political challenge of winning and building public trust in the system.

Table 1 Economic assessments of meteorological services

Study	Location	Sector	Methodology	BCR
'The benefits to Mexican agriculture of an El Niño/Southern Oscillation (ENSO) early warning system' (Adams et al., 2003)	Five-state region in Mexico	Agriculture	Change in social welfare based on increased crop production with use of improved information	2:1 to 9:1
'The value of hurricane forecasts to oil and gas producers in the Gulf of Mexico' (Considine et al., 2004)	Gulf of Mexico	Oil drilling	Value of avoided evacuation costs and reduced foregone drilling time	2:1 to 3:1
'Social and economic benefits of enhanced weather services in Nepal' (part of a Finnish–Nepalese project) (Perrels, 2011)	Nepal	Agriculture, transport and hydropower	Statistical inference and expert judgement	10:01
'Benefits and costs of improving met/hydro services in developing countries' (Hallegatte, 2012)	Developing countries	National level and weather-sensitive sectors	Benefits-transfer approach to quantify avoided asset losses, lives saved and total value added in weather-sensitive sectors	4:1 to 36:1
'Benefits of Ethiopia's Livelihoods, Early Assessment and Protection (LEAP) drought early warning and response system' (Law, 2012)	Ethiopia	Households	Quantification of avoided livelihood losses and decreased assistance costs	3:1 to 6:1
'Socioeconomic evaluation of improved met/hydro services' (Pilli-Sihvola et al., 2014)	Bhutan	National level	Benefit transfer, expert elicitation, cardinal rating method	3:1

Source: WMO (2015: 8–9)

These studies all focus on very specific sectors and actors, so the full range of benefits of these services is not well understood. They also largely ignored intangible costs and benefits (WMO, 2015) and the indirect benefits from avoided damage when an EWS is functioning effectively.

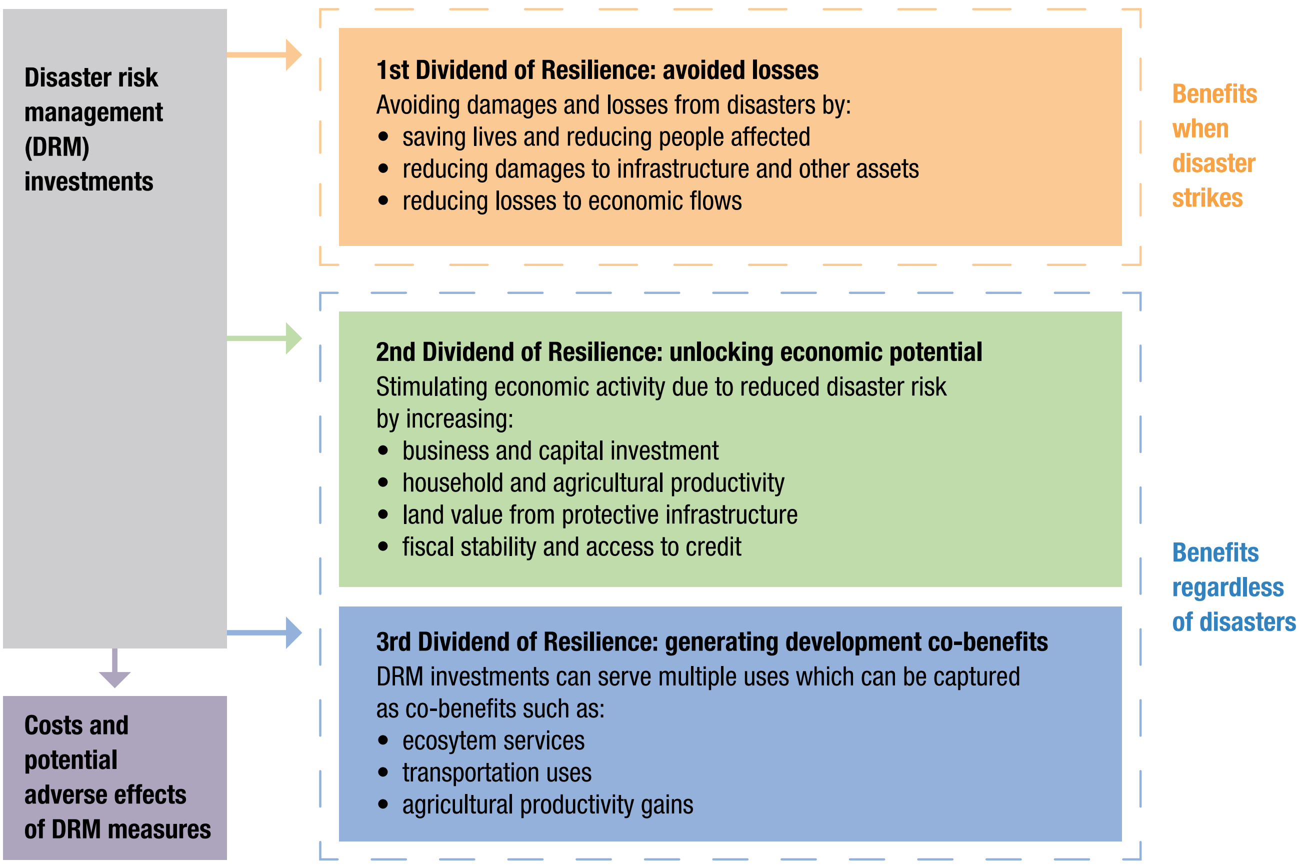
The TDR is a conceptual framework designed to encompass these broader benefits and improve the business case for investing in disaster risk management (Tanner et al., 2015). The framework identifies three dividends: reduced losses from disasters, increased economic activity due to lower risks and social, environmental and economic co-benefits associated with specific DRR investments. The three dividends are described in more detail in the rest of this chapter and in Figure 1.

2.1 The first resilience dividend

The first dividend relates to the avoided losses associated with weather extremes and other hazards, and derived from interventions that aim to do just that. In the case of extreme weather, benefits can be monetary (such as reduced infrastructure damage) and non-monetary (such as reduced number of injuries). EWSs could contribute to reducing damage to buildings, infrastructure and crops, and to a reduction in loss of life and injuries among individuals and livestock. EWSs could also produce indirect benefits, such as a reduction in losses due to transport disruption affecting supply chains.

To quantify the socioeconomic benefits of weather and climate services, the outcomes from the use of these services should ideally be compared to a situation of no service, to identify any differences (Met Office, 2017). This comparative approach is difficult to implement, however, due to insufficient data on loss and damage, along with a lack of knowledge about the processes leading to these impacts. The fact that different methods for reporting damage are used in international and national disaster databases, in assessing humanitarian needs and for loss reporting by insurance companies also makes it difficult to assess and compare losses with and without an EWS.

Figure 1 The Triple Dividend of Resilience framework



2.2 The second resilience dividend

The second dividend refers to the wider benefits of interventions in reducing 'background risk' and unlocking development benefits. These could, in theory, be realised even when there is no extreme event. By offering better detection and forecasting of natural hazards and the risks they present, EWSs can contribute to these development gains by encouraging people to take positive risks (e.g. larger investments in productive assets, entrepreneurship and innovation).

These wider benefits are difficult to value or monetise but could be modelled or analysed empirically using surveys and statistical analysis (for a review of these methods see Met Office, 2017).

2.3 The third resilience dividend

The third dividend includes all economic, social and environmental co-benefits associated with a specific intervention. Examples include community-based disaster preparedness bringing improvements in women's status, and climate-resilient protective infrastructure with ecological co-benefits (Tanner et al., 2015; Calderone and Subsol, 2019). Issues such as gender impacts in communities and protected and conserved biodiversity have been mentioned in the literature as potential co-benefits of EWSs, but they have not been further explored (Tanner and Rentschler, 2015; Tanner et al., 2015).

Strengthened planning capacities are another potential co-benefit. For instance, farmers can use climate information to plan better and avoid losing crops during periods of drought or intense rainfall and flooding, as well as taking decisions about planting and using fertilisers that are more efficient and take advantage of favourable weather. In the energy sector, strengthened planning capacities can lead to better-managed production, or can reduce dependence on higher-cost production units. In transport, they can be used to optimise air traffic and shipping routes, and plan road salting and other preventive actions in a more cost-effective way (USAID, 2013).

Against this background, we examine the broader socioeconomic benefits of EWSs in Tanzania, applying the TDR framework to coastal fishing communities in Tanga province. Because of the lack of longitudinal studies in the region or data from evaluations of EWS investments, we use a qualitative method to shed light on changes in the community and the processes behind any benefits that could be attributed to receiving early warnings.

3 Early warning systems in Tanzania

3.1 Vulnerability to natural hazards

Tanzania ranks 149 out of 181 countries in the resilience ND-GAIN index. Specifically, it is 152nd on vulnerability and 145th on readiness – meaning that it is highly vulnerable to climate change effects, and its ability to combat these effects is limited.[3] Climate projections for the country include 1.4–2.3°C increases in temperatures by 2050, longer dry spells and heat waves, and more frequent and intense heavy rainfall, along with a 16–42cm rise in sea levels by the 2050s (USAID, 2018). These changes will increase the risk of floods, droughts and cyclones and the destruction of natural resources such as coral (through bleaching) and depleted mangroves. Sea level rise is also putting coastal infrastructure, populations (about 25% of the total) and ecosystems at risk of inundation, salinisation and storm surges, while sedimentation, exacerbated by heavy rains, further threatens fisheries, which provide more than 4 million jobs and are an important source of protein.

Figures 2–6 provide evidence on the occurrence and impacts of hydro-meteorological and related hazards in Tanzania as a whole (drought, flood, landslide, rain, storm, thunderstorm, wind and windstorm) and in coastal areas. Marine accidents are also included in the analysis, as EWSs have the potential to reduce these if action is taken based on enhanced forecast information.

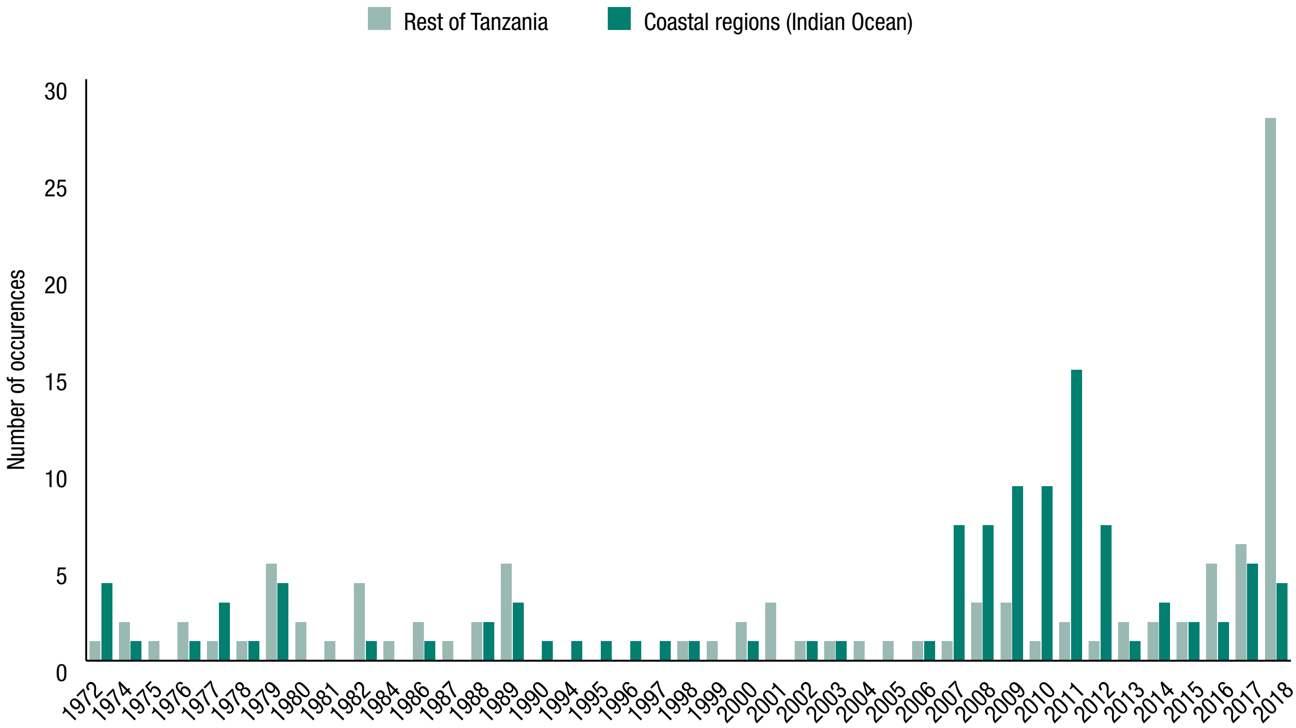
Some important trends to note for this study include:

- Climate-related disasters have become more frequent since 2007.[4]
- Flooding is the most common climate-related hazard, followed by drought.
- Total numbers of lives lost and injuries have declined in recent years, especially for coastal regions. A spike in the number of lives lost and injuries in 2018 in the rest of the country is due to two isolated events: a marine accident in Mwanza, where 227 casualties were reported, and a flood in Manyara, with 310 reported injuries.
- Property damage has increased across the country, although this could be a function of better reporting.

3 In the ND-GAIN index (https://gain.nd.edu/our-work/country-index/rankings/), vulnerability measures the exposure, sensitivity, and ability to cope with climate related hazards by accounting for the overall status of food, water, environment, health, ecosystem service, human habitat, and infrastructure within a country. Readiness targets those portions of the economy, governance and society that affect the speed and efficiency of adaptation.

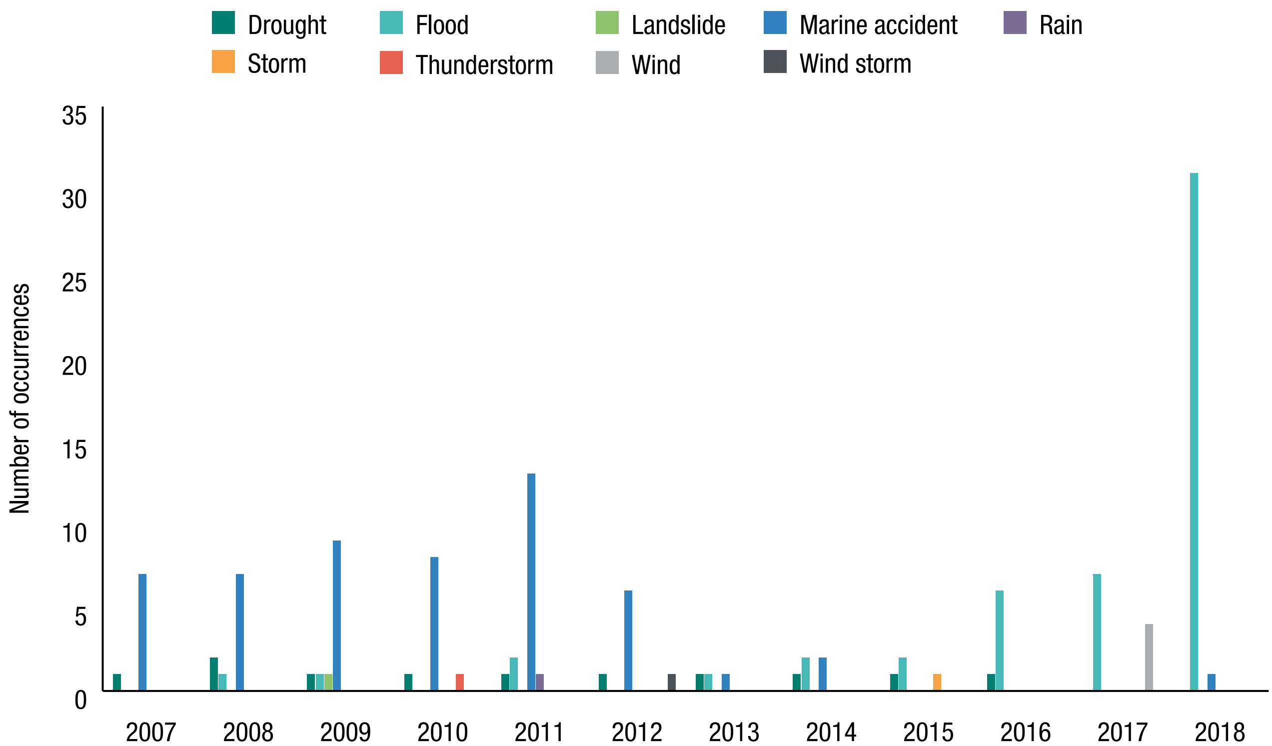
4 The data is taken from the Disaster Inventory System–DesInventar (Sistema de Inventario de Desastres), a tool sponsored by the United Nations Development Programme (UNDP) and the United Nations Office for Disaster Risk Reduction (UNDRR) for the creation of national disaster inventories and databases of the effects of such disasters (www.desinventar.net).

Figure 2 Occurrence of climate-related hazards in Tanzania since 1972



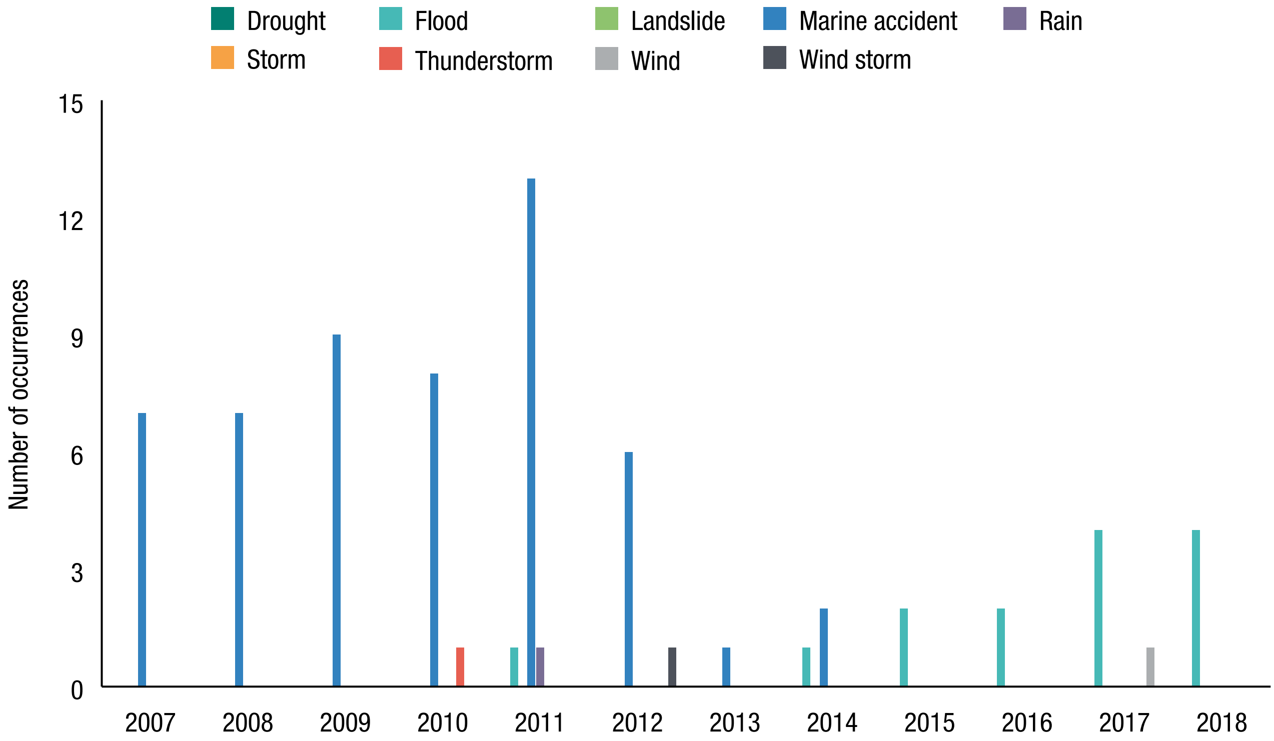
Note: This includes droughts, floods, landslides, rain, storms, thunderstorms, wind, windstorms and marine accidents.
Source: www.desinventar.net

Figure 3 Occurrence of climate-related hazards in Tanzania since 2007



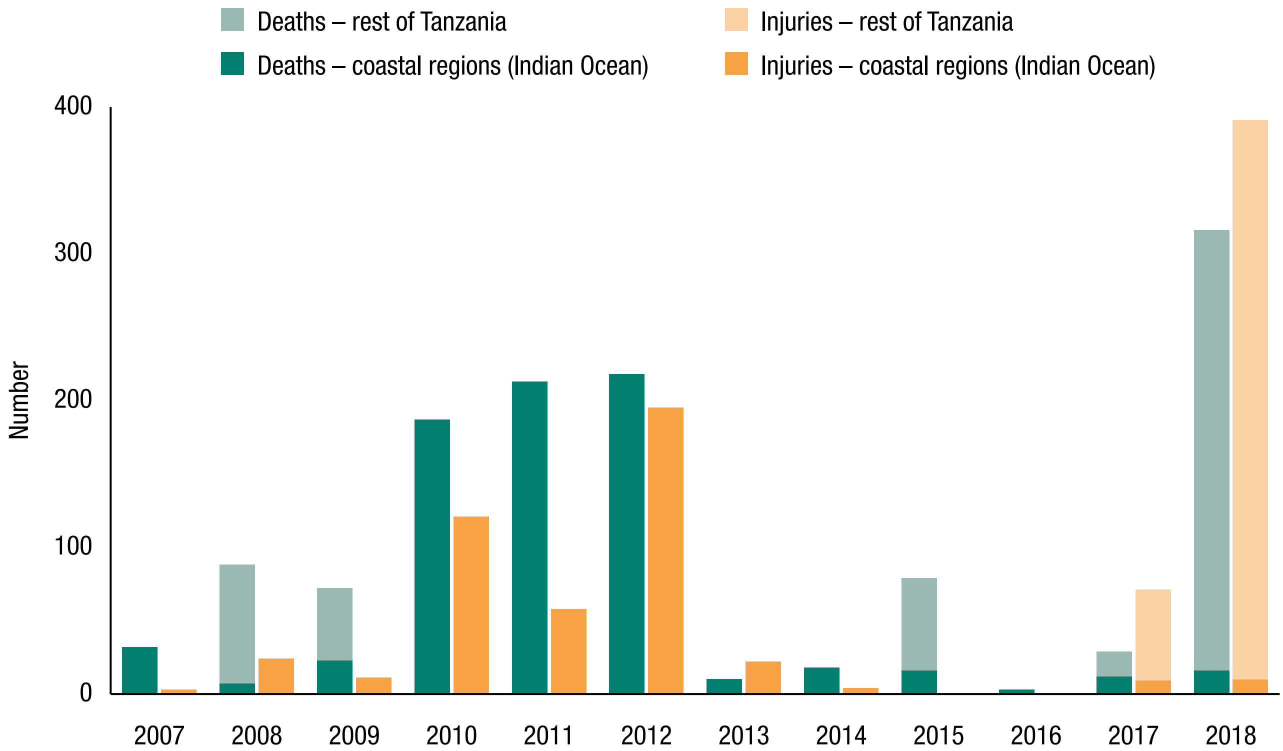
Source: www.desinventar.net

Figure 4 Occurrence of climate-related hazards in coastal areas (Indian Ocean) of Tanzania since 2007



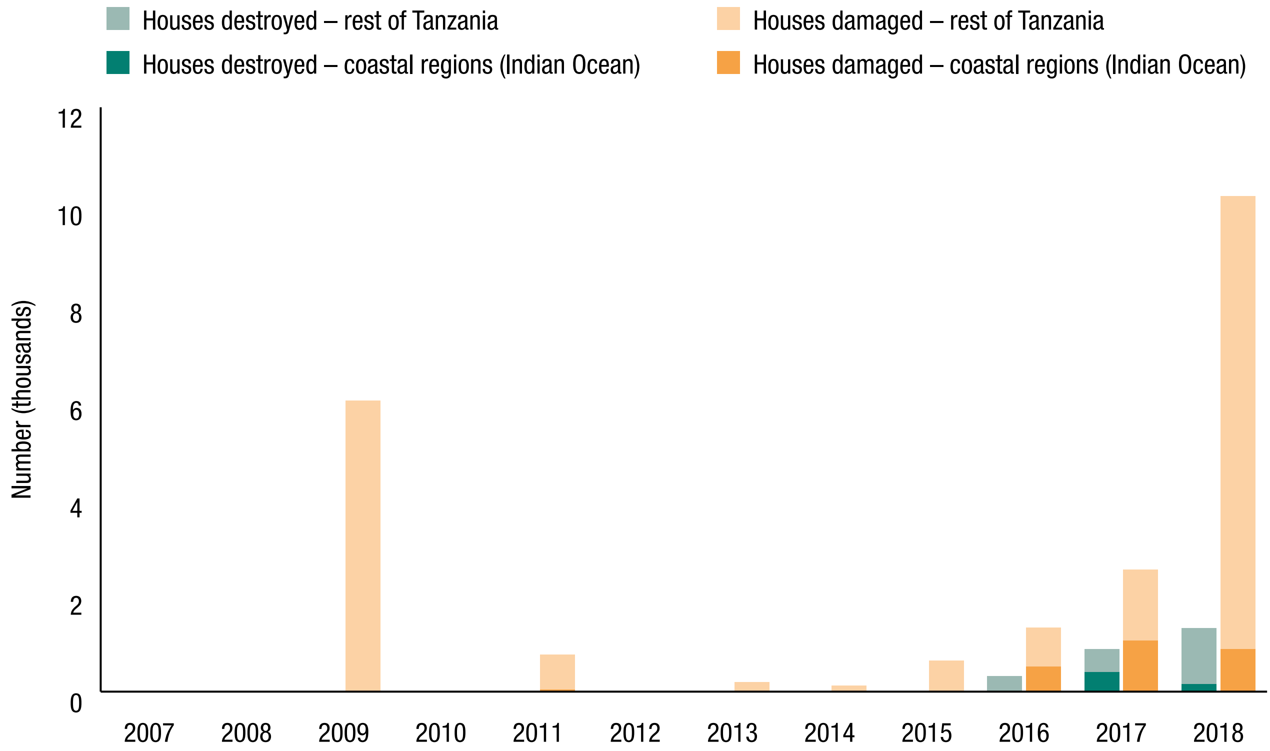
Source: www.desinventar.net

Figure 5 Impact of climate-related hazards in Tanzania (lives lost and injuries) since 2007



Note: This includes droughts, floods, landslides, rain, storms, thunderstorms, wind, windstorms and marine accidents.
Source: www.desinventar.net

Figure 6 Impact of climate-related hazards in Tanzania (houses damaged or destroyed) since 2007



Source: www.desinventar.net

3.2 The MHEWS project

The MHEWS project aimed to strengthen disaster preparedness in Tanzania by enhancing the capacity of the TMA to deliver an impact-based five-day weather forecast service, including warning information for extreme events such as heavy rain, flooding, landslides, strong winds, high waves and extreme temperatures. The project, a partnership between the TMA and the UK Met Office, started in early 2016 under WISER programme (see Box 1). It focused principally on fishing communities along the coast.

During a pilot phase, stakeholders in relevant ministries and three Beach Management Units (BMUs) received the trial service.[5] TMA Zonal Managers (ZMs) were also involved in distributing the service around the different regions of Tanzania, and three agreements were established with local community radio stations.[6] Initial feedback was that the BMUs had successfully disseminated the early warning information to their communities and, in particular, to fishermen, but that broader dissemination across different regions of Tanzania may not have been as successful.[7]

5 Departments, ministries and institutions included in this process are: District Fisheries Officers (DFO) from the Ministry of Livestock, Agriculture and Fisheries (MALF); Tanzania Port Authority (TPA) and Ministry of Transport; Disaster Management Department (DMD) from the Prime Minister's Office; Surface and Marine Transport Regulatory Authority (SUMATRA); BMUs; and media organisations.

6 Previously, the UK Department for International Development (DFID) Climate Adaptation, Risk and Opportunities in Tanzania (CAROT) project had developed the skills of ZMs in stakeholder management and communications training. WISER further developed ZMs as local TMA champions for the delivery of MHEWS.

7 Feedback reported in the WISER 'Quick Start' Extension Proposal for MHEWS.

Box 1 The Weather and Climate Information Services for Africa (WISER) programme

The goal of the WISER programme is to deliver transformational change in the quality, accessibility and use of weather and climate information services at all levels of decision-making for sustainable development in Africa. WISER is a DFID programme with two components: one pan-African, managed by the African Climate Policy Centre (ACPC), and the other focused on East Africa, managed by the Met Office. Under the latter, a series of projects comprised WISER phase 2, which started in early 2018. Many of the phase 2 projects focus on applying co-production approaches to improve the uptake and use of weather and climate services.

The main innovations of MHEWS consist in helping the TMA to present information about extreme weather in two ways:

1. Using pictorial symbols (for example, a flood warning is represented by a partially submerged house, and a strong wind warning is represented by bent-over palm trees).
2. Issuing colour-coded warnings that signal different levels of danger. These are based on an assessment of potential impact, and were developed in consultation with communities to address local needs (prioritising disasters that occur frequently, and ensuring that information is provided in an intelligible way).

The forecast service was developed and improved between 2016 and 2018 through co-production activities with information producers at the TMA and stakeholder groups (including partnerships with national ministries and local communities), facilitated by UK Met Office consultants.

Users from local communities and intermediaries (e.g. fishermen, seaweed farmers, farmers, local radio stations) were engaged at the design phase of MHEWS and consulted on how the information should be presented. Workshops were organised to discuss the hazards relevant to communities, and the appropriate pictorial symbols to communicate these hazards and their impacts. Users were also trained in understanding the weather information. Dedicated training sessions for journalists included how to report on weather information in a timely fashion (i.e. allowing enough time for people to take action after reading or listening to the report).

The service was formally launched in early 2018. The initial focus was on coastal areas, but TMA felt that the service could deliver significant benefits to the wider population, and decided to roll it out nationwide. The service is now one of TMA's regular forecasting products.[8]

Forecasts are disseminated through various channels, including Facebook, Twitter and a mailing list of government ministries, agriculture extension workers and the media, as well as through TV, radio and newspapers. Village meetings, public announcements, alarms and seminars are also used. Word of mouth is another important avenue through which weather information reaches the very local level. In urban areas, people typically receive weather information through smartphones, and journalists receive information via a WhatsApp group, YouTube videos or email. General information is then tailored to specific consumers. There are plans to use mobile phones (e.g. through SMS) to reach more people at the local level, although initiatives are currently on a very small scale. One suggestion is to link MHEWS to FarmSMS, which provides weather updates via SMS to around 10,000 users in the agricultural sector.

3.3 Other initiatives to strengthen early warning in Tanzania

Several investments in EWS in Tanzania were made during the course of the MHEWS project. This section reviews the most prominent initiatives, and their outcomes.

The Tanzania Urban Resilience Programme (TURP), established in 2016, grew out of a

8 TMA also issues seasonal forecasts (every three months) and updates of seasonal forecasts as well as 10-day forecasts, tailored climate information, agrometeorological bulletins on a 10-day basis and daily forecasts and warnings.

partnership between DFID and the World Bank to support the Tanzanian government to increase urban resilience to climate and disaster risk. Under the TURP, the Dar es Salaam Multi-Agency Emergency Response Team (DarMAERT) was created to bring together emergency response actors across the city.

TURP also collected data on households' risk vulnerability and coping strategies, and whether people received warning messages or not. The study shows that access to early warnings is widespread, and that most households affected by disaster received a warning from the TMA (TURP, 2018).

The World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR) and Humanitarian OpenStreepMap implemented a risk mapping project in Dar es Salaam between 2015 and 2017. University students and local community members were trained in creating maps of parts of the city with the highest flood risks, identifying drainage systems, buildings, materials and assets within communities (e.g. hospitals and schools), and potential threats.

The UNDP Global Environmental Finance (UNDP-GEF) project Strengthening Climate Information and Early Warning Systems in Tanzania for Climate Resilient Development and Adaptation to Climate Change was implemented between 2013 and 2018. The project transferred technologies for climate and environmental monitoring infrastructure, setting up new automated weather stations, rain and river gauges and hydro-met stations. This has increased the capability of TMA to forecast droughts and floods. An additional objective of the project was to integrate climate information into development plans and EWSs. Agro-meteorological information for activities such as crop farming and livestock-keeping was disseminated in two pilot locations (Liwale district in Lindi region and Arumeru district in Manyara region). This included the distribution of smartphones to smallholder farmers and registering them with an SMS system. Dissemination channels have however not been widely used (only 3–4 messages had reportedly been sent to target beneficiaries), and some farmers were apparently out of reach of the network or did not have the appropriate phones to use it.

4 Evaluating the MHEWS

This section presents the research methodology and main findings of a study examining the outcomes of the MHEWS project, conducted in Tanzania from 4–13 September 2019.

4.1 Methodology

Semi-structured interviews were conducted with a range of key informants, as well as FGDs in the coastal area of Tanga where the MHEWS trial service was implemented. The interviews and FGDs included questions on disaster impacts, how people respond to early warnings and whether and how a reduction in losses might be linked to receiving this information (the first dividend). For the second dividend of resilience, we included questions on productive activities, income and investments in productive assets, the savings of households engaged in fisheries and if/how these household decisions and actions might be influenced by perceived levels of disaster risk. To investigate the social, environmental and economic co-benefits related to the third dividend, we asked whether there had been any changes in local planning, transparency, social cohesion or protection of watersheds and other natural resources in recent years. We also explored any economic co-benefits associated with the use of weather information.

The FGDs in Tanga focused on people employed in fisheries and seaweed farming, both sectors where there has been significant and sustained investment in EWSs and information dissemination at the local level. Previous studies from the UK Met Office identified these two sectors as the most relevant for the implementation of the MHEWS (Venton, 2018; Met Office, 2018). In Tanga, a few radio stations recently increased the power of their transmitters, expanding the range of their audiences (Green and Groves, 2018) and therefore the number of people receiving information, making this a good study site. Two FGDs of three hours each were conducted on 13 September 2019. Twenty-seven people participated including local fishermen, as well as representatives from local media stations, fishing associations, BMUs and the TMA.

Eleven semi-structured key informant interviews (KIIs) were conducted with representatives from the Ministry of Livestock, Agriculture and Fisheries (MALF), the Tanzania Port Authority (TPA) and Ministry of Transport, the Disaster Management Department (DMD) of the Prime Minister's Office, the TMA and media organisations and organisations focusing on disaster risk management. Interviewees were based in Dar es Salaam, Pemba, Zanzibar, Tanga and Dodoma. National-level interviews covered the Tanga region and other coastal areas.

The qualitative information collected served as the basis for a comprehensive discussion of the benefits of EWSs. However, it has not been possible to isolate the specific impacts of the MHEWS project due to a number of constraints:

- Several other interventions were implemented during the same period (described in section 3.3), all contributing to improving EWSs in Tanzania.
- Lack of detailed data on the intensity of weather-related events (in order to compare changes in losses over time relative to intensity of shock).
- Lack of precise information on who received messages, to make comparisons over time of changes in behaviour related to receiving that information.

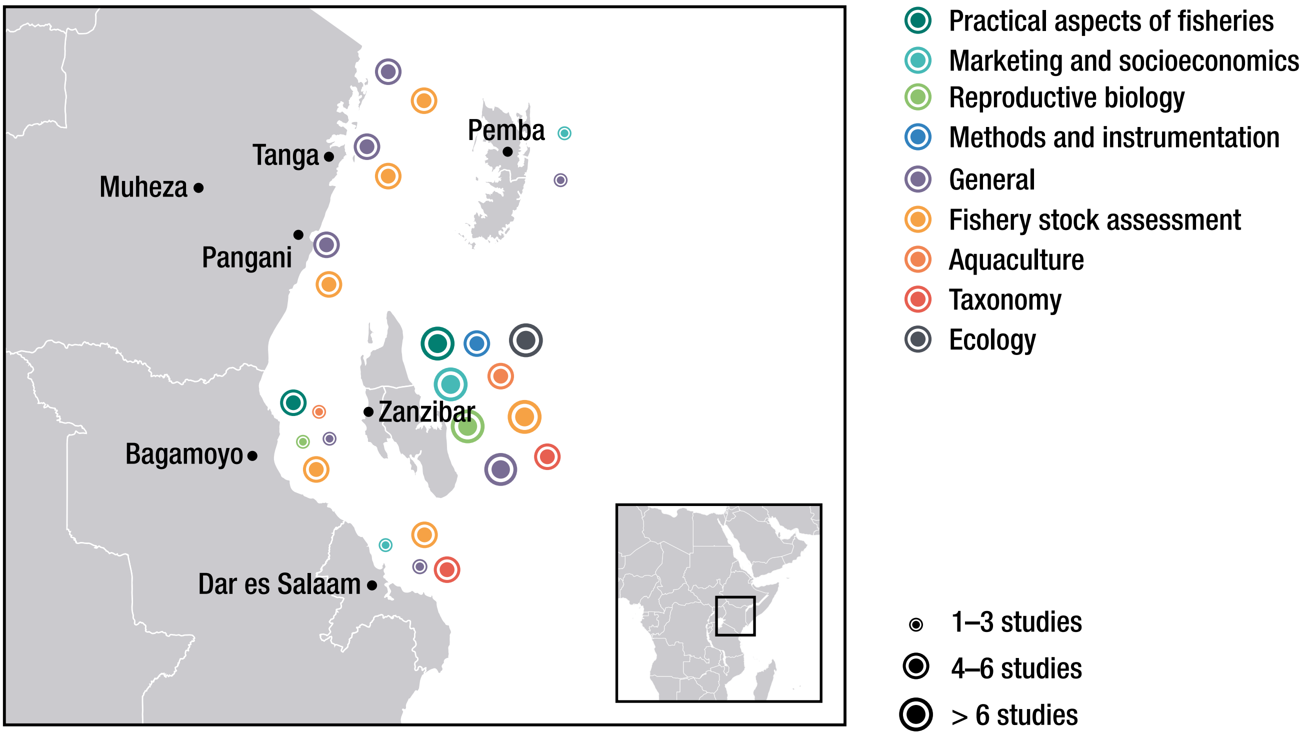
A quantitative estimation of the different dividends could be explored in the future given more time and resources.[9]

4.2 The context of the study: Tanzania's coastal areas

Each day around 50,000 fishermen work at sea off Tanzania's coastline. Another 15,000–20,000 people work on commercial seaweed farms, and another 3,000 on their own small-scale farms (Met Office, 2018) (see Figure 7).[10] Seaweed farming is particularly affected by weather variability, notably strong winds and waves, which can make it difficult and dangerous to tend the lines of growing seaweed suspended between the high and low water marks.

The global species database FishBase reports that Tanzania has one of the world's richest fishing grounds, with more than 1,700 recorded species, 47 of which are commercially important.[11] Fisheries are a significant source of food and nutrition, providing about 22% of animal protein in the Tanzanian diet (World Fish Center, 2020). Fisheries are also important to Tanzania's economy, providing export revenue and accounting for about 35% of rural employment (4 million jobs). About a quarter

Figure 7 Studies of marine fisheries along Tanzania's coastline from Tanga to Dar es Salaam



Source: Jiddawi and Ohman (2002: 518).

9 This could be done using an experimental design or other methods that control for selection bias by constructing credible control groups for comparisons (propensity score matching, regression discontinuity design, difference-in-differences, fixed effects).

10 According to the Food and Agriculture Organization of the United Nations (FAO), there are two main areas in Tanzania where cultivation of seaweed is historically practiced: the east coast of Zanzibar where cultivation of seaweed is commercial and the Tanga region, where collection of seaweed has been a sporadic economic activity (FAO, 1991).

11 www.fishbase.org/country/CountryChecklist.php?what=list&trpp=50&c_code=834&csub_code=&cpresence=present&sortby=alpha2&vhabitat=commercial.

of the population depend on coastal resources or inland lakes for their livelihoods. Around 97% of fish is sourced from small-scale fisheries. However, due in part to harmful fishing practices the sector is contracting (USAID, 2015).

4.3 Main findings of the study

4.3.1 Improvements in communicating weather information

Overall, stakeholders reported that MHEWS had brought about positive changes. A number of interviewees reported that people are now more familiar with the benefits of weather information and how to receive it. Intermediaries, including the media, are also more confident in interpreting and conveying weather information as the information provided by MHEWS is more accessible, user-friendly and easier to understand. Community involvement in developing warning products during the inception phase 'has led people to believe in the product 100%' (KII, Dar es Salaam, 11 September 2019).

As community stakeholders noted in two interviews:

> Fishermen in coastal areas were using weather information to plan their activities a long time ago before MHEWS, but MHEWS made it easier for them to receive the information (Dar es Salaam, 12 September 2019).

> We can see that there is increased demand for weather information. We also see an increased interest from the comments we receive through our social media (Dar es Salaam, 12 September 2019).

A journalist also noted being able to report weather forecasts more effectively than previously:

> Before MHEWS the information shared was very long, but now it is a short message and it is much more easily shared (Phone interview, 12 September 2019).

The same interviewee reported that local journalists had been trained in workshops to communicate information more effectively, and as a result felt more confident answering questions posed by users of the services in call-in radio programmes or online platforms. Thanks to the workshops, journalists were also more interested in reporting on the weather.

TMA forecasts appear to have significantly improved in recent years: several government interviewees confirmed that, five years previously, the accuracy of weather information was less than 50%, but was now more than 80%. This improvement is not a direct outcome of MHEWS, but improved weather forecasting has certainly increased the effectiveness of early warnings. TMA staff reported that MHEWS had also had a positive impact on TMA itself, prompting the agency to rethink how to package weather information and involve users in the design and development of information services.

It was widely reported that the increased legibility and accuracy of weather information means that users not only understand it better, but also appear to trust it more. As people see how weather information can benefit them, more are using the MHEWS product. Interviewees noted that coastal communities were well-prepared for Tropical Cyclone Kenneth in April 2019.

The MHEWS initiative, and the way in which weather information is provided, appears to have triggered further action at the local level. According to one key informant: 'MHEWS happened then other projects started' (Dar es Salaam, 11 September 2019). Some of the ways users said they would like to receive information during the stakeholder consultations (e.g. noticeboards and LCD screens at ports and BMUs, or SMS) were later implemented in other initiatives. As one stakeholder noted:

> Because of MHEWS we know how to communicate this information to the broader public. We receive the information and then we elaborate according to local circumstances … After MHEWS we started using more of public address equipment (Phone interview, 11 September 2019).

Another example is the case of Pemba, an island off the coast, where local authorities send district-specific weather information to communities. Warnings are issued for high-impact weather conditions as well as general weather information/forecasts for normal use (a 10-day forecast including advisory information from the TMA). The authorities use weather information from the TMA to produce practical, localised advice tailored to fishing and seaweed farming activities. This advice centres on when people should increase economic activity and when to avoid doing certain things. As one informant explained:

> For fishermen it is important to be aware of the dangers posed by extreme weather events. For example, they get informed about instances of high waves and strong winds and they are also given specific advice on whether to go fishing or not. However, they also use this information to better plan their economic activities, as when there are high waves, they are not going to be able to catch fish. The same holds for the seaweed farmers. For example, for seaweed farmers it is important to know the rainy days ahead of time as it is crucial for planning the drying of their products (Phone interview, 10 September 2019).

In addition to more established communication channels (radio, TV), a system was also established where registered users receive information on their phones via SMS. Users receive information on the expected event, its timing and how to respond. Community leaders were trained to communicate information through other public engagement activities. As one stakeholder explained: 'when we do awareness (on other unrelated issues) to the communities we incorporate the MHEWS component' (Phone interview, 10 September 2019).

Similarly, in Tanga, weather information comes predominantly through local radio stations and SMS messages. Fishermen and seaweed farmers use the information to inform household decision-making and for recreational activities (for example, when to play outdoor sports such as football). Weather information and warnings were used in a similar way in Pemba.

In Tanga, users and intermediaries agreed that presenting the weather information using colours and symbols was clear and useful. The training people received helped them interpret the information, which prior to MHEWS they had found hard to understand and paid little attention to.

The increase in information dissemination – from disseminating weather alerts in community meetings to local radio broadcasts, TV announcements, SMS and social media – means that information is received quickly and is reaching more people. As one community leader in Tanga explained:

> In the past, not even TMA was known to most of the users in remote areas; currently more information is provided and reaching users in rural areas (Tanga, 13 September 2019).

People in Tanga have also been made aware of the importance of using weather information to avoid accidents at sea:

> Two years ago, fishermen went fishing to Kenya based on their own weather observation and experience, disregarding a weather alert that had been issued [and as a result] they lost their lives and property (Tanga, 13 September 2019).

4.3.2 Limitations of community weather information

Despite successes, a number of challenges remain. These are largely beyond the scope of MHEWS, but need to be addressed if the service is to have wider impact.

Stakeholders involved in disaster preparedness admitted that warning messages do not always reach communities, and that community preparedness and response capacity is limited. One explanation for this is the lack of resources, and the fact that different government bodies are responsible for warnings related to different risks. Seasonal forecasts were outside the scope of MHEWS, but stakeholders noted that this information is communicated very slowly and inefficiently through official channels. The government communicates these forecasts through official letters, and there is no mechanism to reach the village level. It is in any case difficult for people to understand seasonal forecasts (for example, what 'below normal' rainfall means).

A lack of evacuation plans was also cited as a limitation. As one stakeholder explained:

> There was a tsunami warning a few years ago in Dar es Salaam and people were stuck in traffic. If disaster had hit there would have been thousands and thousands of people hit in their cars (Dar es Salaam, 10 September 2019).

This was also demonstrated during an evacuation along the southern coast of Tanzania following the alert from Cyclone Kenneth in April 2019:

> It took long to evacuate people as the rescue teams had to go from door to door to inform people. In addition, the evacuation centres were ill-prepared as there was no food or water (Dar es Salaam, 10 September 2019).

Other interviewees agreed that MHEWS messages do not always reach isolated or remote areas. As one journalist noted:

> In a recent case of bad weather although the warning reached community leaders they did not manage to inform all fishermen who went fishing anyway. In addition, community leaders are often also not reachable as some of them live in remote areas and their phones often run out of battery or do not have reception. Finally, sometimes we cannot send SMS to all users. Another challenge is the regulation that we have to get permission from superiors before we send information to the users (Phone interview, 10 September 2019).

One interviewee observed that 'the average fisherman continues to rely mostly on indigenous knowledge (rather than TV or radio)' (Dar es Salaam, 10 September 2019).

Another limitation is that, even when people receive information on time, they sometimes fail to take appropriate action. Some receive information but do not take it seriously because they have never had a very bad experience related to adverse weather.

In addition, although regional information issued by the TMA is considered fairly accurate, it is more difficult to produce detailed, localised warnings. The TMA can only provide localised information where it has access to long-term data. For example, there are only a handful of observation stations in Tanga, and therefore a lack of localised forecasts. This means that extreme weather events are often accurately predicted, but end up affecting another part of the coast. This might be why some people have been disregarding warnings. Another suggested motive for inaction is that fishing during adverse weather conditions could be more profitable as the catch can be sold for a higher price.

Another widely reported issue is that, despite information being presented in a much clearer, less technical way, in some instances people still do not understand it. The media has sometimes misrepresented information, and one key informant stated that there have been examples where exaggerated reporting has led to unnecessary panic. The TMA is reportedly trying to address this misrepresentation of data through seminars and capacity-building activities with journalists, and efforts have been made to further simplify information.

Similar limitations were reported in Tanga. Many fishermen do not watch television or listen to the radio, and they lack internet access. Frequent power outages lead to delays in receiving warning messages and there are persistent problems with interpretation and inattention. As a result of these issues, and due to local cultural practices that are beyond the scope of this study, many fishermen continue to rely predominantly on indigenous knowledge for their weather predictions (see Box 2), and use MHEWS as a secondary source of information, where available.

Box 2 Use of indigenous knowledge in Tanga

Fishermen use indigenous knowledge to make weather predictions. These predictions largely depend on seasons and associated average weather conditions e.g. prevalence of *Kusi* (southerly winds during the southern hemisphere winter). Fishermen use their experience to make short-term predictions – dark clouds, for instance, may indicate strong winds – but daily variations mean that scientific weather forecasts are indispensable.

4.4 Resilience dividends associated with investment in early warning systems

4.4.1 The first dividend of resilience

Better communication of extreme weather information is allowing people in Tanga to take precautions based on the weather information they receive, and as a result community members believe that loss and damage from extreme weather has decreased. Actions include making adjustments to homes and anticipating impacts: fixing roofs and doors; evacuating property in a timely manner; repairing/maintaining grass on roofs in preparation for rains; refraining from going fishing; and relocating fish freezers/coolers when heavy rainfall is likely. Local government is also better prepared, engaging in activities to reduce potential damage such as cleaning drains after receiving a forecast of heavy rain.

Stakeholders believe that MHEWS has led to reduced mortality and property damage from extreme weather events along the coast of Tanzania, in particular loss of life and boats being lost or capsizing during bad weather. According to one key informant:

> When users receive warnings they evacuate, and the overall number of people affected is minimised. In addition, as far as marine users are concerned small vessels stop fishing when rough seas are forecast (Phone interview, 10 September 2019).

Another stakeholder, in Pemba, noted that:

> Recently there was a warning for Tropical Cyclone Kenneth, and information was disseminated to users; many people didn't go fishing; those who went lost their boats and risked their lives (Phone interview, 10 September 2019).

4.4.2 The second dividend of resilience

Lower levels of disaster risk in coastal communities in Tanzania appear to have encouraged small increases in investment: in a number of key informant interviews it was reported that some fishermen were able to buy new fishing gear and motorboats and switch to better vessels. Engines are larger now compared to previous years, and people are buying larger boats better able to withstand strong winds. These changes have also created opportunities for traders selling boats and engines. Some have engaged in new economic activities, for example offering water sports. Overall, however, these increases in investment are not widespread – the reduction in risk has not had a significant effect on people's willingness to take 'positive risks' and make new investments, largely because most are involved in small-scale economic activities that do not allow for savings. Risk from extreme weather events is only one of the obstacles preventing households in coastal communities from investing in potentially more profitable activities:

> Eighty percent of our population depends on subsistence agriculture. People farm to meet their own nutritional needs. Therefore, decisions to invest more are only relevant to very few people who are involved in commercial agriculture (Dar es Salaam, 10 September 2019).

In the FGDs in Tanga, participants agreed that extreme weather events limit saving and reduce the profits from fishing by rendering certain fishing areas inaccessible and damaging equipment. Such weather events also reduce profits from farming by damaging seeds, plants and harvests. FGD participants agreed that they had greater capacity to save now as better warnings meant lower risks, and increased productivity has created employment in farming, fishing and sales.

However, community members in Tanga also underscored that these positive changes only benefited a small proportion of people. Most fishermen are still not able to save, and where they are, this is often linked more to microfinance initiatives: even if 'the risks have been reduced, people in Tanga are poor and therefore they don't invest' (Tanga, 13 September 2019).

In addition, some of the positive changes in productivity are offset by the declining number of local fishermen in past years due to the impacts of climate change on the sector. Where there has been investment in fishing equipment in Tanga, this is not directly due to the MHEWS initiative; the main reason behind these increased investments is subsidies offered to fishing associations by the government as part of an initiative to mitigate the effects of climate change.

4.4.3 The third dividend of resilience

The study found two types of co-benefits associated with improvements in EWSs. One is through community engagement and training activities, which have led to improved governance, more organised social structures, increased involvement of women in community activities, the creation of social capital through shared learning experiences, and strengthened capacity of civil society to undertake disaster risk management.

The MHEWS service provides weather information that is useful to people and has strengthened local governance and social capital in coastal communities. One interviewee in Pemba, for example, noted that organised training and community meetings helped strengthen relationships between community members and their leaders. One stakeholder noted that communities that had participated in MHEWS activities (i.e. pilot communities) were now better organised.

The second co-benefit is economic: improved weather forecasting has allowed local communities to use forecasts for economic planning even where no extreme weather is expected. Some stakeholders reported that weather information was being used on a daily basis to plan economic activities – i.e. not just in relation to avoiding the impacts of extreme weather. It was noted, for example, that people can now catch larger quantities of fish because they can go further out to sea and for longer knowing they will not be affected by adverse weather. For fishermen, information regarding strong winds is the most important, as few fish are available to catch under these conditions. In another example, fishermen can now dry sardines with more confidence because they know when to expect rain. Fishermen can also switch to other income-generating activities, in response to weather alerts including buying and selling fish in local markets and farming. Likewise, it was reported that seaweed farmers now know when to harvest seaweed and farmers know when to conduct activities such as burning grass to clear land before the rains start, increasing productivity and boosting incomes.

Other examples of weather information being used to plan economic activities in Tanga specifically include coconut farmers making better decisions about when to harvest their coconuts (prior to strong winds in order to avoid damage). Alerts of rainfall and strong winds can help restaurants decide whether to cook in the open air, and hence on a larger scale, or allow producers to decide when to make ice cream and cold drinks (juice). Warnings of rain are also important for carpenters, as rainfall affects polishing and drying. Businesses that depend on road transport for their products also need to know if there will be heavy rains as roads are easily flooded and become impassable.

Weather information also helps households plan non-productive activities such as sending children to school and when to play outdoor sports.

Women engaged in subsistence agriculture and seaweed farming benefit directly from better early warnings, as do those involved in the retail fish trade. As one stakeholder commented:

> MHEWS has empowered them by enabling them to make decisions when to buy fish (before scarcity occurs during severe weather days) (Dar es Salaam, 11 September 2019).

Women who sell cooked fish in markets can adjust their income-generating activities if they know bad weather is expected.

Finally, it was reported that, during the campaign to promote the use of MHEWS, certain activities such as advertising created local business opportunities, and motivated some media networks to invest in additional radio and TV programmes. Although these are not economic co-benefits directly linked to using weather information in decision-making, they do represent additional income-generating activities for local communities that arise from the creation of this service.

5 Conclusion: the multiple dividends from early warning systems

This study of EWS implementation in coastal areas of Tanzania suggests that there are significant benefits from enhanced communication of weather information in these communities, many of which could increase over time. However, other types of support and services such as microfinance may be key to realising some of these benefits.

5.1 Resilience dividends arising from enhanced weather information

Results indicate that the early warning service introduced through the MHEWS project has brought about a number of positive changes, principally by increasing the accessibility and usability of weather information and by strengthening the channels through which this information is disseminated. This has resulted in an increase in the use of weather information in coastal communities and beyond, with a number of positive benefits. Some of these were unanticipated by the project and will require further exploration to better understand the scale of change (how many people have benefited and in what way) and sustainability (whether positive changes can be sustained over time).

People have been able to protect themselves from extreme weather events, as might be expected as this is the principal purpose of an EWS. A reduction in the number of deaths and damage to boats and other assets was reported by all stakeholders, although these observations should be further corroborated and quantified by examining time series disaster loss data controlling for storm intensity, including for small-scale hazards. This data was not available at the time this study was conducted. Nonetheless, it appears clear from this study that there are important benefits from improving EWSs in terms of loss avoidance (the first dividend of resilience).

The MHEWS initiative also triggered further action at the local level, initiating what some stakeholders referred to as 'a process of transformation'. A less obvious finding, but one which came out clearly in the interviews and FGDs, is the benefits of having EWSs for household economic planning (the third resilience dividend). For people in coastal communities, where livelihoods are so dependent on the weather, using MHEWS to inform decisions about economic activities, such as when and how far out to fish, has been beneficial, and in some cases has improved incomes.

The reduction in risk associated with extreme weather has not clearly led to higher levels of saving and investment in coastal communities. Risk from extreme weather events is only one of the obstacles preventing individuals from investing in more risky and profitable activities. Microfinance initiatives and programmes offering subsidies for investments to upgrade local businesses (e.g. advanced fishing gear) may help overcome these barriers, and it would be useful to study their potential effects, in combination with improved weather information, in future research. Another interesting issue that merits further study is the question of the socioeconomic starting point, or level, at which people can use information and respond to the lower risk environment by increasing investment.

This potential for economic transformation may not exist everywhere, and results from this study suggest that the second resilience dividend is less likely to arise than the other two from investment in EWSs.

Finally, it should be noted that the MHEWS service had a much wider national reach beyond fishing communities, and it is possible that the impact differs in communities with other characteristics. We were not able to assess this given the focus and scope of our study.

5.2 Implementation

There are also important lessons regarding implementation of EWSs arising from this study. The MHEWS initiative has generated improvements in the communication of weather information and prompted greater local specificity in the messages: district weather information is now being produced with practical localised advice, disseminated through SMS, and is reaching some of the most remote areas. However, a number of challenges remain, which are common to many attempts to implement EWSs. MHEWS was a short-term and relatively low-value project, so many of the challenges may be beyond the scope or remit of the project to address; nevertheless, it is important to acknowledge these as they affect the impact of this service and should be considered in the design of future projects:

- The inability to reach some remote users.
- Persistent limitations in interpreting weather information by users and the media.
- Limited response capacity (e.g. lack of evacuation plans). In addition, there are certain limitations in providing very localised weather forecasts.

Enhancing dissemination channels, including through SMS, infrastructure programmes to increase internet and electricity access, diffusion of mobile phones and use of loudspeakers and better communication and coordination among government authorities with different responsibilities could help address these limitations. In addition, to continue to improve and expand localised weather forecast services, further investment in the capacity of the TMA is critical. The importance of capacity development and training for producers, users and intermediaries of EWSs cannot be emphasised enough. According to Meechaiya et al. (2019), decentralising government responsibilities and resources could bring huge benefits, including higher-resolution risk maps, investment in local monitoring stations, a greater focus on response planning and engagement with communities and marginalised groups. For this to happen, community-based and non-governmental organisation (NGO) initiatives need to be well-integrated within the national EWS, and local agencies will need substantial training and capacity development to meet their new responsibilities. There is also a need to provide regular, tailored training and capacity-building for responders and community members on what to do when they receive warning information.

This study has revealed a range of positive outcomes linked to the provision of targeted early warnings and advice to people living in coastal communities, suggesting that EWSs help increase resilience in places where safety and livelihoods are so highly dependent on the weather. More of these studies will be needed to explore these benefits in more depth and, for example, determine whether they increase over time as the quality of forecasts and trust in the information improve. Quantifying these resilience dividends would also be beneficial. This would help governments and donors understand the contribution that EWS and complementary actions aimed at strengthening resilience, such as microfinance, can make towards sustainable development in relation to other development interventions.

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