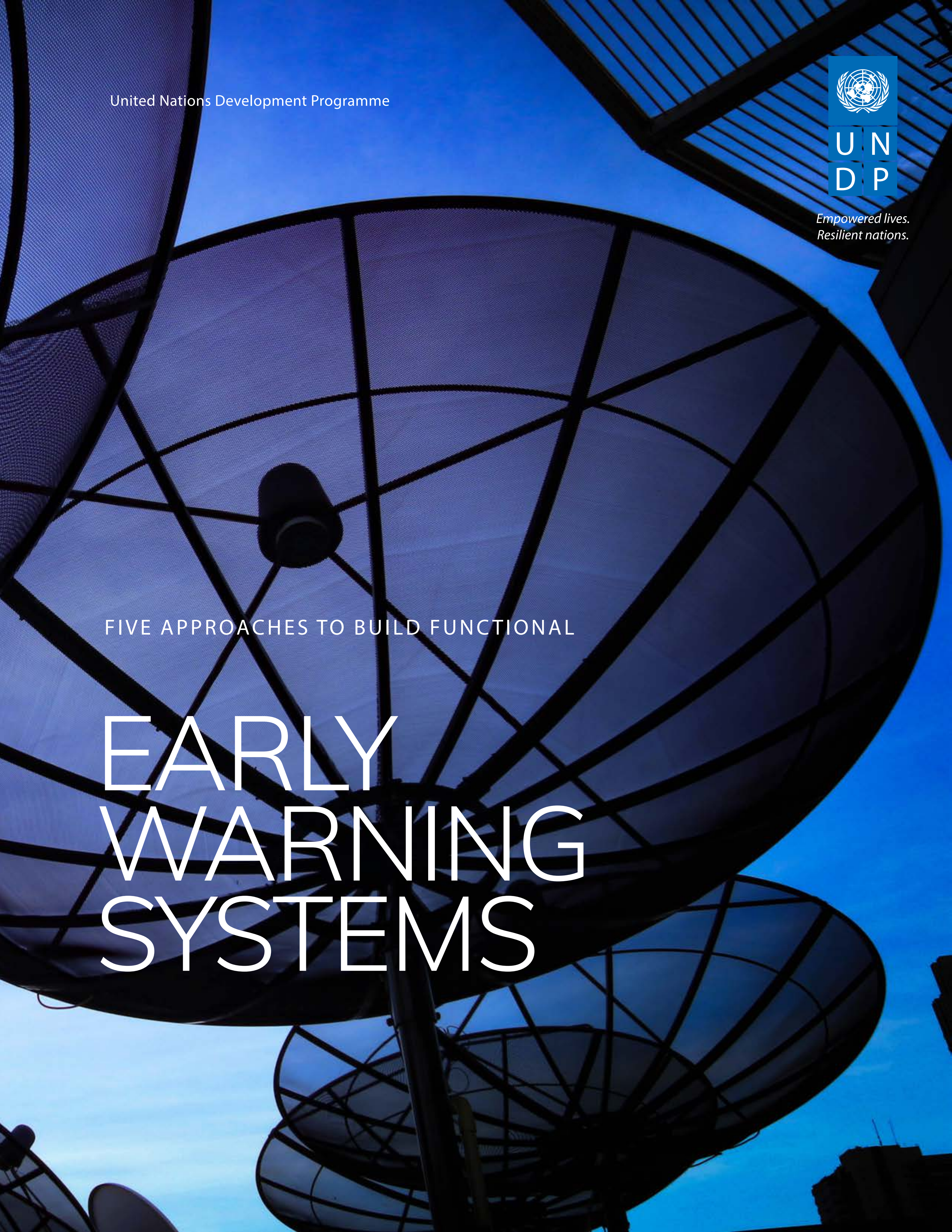

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Empowered lives.
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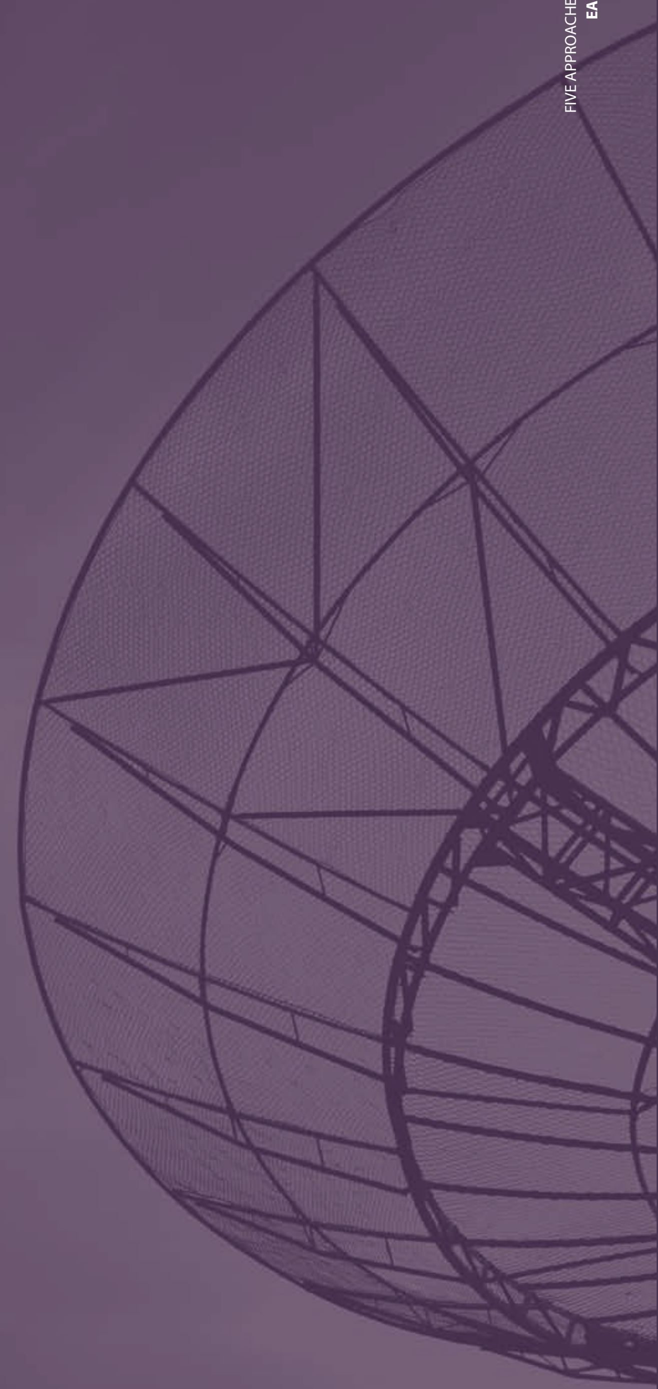
FIVE APPROACHES TO BUILD FUNCTIONAL

EARLY WARNING SYSTEMS



UNDP partners with people at all levels of society to help build nations that can withstand crisis, and drive and sustain the kind of growth that improves the quality of life for everyone. On the ground in nearly 170 countries and territories, we offer global perspective and local insight to help empower lives and build resilient nations.

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This publication aims to support UNDP practitioners and partners (international organisations, nongovernmental organisations, governments, as well as civil society organisations) in the process of setting up or improving early warning systems. Distinct from the many existing step-by-step guides and checklists, this publication identifies targeted interventions which can boost the efficiency and effectiveness of early warning systems in five key areas. It highlights innovative perspectives and associated solutions to common challenges in the early warning process, such as budget constraints, limited technical and institutional capacities, as well as the lack of human resources. Through its practical approach, whereby theoretical considerations are underpinned by concrete examples of projects and solutions, this publication also contributes to the sharing of local knowledge and can inspire the spread and export of solutions to different countries and communities.

The publication is divided into two main sections:

- In the first part, **theoretical tools** to understand the legal and institutional framework needed for the early warning process are presented, followed by an introduction to what early warning systems are and what they are composed of. To conclude this introductory section, common challenges encountered during the early warning process are reviewed.
- In the second, core part of this publication, the aforementioned challenges are addressed through a **catalogue of solutions**. A number of projects, both at the global and regional levels (Eastern Europe, Caucasus, Central Asia), have been analysed to highlight how to address specific challenges and how to efficiently implement early warning systems. These are divided into five intervention areas:
  - Institutional and legal capacity development
  - Technology deployment
  - Community outreach and community-based solutions
  - Private sector engagement
  - International co-operation and data sharing.

In each of these intervention areas, an illustrative selection of practical solutions implemented within development projects is presented. These are disaster risk preparedness measures developed in regions that are facing increases in climate-related hazards, combined with high levels of pre-existing social vulnerability.

This publication is not intended to be a comprehensive guide to the implementation of early warning systems, but rather a practical tool to help boost early warning systems through the five aforementioned intervention areas. Neither these five areas nor the solutions cover all possible intervention possibilities and measures; rather, they highlight innovative and cost-efficient methods that have already been successfully tested.

I. MOTIVATION

The number and severity of natural disasters is rising as the climate undergoes changes, and as the world's population continues to increase. This trend is exacerbated by populations clustering in vulnerable areas, by the degradation of the environment, and by the expansion of areas at risk due to climate change.

An estimated

90%

of recorded major disasters caused by natural hazards from 1995 to 2015 were linked to climate and weather, including floods, storms, heatwaves, and droughts (UNISDR). As a result, direct disaster damage costs are exponentially increasing, from

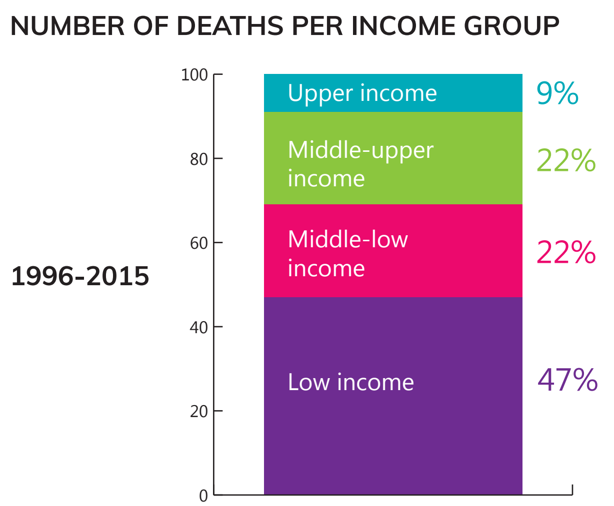
USD 75.5 billion

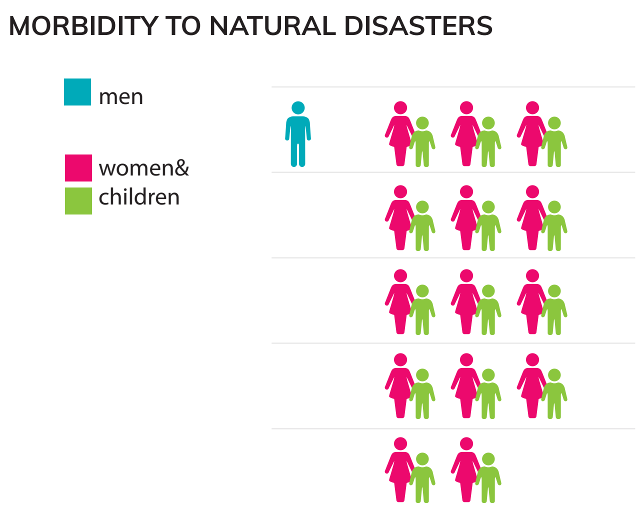
in the 1960s to over a trillion dollars for the 2007-2016 decade (CRED, 2018).

Disasters threaten especially the segment of the population which is more vulnerable, largely because they are both highly sensitive to hazards and have limited capacities to cope with the resulting impacts. Around 85% of the people exposed to earthquakes, cyclones, floods, and droughts live in developing countries, and more than 69% of all people killed by disasters between 1996 and 2015 were classified as receiving a low or lower-middle income (CRED-UNISDR, 2016).

Disasters disproportionately affect those with the lowest socioeconomic status – including those suffering from poverty, as well as minorities and discriminated groups. In many developing countries, women's lower socioeconomic status - which implies an unequal access to information, health, and assets -contributes to a reduced ability of women to cope with disasters. This has led to gendered inequalities in the death ratios and livelihood losses during natural hazards. A 2013 UNDP report found women and children to be 14 times more likely to die due to a natural disaster (UNDP, 2013). During the 2004 Indian Ocean tsunami, more than 70% of the victims were women. Similarly, in 2008, cyclone Nargis in Myanmar killed twice as many women aged 18- 60 as men. In 2005, Hurricane Katrina affected predominantly African American women, illustrating the fact that poorer minorities are more exposed to natural disasters.

Figure 1. Natural disaster and disequality





Disasters threaten the food security of the poorest people, and if measures are not taken to mitigate disaster risks and impacts, hazards may cause or create circumstances promoting economic downturns and civil disorder in areas already impacted by disease, poverty, conflict, and the displacement of people.

Despite the pressing need for innovative techniques and efforts to reduce risk in disaster-prone areas, several factors have limited the spread of technologies and strategies to face natural hazards and climate change. This publication highlights examples and identifies strategies to overcome difficulties using one of the most valuable - yet often neglected - tools for dealing with climate change and disaster risk: early warning systems.

Early Warning Systems (EWS) are complex processes aimed at reducing the impact of natural hazards by providing timely and relevant information in a systematic way. If effectively implemented, EWS can contribute to increasing the resilience of developing countries to natural disasters and climate-related risks, and offer simultaneous support for the achievement of the Sustainable Development Goals (SDGs) in reducing the loss of life and livelihood.

The benefit of EWS has been proven on several occasions in recent years. In Bangladesh, for example, the use of modern EWS helped limit casualties from cyclone Sidir in 2007 to 3,000 -

only 1%

of the 300,000 casualties caused by the equally strong cyclone Bhola in 1970, despite a population that has grown rapidly in the interim. The Cuban hurricane EWS helped prevent mortalities from Hurricane Gustav on the island - the strongest hurricane in Cuba in the last 50 years – which did not result in a single death despite the destruction of 100,000 houses. The early warning system, coupled with the country's response capacity, ensured a prompt evacuation to emergency shelters.

The value of EWS can also be measured in monetary terms through cost-benefit ratios, which can manifest gains of up to

500:1

depending on the hazard type and on the overall response capacity of communities (Teisberg & Weiher, 2008).

In China, for example, an initial investment of USD 3.15 billion to reduce the impact of floods managed to avert losses of approximately USD 12 billion. Teisberg and Weiher (2008) furthermore calculated that the ratio of benefits to costs for EWS is around 3:1 for hurricane warnings, 4:1 for tornado warnings, 500:1 for flood-prone areas (e.g. Bangladesh), and 2500:1 for heat waves in densely populated urban areas (e.g. Philadelphia).

Despite the proven effectiveness of well-functioning EWS, weak strategies, limited capacities, and fragmented implementation of EWS often lead to limited or no benefits. EWS are complex processes that involve a wide range of stakeholders and require both national and international co-operation. This complexity requires well thought-through design and strong institutional capacity to be addressed correctly. Therefore, in recent years UNDP, together with other UN agencies such as UNISDR and WMO, has increased efforts to upgrade EWS on a global scale. Through these efforts, UNDP has developed as of early 2016 a

USD 694 million

portfolio, giving access to climate-related information to

75 countries

and developing

67 EWS

(Tadross, 2016). Currently, UNDP is completing 96 early warning and preparedness projects in line with the Sustainable Development Goals.

UNDP Eurasia has been active in upgrading and implementing early warning and preparedness policies in South East Europe, South Caucasus, and Central Asia - regions highly vulnerable to natural disasters and climate change risks. The extensive mountain chains, grasslands, and river systems particularly expose these regions to climate change and natural hazards. Earthquakes, floods, landslides, extreme weather events, and droughts - which in some areas are expected to either increase in number and intensity (or both) due to climate change - not only regularly cause human and material loss, but also lead to large-scale economic and environmental damage. In addition to the high hazard exposure of the region, most countries are constrained in their financial resources and disadvantaged by their physical and social vulnerability. The confluence of these factors makes the region particularly vulnerable to natural disasters.

UNDP Eurasia has initiated different programmes to upgrade the preparedness and resilience of governments and communities throughout the region. The ClimaEast programme, for example, has helped

192,000

people in Belarus, Moldova, Ukraine, Russia, Azerbaijan, Armenia, and Georgia become more resilient to the consequences of climate change[1]. The SEE-Urban project focusses on making the cities of South Eastern Europe more resilient[2]. Disaster risk reduction policies have been developed under the guidance of UNDP Eurasia in Kyrgyzstan, Tajikistan, Armenia, Kazakhstan, Serbia, and the former Yugoslav Republic of Macedonia.

Within these regional efforts, many national to local-scale projects have specifically focussed on the implementation of EWS, or incorporated EWS into broader adaptation and resilience-building projects. This publication focusses on showcasing early warning system examples from both inside and outside the Eurasian region. It provides, through case studies and project examples, exemplars of how to address challenges in the implementation of EWS. The focus is on highlighting the importance of strengthening institutional frameworks, of utilising modern technologies, of targeting and involving communities in the design and implementation of EWS, of engaging the private sector, and of fostering international co-operation.

1 From the ClimaEast website: 'The EUR 19.2 million package consists of two components: the first, with a budget of EUR 11 million and implemented by UNDP, consists of a number of Pilot Projects that support the development of ecosystems-based approaches to climate change; the second is a Policy component that seeks to foster improved climate change policies, strategies and market mechanisms in the partner countries by supporting regional cooperation and improving information access to EU climate change policies, laws and expertise'.

2 From SEE-Urban website: 'SEE-Urban is primarily aimed at strengthening the capacity of local authorities and institutions to reduce the risk of elemental disasters and other accidents and risk management in six SEE countries by formalizing local cooperation in the area of risk reduction.'

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CONTENTS

II. LIST OF ACRONYMS

ABU	Asian-Pacific Broadcasting Union
ACTED	Agency for Technical Cooperation and Development
CAP	Common Alerting Protocol
CCA	Climate Change Adaptation
CIS	Commonwealth of Independent States
CBO	Community Based Organisation
COP21	21st United Nations Climate Change Conference
CPESS	Civil Protection and Emergency Situations Services
CPD	Continuous Professional Development
CSR	Corporate Social Responsibility
CREWS	Climate Risk Early Warning System
DEWS	Drought Early Warning System
DRR	Disaster Risk Reduction
DWRM	Directorate of Water Resources Management
EC	European Commission
ECHO	European Civil Protection and Humanitarian Aid Operations
EIEC	Environment Information and Education Centre
EDO	European Drought Observatory
EMA	Georgia Emergency Management Agency
EMMA	European Multi-services Meteorological Awareness
ESA	European Space Agency
EU	European Union
EUCOS	Eumetnet Composite Observing System
Eumetnet	European Union Meteorological Network
EWC	Early Warning Conference
EWS	Early Warning Systems
FDMA	Japanese Fire and Disaster Management Agency
FFEWS	Flash Flood Early Warning System
FEWS-Net	Famine Early Warning System Network
FFEWS	Flood Forecasting and Early Warning System
FRM	Flood Risk Management
fYR	former Yugoslav Republic
GCF	Green Climate Fund
GCMs	Global Climate Models
GEF	Global Environmental Fund
GIS	Geographical Information System
GFDRR	Global Facility for Disaster Risk Reduction
HECRAS	Hydrologic Engineering Center's River Analysis System
ICIMOD	International Centre for Integrated Mountain Development
ICT4DRR	Information and Communication Technology for Disaster Risk Reduction
IFRC	International Federation of Red Cross and Red Crescent Societies
IMC	Inter Municipal Cooperation
IRH	Istanbul Regional Hub
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
JRC	Joint Research Centre
LGSAT	Local Government Self-Assessment Tool

LLRM	Local Level Risk Management
MHEWS	Multi Hazard Early Warning System
MKFFIS	Macedonian Forest Fire Information System
MoENRP	Ministry of Environment and Natural Resources Protection of Georgia
MPE	Multi-sensor Precipitation Estimates
NHMS	National Hydro-Meteorological Service
NEA	National Environmental Agency
NGO	Non-Governmental Organization
O&M	Operation & Maintenance
PPEW	Platform for the Promotion of Early Warning
PPPs	Public-Private Partnerships
PTWC	Pacific Tsunami Warning Center
SDGs	Sustainable Development Goals
SDC	Swiss Agency for Development and Cooperation
SECO	State Secretariat for Economic Affairs
SEE	South East Europe
SEE-MHEWS	South-East European Multi Hazard Early Warning System
SHS	State Hydrometeorological Service
SMS	Short Messages System
SOP	Standard Operating Procedure
UN	United Nations
UNDP	United Nations Development Programme
UNGA	United Nations General Assembly
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
UNISDR	United Nations International Strategy for Disaster Reduction
UNMA	Uganda National Meteorological Authority
USD	United States Dollar
WPF	Weather Philippines Foundation
WMO	World Meteorological Organization

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1. EARLY WARNING SYSTEMS

What are they, how did they become central to international risk reduction strategies, and what are the primary obstacles for effective implementation?

The importance of EWS for global to local climate change adaptation and disaster risk reduction strategies has been increasingly recognised during the last 15 years. During this time, EWS have progressively received attention within the framework of international treaties, conferences, and action plans. To illustrate how EWS became one of the central elements of many international strategies, this chapter will first review relevant international legislation and treaties.

Afterwards, to understand how an early warning system can be efficiently implemented, definitions for EWS and their components (including variants) are presented.

Finally, this chapter will cover some of the challenges encountered both at a global and regional level while implementing EWS. These challenges open up new opportunities to use innovative and sustainable solutions, which will be further explored in the following chapter.

1.1. A history of early warning initiatives: from the first international Early Warning Conference to the Sendai framework

Large-scale disasters such as the 2004 Indian Ocean tsunami have called for a response from the international community and demanded development of appropriate legislation and institutional capacities. Shortly after the 2004 tsunami disaster, then-UN Secretary-General Mr. Kofi Annan made a request to improve EWS to avoid similar dramatic impacts of disasters in future. This request has been articulated throughout the years in various ways. Thanks to the various conferences, agreements, and frameworks for action, special attention has increasingly been devoted to EWS.

The first internationally-recognised effort toward the development of EWS was achieved through several **early warning conferences.** In 1998, the first-ever international Early Warning Conference (EWC'98) was held in Potsdam, Germany. Here, the international community gathered to discuss state of the art knowledge on EWS. Five years later, in 2003, a second conference (EWC II) was held in Bonn, Germany. In this conference, the focus lay on how to integrate early warning into relevant public policy. The conference underlined that even though warnings are based on technical information and monitoring of risks, public policies need to guarantee that technical risk forecasts are translated into warning and that action is taken in response to a warning. The discussion initiated by the conference was fundamental for the future development of EWS because it empowered local governments, local institutions, and communities to participate in the entire policy-making process, promoting awareness and response preparedness. It signalled the transition, for EWS, from a merely technical product to a socio-political embedded process.

The third international conference on early warning (EWC III) in 2006 took place in a more prevention-oriented context. In fact, it followed not only the above-mentioned 2004 tsunami disaster but also the 2005 World Conference on Disaster Reduction, whereat the role of prevention was heavily emphasised. The EWC III conference, which ran under the slogan '*from concept to action*', aimed at translating existing knowledge on early warning into concrete implementation. Many innovative early warning projects were showcased for potential financial support and implementation. Discussions were centred on the identification of unutilised potential in early warning, and the conference itself prepared the ground for multi-disciplinary scientific debate on latest practices and research. Thanks to this conference, many gaps between conceptual design and practical/feasible implementation of EWS were identified.

As these early warning conferences raised international interest on EWS, the role of the United Nations in their promotion became gradually more institutionalised. With the creation of the **United Nations International Strate-**

gy for Disaster Reduction (UNISDR), in 2000, a dedicated inter-agency task force and an inter-agency secretariat for disaster reduction were established. The creation of a designated task force on disaster risk reduction underlined the importance of the topic and stimulated dialogue on how to increase societal resilience. Under the direct authority of the Under-Secretary-General for Humanitarian Affairs, UNISDR has the mandate 'to serve as the focal point in the United Nations system for the coordination of disaster reduction and to ensure synergies among the disaster reduction activities of the United Nations system and regional organizations and activities in socio-economic and humanitarian fields' (UN General Assembly, 2002).

One of the most notable UNISDR contributions to EWS was the development of the **Platform for the Promotion of Early Warning** (PPEW). The PPEW started operations in 2004 with the goal of contributing to developing early warning and preparedness systems. Its work primarily covers the following activities: advocating for better EWS, collecting and disseminating information on best practices, stimulating co-operation among early warning actors, and developing new ways to improve EWS. The PPEW strongly supports the concept of people-centred EWS that will be discussed later in this publication. Thanks to its platform approach, the PPEW has supported the necessary international action that makes it possible to combine technical early warning capacities with policy and practice.

Together with the secretariat of the Third International Conference on Early Warning, the PPEW compiled a **Checklist for Developing EWS** still used today (UNISDR, 2006). The checklist summarises best practices and information gathered during the conference, together with significant input received from organisations and professionals within the United Nations system and beyond.

Another important milestone in the process of institutionalising EWS is the adoption of the '**Hyogo Framework for Action 2005-2015**: Building the Resilience of Nations and Communities to Disasters' at the 2005 World Conference on Disaster Reduction. The framework included specific references to early warnings, and encouraged the development of people-centred systems. In particular, under 'Priority for Action 2: Identify, assess and monitor disaster risks and enhance early warning', many activities belonging to EWS were encouraged. The Framework for Action encouraged the development of risk assessments and maps, the elaboration and dissemination of multi-risk indicators and vulnerability parameters, and the production of data and statistical loss information. When indicating the pathway that early warning should follow in the ensuing decade, the Framework used the key term 'people-centred', and suggested the integration of information systems, public policy, scientific and technological development, as well as data sharing, space-based earth observation, climate modelling, and forecasting.

Through the early 2000s, the dialogue on EWS conceived and discussed them as a tool to be used as part of a wider disaster risk reduction strategy. Only with the publication of the fourth report of the **Intergovernmental Panel on Climate Change** (IPCC) in 2007, which contributed to the IPCC being awarded a Nobel prize in the same year, did it become clearer the role climate change can play in intensifying the severity and frequency of natural hazards - and hence disasters. Later, the 5th assessment report of IPCC, in its summary for policy-makers, underlined the following:

Climate-change-related risks from extreme events, such as heat waves, extreme precipitation, and coastal flooding, are already moderate (high confidence) and high with 1°C additional warming (medium confidence). Risks associated with some types of extreme events (e.g., extreme heat) increase further at higher temperatures (high confidence).

IPCC, 2014: AR5, Impacts, Adaptation, and Vulnerability Summary for policymakers

By highlighting the linkages between disasters and climate change, the IPCC reports play a major role in extending the application of EWS as a way to support climate change adaptation interventions: through warning of any potential impacts, building technical capacities to model and understand climate change, and monitoring ongoing changes in climate. This results in policies and international agendas that address disaster risk and climate change as two sides of the same coin.

The nexus between climate change adaptation, disaster risk reduction, and sustainable development became internationally recognised in 2015, when the international community made a series of commitments towards a more sustainable future which are characterised by a cross-cutting approach. Three global agendas were adopted: the Paris Agreement, the Sustainable Development Goals (SDGs) within the framework of the 2030 Agenda for Sustainable Development, and the Sendai Framework for Disaster Risk Reduction 2015-2030.

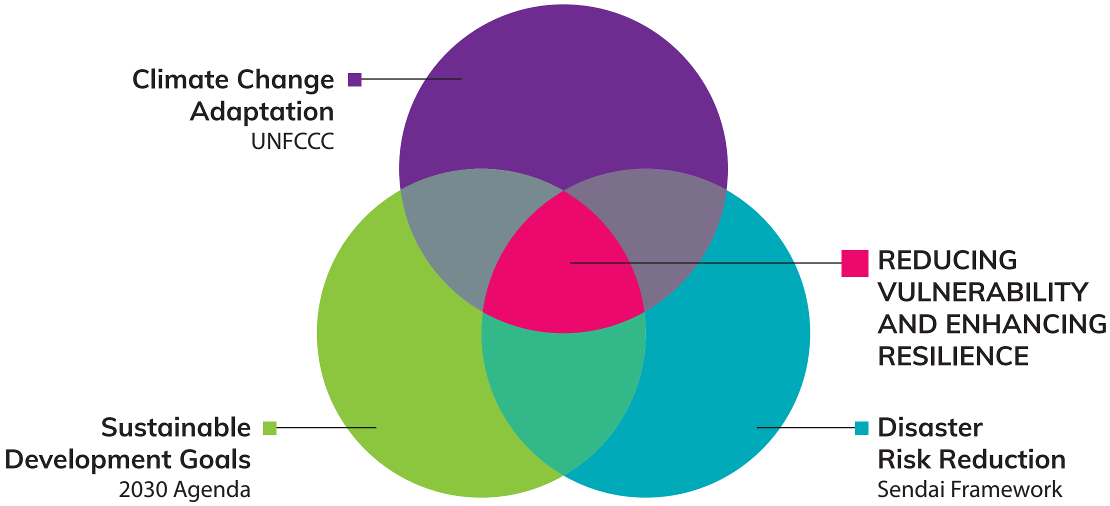
As represented in *Figure 2,* these three global agendas altogether have created a comprehensive framework to reduce climate and risk vulnerability and increase resilience. Although the Paris Agreement focused specifically on climate change mitigation and the Sendai framework on disaster risk reduction, these agendas all underscored the message that it is impossible to have an impact and prompt significant change if solutions are vertical or siloed. A transition to a low-carbon society, for example, not only mitigates the intensity of changes in the climate, but also indirectly contributes to creating resilient societies and economies.

The **Paris Agreement**, approved during the 21st United Nations Climate Change Conference (COP21), has made clear the intention of the international community to channel energies and financial resources to reduce emissions and to advance adaptation to climate change. Besides the main goal of the Agreement to keep global temperature increases well below the threshold of 2°C by the end of the century, during the conference solid attention was dedicated to the importance of climate information for the developing of climate forecasts and monitoring of climate change with the overall goal of improving resilience to climate change. This is reflected in a paragraph of the Paris Agreement encouraging parties and stakeholders to:

(c) Strengthen scientific knowledge on climate, including research, systematic observation of the climate system and EWS, in a manner that informs climate services and supports decision-making;

Paris Agreement, Article 7.7

Figure 2. Conceptual representation of the intersection between the SDGs, DRR, and CCA agendas 2015-2030 (UNFCC C, 2017)



The Agreement, therefore, highlights how the international community has become aware not only of the threats coming from climate change, but also of the importance of monitoring and early warning for a climate-resilient future.

With the adoption of the **Sustainable Development Goals** (SDGs), the linkage between climate change and disasters became even clearer and, above all, the importance of cross-cutting solutions was emphasised. Many of the SDGs, in fact, can be partially attained by shaping a low-carbon, climate and disaster-resilient society. This is the case for SDG 1: reduce poverty, SDG 2: reduce hunger and ensure food security, SDG 6: ensure water and sanitation, and even SDG 5, which addresses female empowerment and gender equality. Disasters and climate change undermine basic human rights (rights to life, food, shelter, heath, well-being, and employment for all) and imperil the lives and livelihoods of the most vulnerable groups. In addition, some of the SDGs explicitly address climate change and disaster risk and promote early warning. SDG 11 highlights the importance of making cities safe and resilient, a part of the global disaster risk reduction agenda. One of its specific targets aims to:

By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030 [...]

Sustainable Development Goals 2015-2030, Goal 11B targets

Goal 13 on climate action addresses the importance of mitigating climate change and reducing its impacts. More specifically, Goal 13 encourages the spreading of EWS to reduce climate change-related hazards through the following targets:

- **Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries [...]**
- **Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning**

Sustainable Development Goals 2015-2030, Goal 13 targets

With the adoption of the '**Sendai Framework for Disaster Risk Reduction** 2015-2030' by the World Conference on Disaster Reduction, the importance of early warning not only for disaster risk reduction, but for sustainable development generally, was enunciated. The Sendai Framework highlights, through its seven targets and four priorities for action, specific priority actions to undertake for a risk resilient society. Through the seventh target in disaster risk reduction, the Sendai framework addresses early warning through its recommendation to:

Substantially increase the availability of and access to multi-hazard EWS and disaster risk information and assessments to the people by 2030.

Chart of the Sendai Framework for Disaster Risk Reduction 2015-2030, Target 7

During the Conference on Disaster Risk Reduction in Sendai, France's Minister of Foreign Affairs Laurent Fabius proposed a plan to integrate climate risk into early warning strategies. Responding to this appeal - and as part of the climate change solutions in the spotlight at COP21 - the **Climate Risk EWS** (CREWS) initiative was launched at the Oceanographic Institute in Paris. The initiative - supported by the World Meteorological Organization, the UNISDR, and the World Bank's Global Facility for Disaster Reduction and Recovery - actively operates to reduce the vulnerability and exposure of nations and communities to weather-related disasters. Its mandate is primarily to develop climate change-induced disaster risk EWS in developing countries.

Building on the aforementioned treaties, agendas, and initiatives, the international community has a significant body of EWS implementation work underway. With strong institutional capacity, local knowledge, modern technology, engagement of the private sector, and cross-boundary co-operation there is much that can be achieved.

1.2. The four components of early warning systems

Early warning is a strategy adopted by many societies to reduce the impacts of disasters. EWS are often based on interconnections between visual observations, past experience, and co-operation to mitigate losses from upcoming hazards. Early warning strategies are the set of measures taken to increase resilience that is not subsumed within risk-reducing initiatives such as urban design features or green infrastructure.

If correctly implemented, EWS can help to reduce losses of lives and property, and to minimise environmental damage. All this coheres in a favourable cost-benefit ratio while also increasing safety. To build an effective early warning system, the following definition is used as a starting point:

The provision of timely and effective information, through identified institutions, that allows individuals exposed to hazard to take action to avoid or reduce their risk and prepare for effective response.

UNISDR, 2004

As this definition highlights, an early warning system is much more than just hazard forecasting in combination with a network for transmitting warnings to the public. For an early warning system to be effective, the inclusion and interaction between four key elements is vital: risk knowledge, monitoring and warning services, dissemination and communication, and response capability.

Graph 1. Key elements of EARLY WARNING SYSTEM

Box 1:

Belgian flood early warning system

EWS have to be understood as the ensemble of different components to inform communities in a timely manner about imminent threats. For example, the Belgian flood early warning system uses different data inputs (satellite imagery, rain radar, precipitation monitoring for flood model calculations) to elaborate forecasts and flood hazards maps. These maps are used to classify imminent flood threats into four danger levels. Inhabitants are then made aware of the impending threat through media and are in turn encouraged to seek further information on the dedicated website waterinfo.be.

1.2.1. Risk Knowledge

Risk arises from the combination of hazards and vulnerabilities at a particular location. For this reason, risk knowledge is a key element of successful EWS. Risk knowledge is defined as the interplay between establishing organisational arrangements, identifying natural hazards, community vulnerability assessment, risk assessment, and information storing and sharing. Risk knowledge is the baseline needed before undertaking further action. When addressing end-users through an early warning system, it is fundamental that the importance and potential of the system are well understood by the community itself. To achieve this, the public must be informed about risks, risk communication channels, and emergency plans.

Risk information is continuously changing. Not only are population and infrastructure in flux - through changes in extent/location (exposure) and sensitivity/coping capacities (vulnerability) - so are the hazards to which they are exposed. Climate change alters hydrometeorological conditions across the world and impacts the frequency and intensity of hazards, bringing uncertainty to hazard and risk forecasting. For these reasons, an early warning system needs to continuously adapt in response to changing conditions; written emergency plans and procedures should be periodically updated.

1.2.2. Monitoring and Warning Services

Monitoring and warning services are what most often comes to mind when talking about EWS. This is the infrastructure that delivers forecasts and warnings. Monitoring is the act of collecting information along with a set of proxy variables related to risk, such as rain (correlated with floods/droughts), or seismic waves (correlated with earthquakes). This can be done through direct observations, e.g. through seeing an approaching wildfire or landslide. However, such observations have limited usability due to the close proximity of the threat and limited possibilities for taking risk-reducing actions. The same problem arises with earthquakes, where seismometers are able to trigger a warning just seconds before impact. For many other hazards, where EWS allow warnings with a considerably longer lead time (weeks to months) such as storms, flooding, and droughts, continuous monitoring of significant proxy variables can trigger risk mitigating actions.

Modern technology provides the possibility of compiling data from multiple monitoring sources and at high speed, creating possibilities for improving the accuracy and rapidity with which disaster forecasts can be produced. Some common technological monitoring solutions that can provide such data are showcased below.

Satellite imagery can aid in estimating temperature, wind speed, precipation	Land based radar for estimating downpour
On-ground points of measurement for water flow rainfall, wind speed, etc.	Trend analysis of online communication to find indications of future disasters

One promising monitoring system is the emerging practice of sourcing data through social media. Numerous researchers have experimented with extrapolating from social media or from built-in smartphone sensors regarding nascent disasters. An example of a success in this area is represented by the I-React project (www.i-react.eu), which is led by the Italian research and innovation center 'Istituto Superiore Mario Boella' in partnership with different institutions and agencies (UNESCO among them). I-React is developing a strategy to upgrade risk management systems. In particular, I-React is developing new technologies such as a mobile app, wearable positioning systems, and a social media analysis tool to account for real-time crowdsourced information. This type of data collection can be especially helpful for gathering large datasets from the stakeholders personally affected by nascent disasters, while also adding location-specific knowledge to the provided information.

For many countries, historical weather information and monitoring infrastructure already exists, but may belong to different institutions, resulting in a fragmentation of monitoring capabilities as well as reducing the information available when making forecasts. If various stakeholders are able to bridge this gap, rapid improvements in forecasting abilities are possible. These arrangements can be achieved via legislation, institutional arrangements, or informal collaboration.

1.2.3. Dissemination and Communication

The distribution of understandable warnings and preparedness information to those at risk of a hazard underpins the dissemination and communication process. Warnings dissemination and communication are centred around communication systems that provide recognisable warning messages that rely on institutionalised decision-making processes. In this sense, this component of EWS can be seen as the ensemble of risk communication infrastructure (reliable and disaster-resistant hardware, information and communication technologies) and strategies (appropriate interactions among main stakeholders, effective and customised warning messages).

Inappropriate communication and dissemination of warnings usually results in inappropriate (or absent) response. Historically, most failures in EWS occurred due to miscommunication – not equipment or infrastructure failure – further underscoring the gravity of this element.

The major objective of disaster communication is to not only deliver an early warning about a specific, geographically-constrained disaster risk, but primarily to empower people to take action and to initiate mitigation or security measures before a catastrophic event occurs (Sarun, 2011).

To reach this goal, early warning communication must be able to address threatened individuals or communities using the right linguistic and technological tools, and to trigger action through effective warning messages (UNISDR, 2017). Extra care should also be given to message clarity, due to the urgency with which the message has to be distributed. Therefore, many contemporary systems utilise a visual colour scale. One such example is in Belgium, where areas are mapped along a spectrum from red (high risk), through to orange, yellow, and green (low risk), to visually communicate the spatial threat distribution, while also allowing for expansion when more detailed information is required. Such streamlined communication is valuable in situations where the receiver of information may be under pressure or in extremis.

Another step towards an efficient information flow is to institutionalise clear organisational and decision-making processes through the assignment of mandates. Clear roles ensure that warnings are provided swiftly without having to circulate through multiple levels of administration. Moreover, they prevent the confusion that is created when different entities provide contradictory or incomplete information. Standard protocols for warning dissemination allow for smooth co-ordination and data exchange among actors.

In a world where technology increasingly plays a leading role in almost every sector, the available technological tools for risk communication and dissemination are increasing in quality and number.

Alongside the traditional early warning information and communication technologies (audible sirens, radio, TV, SMS, email), the rapid spread of smartphones has increased access to internet-based tools such as mobile applications and websites.

Mobile applications offer the opportunity of distributing messages that not only warn about impending hazards, but also provide additional information upon user request (see Box 2). Some social media platforms, e.g. Facebook, have integrated risk warning functions. Finally, when a social media platform does not have an integrated warning function, many providers (e.g. Twitter, WhatsApp, Instagram, YouTube, blogs) are frequently used informally by generating a wave of warnings through active user posts.

Box 2: Disaster Warning through Mobile Apps

General emergency warnings:

No apps are able to give warnings for all disasters and ongoing emergencies. There are a few examples of nation-wide efforts, mostly in industrialised countries, to build individual clearinghouse apps with a broad set of disaster warning capabilities. Examples include:

- The 'Emergency - American Red Cross' app: real-time alerts are combined with features for keeping track of family members, interactive learning opportunities, and a toolkit with functions such as a flashlight.
- The 'DisasterAlert' app by Alert Systems Group alerts its US-wide users of hazards in the following categories: earthquakes, tornadoes, hurricanes, tsunamis, ice, flood, freezing, fire, wind, snow, etc.

Agro-meteorological early warning apps:

In recent years, community-based projects have started to improve the resilience of farmers and vulnerable communities to extreme events and hazards. Through agro-meteorological early warning, the apps 'LARI' in Lebanon and 'SMS Lapli' in Haiti are able to warn farmers about expected heat waves, flooding, and drought periods. These applications also provide practical suggestions on how to behave in specific situations.

Earthquake early warnings:

Earthquakes can be detected a maximum of a few minutes in advance; many countries are still developing earthquake early-detection systems connected to apps that warn affected individuals and give simple instructions. These systems work better where p-wave detection sensors are densely distributed, such as Japan's 'Yurekuru Call', Mexico's 'SkyAlert' or 'QuakeAlert' in the US. The 'eQuake' application relies on Zizmos sensors to detect earthquakes worldwide, but performance is constrained by location-specific data availability.

The 'Code for Resilience' initiative:

'Code for Resilience' is an initiative of the World Bank Group to promote apps and digital solutions to cultivate community resilience to disasters. Many apps for early warning were designed and developed locally within this project.

Hydrometeorological early warning apps:

Some countries have made efforts to bind the data produced by national hydrometeorological observation agencies into apps for early warning such as Australia's 'EWN app'.

1.2.4. Response Capability

The last component that should be considered in all early warning system plans is response capability. This is the centralised knowledge, plans, and inputs needed for timely and appropriate action by authorities and those at risk. Response capability can be enhanced either by increasing public and institutional preparedness, or by automating emergency responses. For rapid onset disasters such as earthquakes, monitoring sensors may trigger actions to disable power and gas supplies to avoid further consequences.

To succeed in prompting a response to warnings, it is vital that endangered communities have trust in the early warning system. In fact, responses can be undermined if warning systems repeatedly call for action in situations where they are not needed. Therefore, an early warning system should also include routines to minimise false or unnecessary emergency warnings.

Preparedness and prompt responses can be additionally enhanced through drills and training, or by producing checklists of actions to undertake in certain situations. Direct campaigns to raise risk perception are also an example of how to increase awareness. Response capability also needs to take into consideration the fact that all people should receive the same protection regardless of gender, age, education, or disability.

An additional factor must underpin a risk-informed society in order to issue and properly respond to early warnings: institutional capacity. Capacity is the 'ability of individuals, organizations, and systems to perform functions effectively and in a sustainable manner' (UNDP, 1998). In the context of early warnings and disaster risk reduction, capacity is the combination of the strengths, attributes, and resources available in a community or society to issue and react to warnings to mitigate disaster impacts. This may include infrastructure and physical means, institutions, societal coping abilities, as well as human knowledge, skills, and collective attributes such as social relationships, leadership, and management. Later in this publication, the development of institutional capacity will be addressed as a necessary step for the implementation of EWS. Institutional capacity refers specifically to that capacity that is built on an organisational level. It represents the structural framework necessary to deliver the early warning system's mandate through the development and application of internal policies, arrangements, procedures, and frameworks.

1.3. Why EWS fail: challenges and obstacles that limit the expansion or success of early warning systems

EWS are acquiring growing recognition as a valid disaster risk reduction and climate change adaptation tool. However, early warning is a complex process which, as highlighted previously, consists of different elements. This complexity multiplies the chances that one of the elements is not well developed, and can eventually lead to the failure of the whole system.

In developing countries, where either the expertise, the technology, or the budget needed for EWS are lacking, many challenges are encountered during the implementation and maintenance phases. To better understand how to overcome these obstacles, this chapter will highlight common challenges. For each challenge, we will suggest a possible solution. In section 2 of this publication, these solutions or approaches will be expanded and analysed in detail through practical examples.

The following is not a comprehensive review of all existing challenges within the early warning process. Rather, we address the most important and common issues that were identified through desk research, qualitative interviews with professionals in the sector, and experience during the implementation of existing and completed projects.

1.3.1. Legal and institutional arrangements

Gaps in legal, institutional and co-ordination frameworks can prevent the operationalisation of EWS and the integration of risk information into decision-making across all sectors. Laws and regulations are of paramount importance for clearly defining roles, responsibilities, and actions to undertake for the operation and management of EWS. An inefficient legal and institutional framework leads to confusion, which - in an emergency situation where the time factor is crucial - can result in delayed release of, or reaction to, warnings. This scenario not only may compromise the effectiveness of the system, but it could ultimately result in a loss of faith in the system by the public.

To overcome these obstacles, in the next chapter, through project-based examples, we will illustrate:

- How to upgrade the regulatory and co-ordination framework so that roles and responsible institutions over the different elements of EWS are defined (see 2.1.1);
- How to set up and guarantee the success of the early warning process through development of technical guidance (see 2.1.1);
- How to continuously keep the institutional and legal capacity updated through capacity assessments and training (see 2.1.2).

1.3.2. Technology, infrastructure, and forecasting capability in developing countries

Technology plays a key role for EWS, especially for its monitoring, forecasting, and warning dissemination components. Yet in many developing countries, necessary infrastructure and capabilities are lacking. To overcome these obstacles, we will illustrate:

- How to prioritise investments in infrastructure through risk and vulnerabilities assessments, using easy tools and software (see 2.2.1, also 2.3.4 & 2.4.1);
- How to upgrade monitoring infrastructure through automated stations, remote sensing, and ground data collection (see 2.2.2 & 2.5.1);
- How to increase the quality of forecasts through low-cost data sharing (see 2.5);
- How to improve forecasting through the development of climate and hydrologic models on a local scale (see 2.2.1 & 2.2.2)
- How to manage data produced through the use of data management systems (see 2.2.2 & 2.5.1);
- How to disseminate effective warnings through low-cost technology and social media (see 2.2.3, also 2.2.4 & 2.5.2);
- How to build technical capacity through capacity assessment tools and capacity development plans (see 2.1.2).

1.3.3. Human resources and expertise

The effectiveness of EWS goes well beyond the efficiency and availability of early warning technology. Personnel responsible for maintaining and operating the systems also have to be competent and well trained. In many developing countries, the public sector lacks human resources with the necessary experience and skills, and often after training its personnel, higher available wages in the private sector lure competent and trained personnel away from their jobs.

To overcome these obstacles, we will illustrate:

- How to utilise services and expertise from the private sector (see 2.4.1);
- How to train the community to operate and maintain community-based EWS (see 2.3.3, also 2.1.2);
- How to improve the effectiveness of warnings through disaster risk reduction training for the private media sector (see 2.3.2);
- How to share knowledge and expertise through communicative platforms (see 2.5.1);
- How to harness collective power for response activities through social media and crowdsourcing platforms (see 2.2.3 & 2.2.4, also 1.2.2);
- How to locally implement global guidance and tools through international observation, forecasting, and warning networks (see 2.5.1 & 2.5.2);
- How to build capacity and technical skills through capacity development training and continuous professional development (see 2.1.2).

1.3.4. Addressing impacts of climate change on disaster risks

To forecast future events, the first step is to analyse past events and historical data to identify and model trends. Yet climate change may modify the existing relationships that have historically been successfully used to make forecasts.

To overcome these obstacles, we will illustrate:

- How to enhance climate observations by upgrading monitoring networks (see 2.2.2);

- How to create climate information databases and management systems to continuously update the input and use of historical data within forecasting systems (see 2.2.2);
- How to address the trade-off between local resolution and global validity in the development of climate models (see 2.2.2).
- How to address vulnerable groups, such as people with disabilities, through user-friendly early warning and emergency response mobile apps (see 2.2.4);
- How to reach the broader public using private media and social platforms (see 2.2.4 & 2.3.2, also 2.4.1).

1.3.5.Public engagement, empowerment, and community outreach

Factors such as historical, political, or cultural context will affect how a solution will and can be implemented for each location, making it hard to dictate a standardised solution. For EWS to truly serve the public and be effective, communities have to be involved in the process of designing and implementing EWS. Engaging and empowering communities can be difficult due to cultural and linguistic barriers, as well as political realities. Further challenges include physical distance and lack of effective communication networks that can create difficulties delivering messages to rural settlements and nomads and/or transhumants. The content and presentation of warnings also have to be customised, depending on how communities perceive risk, what degree of detail can be understood, and how prompt actions can be effectively induced.

To overcome these obstacles, we will illustrate:

- How to prioritise locally appropriate solutions through social vulnerability and risk assessments (see 2.2.1, also 2.3.4);
- How to include and target communities in the design of EWS and response plans (see 2.3.4, also 2.3.1 & 2.3.2);
- How to enhance the effectiveness of EWS through risk awareness campaigns, participatory activities, and school-based education (see 2.3.1);
- How to properly address the public through audience-customised communication strategies (see 2.3.3);
- How to make risk communication more effective by teaching communication strategies to civil protection organisations (see 2.3.2);
- How to use suitable communication and dissemination channels depending on the needs of endangered communities (see 2.3.2);

1.3.6.Response co-ordination and disaster preparedness

An early warning system can fail even if the infrastructure is installed and functional and the warnings are issued and disseminated correctly; a warning alone mightn't be sufficient to prompt a response. Public and institutional preparedness, including institutional response capacity, have to be developed to a sufficient degree to allow for an organised, risk-mitigating reaction to warnings. Risk-mitigating reactions and the preparedness of institutions and the broader public can be difficult to achieve, especially if the time between warning and disaster is short or not used efficiently. Several sectors, including government, media, and private enterprise, now have the technical resources to quickly publish information, creating a space where conflicting and confusing information quickly can spread. Moreover, if the priorities of different response actions are not well delineated, warnings can give place to chaotic and interfering actions.

To overcome these obstacles, we will illustrate:

- How to increase risk awareness and response capacity through public campaigns and informal or school-based education (see 2.3.1 & 2.3.2);
- How to increase response capacity and preparedness through regular training, evacuation and simulation exercises, and drills (see 2.3.2);
- How to standardise the warning dissemination chain in accordance with international protocols (See 2.1.1 & 2.3.2);
- How to anticipate the issuance of alerts through real-time data analysis (see 2.2.2 & 2.5.2);
- How to share information and data in a quick and effective way through international monitoring and forecasting platforms (see 2.5.1);

- How to quickly disseminate warnings through international co-operation (see 2.5.2);
- How to minimise the likelihood of dissemination failure through communication channel redundancy (see 2.3.2 & 2.3.4);
- How to harmonise and incorporate international law at the national level to facilitate international co-ordination (see 2.5.2);
- How to clarify roles, responsibilities, and actions through Standard Operating Procedures, checklists, and Codes of Conduct (see 2.3.3 & 2.1.1)
- How to facilitate co-operation through forums and co-ordination committees (see 2.1.1).

1.3.7. Budget

Many good solutions require extensive investments in technology. On top of the initial investment, maintenance of technology can be expensive in terms of both money and human resources. When non-profit organisations often lack the economic resources necessary to fund projects, the private sector can play a key role in supporting the creation of resilient societies. However, investments made by the private sector need to be adjudged financially prudent by investors. Such approaches can create a situation where the driving factor for engagement is not based on community needs, but rather on potential economic returns.

To overcome these obstacles, we will illustrate:

- How to upgrade EWS through free services and funding by the private sector (see 2.4.1 & 2.4.2);
- How to allocate human resources and experts through partnerships with the private sector (see 2.4.1);
- How to efficiently employ cheap, low-tech monitoring and forecasting instrumentation (see 2.4.1);
- How to use low-cost and well-distributed communication and dissemination tools (see 2.4.1);
- How to reduce local/national costs by sharing an early warning network with other municipalities/nations (see 2.4.2).

The challenges listed above and the approaches to mitigate them can be divided into five focus areas of intervention: institutional arrangements, technology, community-based and people-centred early warning approaches, private sector engagement, and international co-operation.

2. HOW TO SUCCESSFULLY IMPLEMENT EARLY WARNING SYSTEMS

Project-oriented lessons to boost early warning systems through institutional arrangements, technology, community-based solutions, private sector engagement, and international co-operation.

From the many challenges highlighted in the previous chapter it is evident that EWS can face many challenges. Yet, the implementation of EWS can be made more efficient if fundamental advance considerations are anticipated. This chapter will present a series of solutions to the challenges previously highlighted. Besides theoretical aspects, specific references to projects that have succeeded in the implementation of early warning will be presented in this chapter. These solutions, responding to the aforementioned global and regional challenges, were collected from regional as well as global projects. The projects will illustrate five main areas of intervention:

1. **Institutional and regulatory arrangements** to ensure a smooth early warning process and to develop capacity among stakeholders;
2. **Technological solutions** to upgrade monitoring, forecasting, and warning infrastructure;
3. **Community-based solutions** to empower communities at risk and prompt an effective response to warnings;
4. **Private sector engagement** to develop and manage EWS at lower costs and with the engagement of sectoral professionals;
5. **International co-operation and data sharing** to minimise costs and to ensure greater impacts for EWS.

The first three solutions cover nearly every aspect of setting up EWS. Institutional arrangements and regulations ensure that the enabling environment and capacity needed for the early warning process is in place. Technology underpins the success of monitoring, forecasting, and warning issuance as well as its communication. Community-based solutions guarantee that warning communications reach communities at risk, and that vulnerable communities are therefore prepared to counteract the risk. The latter two solutions can improve EWS by minimising costs and promoting information- and expertise-sharing. It is important to note that this publication cannot cover all aspects of early warning systems, due to the complexity and magnitude of such a task, and will therefore limit itself to a consideration of the above, aforementioned topics.

2.1. Institutions, Regulations, and Capacity Development

'...The challenge is to move from managing disasters themselves, to managing disaster risk. Poverty, rapid urbanization, weak governance, the decline of ecosystems and climate change are driving disaster risk around the world. We have had great success in reducing the number of lives lost to disasters, thanks to early warning systems, preparedness, and more efficient evacuations. Let's put more effort into tackling disaster risk to create a safer, more sustainable world for all.'

António Guterres, UN Secretary-General, 2017

Institutional capacity, which is the ability of governments and institutions to effectively perform functions in a long-term sustainable manner, sets up the baseline for smooth functioning of an early warning system. As underlined in the second international Early Warning Conference (EWC II), not only must institutional structures produce a warning, but political/governmental decisions must be made expeditiously to act upon the warning. The most critical and immediate response to a disaster will therefore depend on authorities and institutions at various levels. Weak institutional structures and performance can often lead to unclear roles, ineffective actions, and a limited impact of risk-counteracting measures.

Institutional capacity, therefore, must be developed as a preliminary step in the set-up of an early warning system. Capacity development is the process by which institutions stimulate and develop their capacities through the improvement of knowledge, skills, systems, and regulations. In relation to EWS, an enabling environment and capacity development processes focus on developing legal instruments to clarify roles and actions within the early warning chain, producing technical guidance and standardised methodologies, assessing institutional capacities for continuous improvement of organisational procedures, and eventually on building and maintaining the skills necessary to operate the system.

This chapter will explore lessons from different projects that aim at developing the institutional capacity necessary to administer and properly run EWS. In the first part of this section, the establishment of appropriate institutional frameworks will be discussed, while the second part will focus on how to maintain institutional capacity in the long run.

2.1.1. Legal and institutional frameworks to define roles and actions

Since EWS as a preparedness measure has only recently started to be deployed on a wide scale by governments and decision makers, the legal and institutional frameworks regulating disaster risk and climate risk management often fail to include them. This lack of precise indications of roles, responsibilities, and actions vis-à-vis the early warning process results in counter-productive warnings due to contradictory information and a lack of precise operational protocols. To avoid this, a **legislative framework** setting a series of rules regarding EWS is strictly necessary.

When dealing with the establishment of an early warning system or, more generally, when making improvements to disaster and climate resilience in a country or region, many UNDP projects had to first deal with the lack of legislation on this matter. As part of a comprehensive project to reduce the vulnerability of mountain communities of the Greater Caucasus in **Azerbaijan** to climate change-induced water stress and flood hazards, UNDP addressed the lack of climate-resilient water management laws. Besides building an early warning system and engaging communities in water and flood management, the project strongly focussed on institutional capacity development. The first output of the project aimed at developing five normative legal acts on climate-resilient water management at the sub-basin level, and at including climate risk in the existing Water and Land Codes. The project resources were used to form a national Legal Working Group with domestic experts to elaborate specific national legal acts in areas needed to enable adaptation, such as EWS.

To facilitate international co-operation and data sharing, which in turn help to reduce the costs of EWS while enhancing their performance, it is important that EWS design incorporates international best practices and standards for regulations and legislative mechanisms. For this reason, UNDP projects in **Bosnia and Herzegovina** and in **Georgia** have incorporated European Directives into national legislative frameworks. Within these two projects aiming at improving flood (Bosnia and Herzegovina) and multi-hazards (Georgia) EWS, UNDP has been incorporating provisions of the European Union Flood Directive 2007/60/EC into the countries' national legislation. In Georgia, the UNDP project, funded by the Green Climate Fund and Swiss Development Cooperation, will support the government to integrate climate-induced flood and drought risks management into water legislation by the incorporation of Guidance Document No. 24: River Basin Management in a Changing Climate, from the EU Water Framework Directive CIS Guidance Document series.

The aforementioned examples highlight that there are ongoing efforts to incorporate climate and disaster resilience into national legislation. The legislative processes outlined above do not specifically target the operation of EWS, but rather provide a broader legislative framework for climate and disaster risk management. To specifically address the regulation of EWS, many countries are developing **regulatory frameworks and technical guidance** for EWS. Although some of those are not legally binding, these documents provide necessary information and guidance on the usage and operationalisation of EWS.

The multi-hazard EWS project in **Georgia**, for example, will develop and support the implementation of technical regulations and guidance on EWS. This will ensure the definition of roles, responsibilities, and institutional arrangements for EWS at all levels, as well as making provisions for technical aspects and methods. A particular emphasis will be put on developing mandates and methodologies for multi-hazard risk assessments. Standardised and institutionalised hazard, risk, and vulnerability assessment methods for the country will be implemented, and a nation-wide risk zoning policy based on risk maps will be operationalised through relevant national regulations and guidance documents. Technical regulations will also clarify warning details, including the definition of thresholds between major and minor hazards, and setting proper criteria for the definition of different warning levels. This standardisation of early warning procedure is key in making the early warning system exportable to different cities and regions without having to rethink design and implementation.

The Georgian Ministry of Internal Affairs is preparing a **national early warning system concept paper** to achieve a smoother implementation of EWS**.** The document aims to give precise guidance on each element of EWS. It explicitly addresses institutional capacity through the elaboration of a relevant legal-regulatory basis for EWS, including policies on unified disaster response and EWS; rules on collection, processing, and storage of disaster-related information; and policies on telecommunications systems and warning mechanisms. Other outputs give guidance on how to systematically collect data on hazards and risks, how to model and map vulnerability, how to strengthen national and local response capacities, and how to develop the human resources needed for the optimal functioning of EWS.

Clear protocols and regulations underpin the success of warning communications and climate and risk information dissemination. A growing number of projects are, therefore, developing robust **climate and risk information delivery** and **feedback mechanisms**. There are different issues related to climate and risk information, such as its production, its inclusion into the decision-making process, and its onward communication and dissemination. Although climate information and risk warnings are already being produced and are theoretically available to the public, in many countries the communication and dissemination protocols are poorly implemented and only manage to reach a small fraction of the population at risk. Moreover, due to the fragmentation of risk and climate information, which are often produced by a number of different agencies, decision-makers are not provided with a comprehensive set of information, resulting in under-informed decisions.

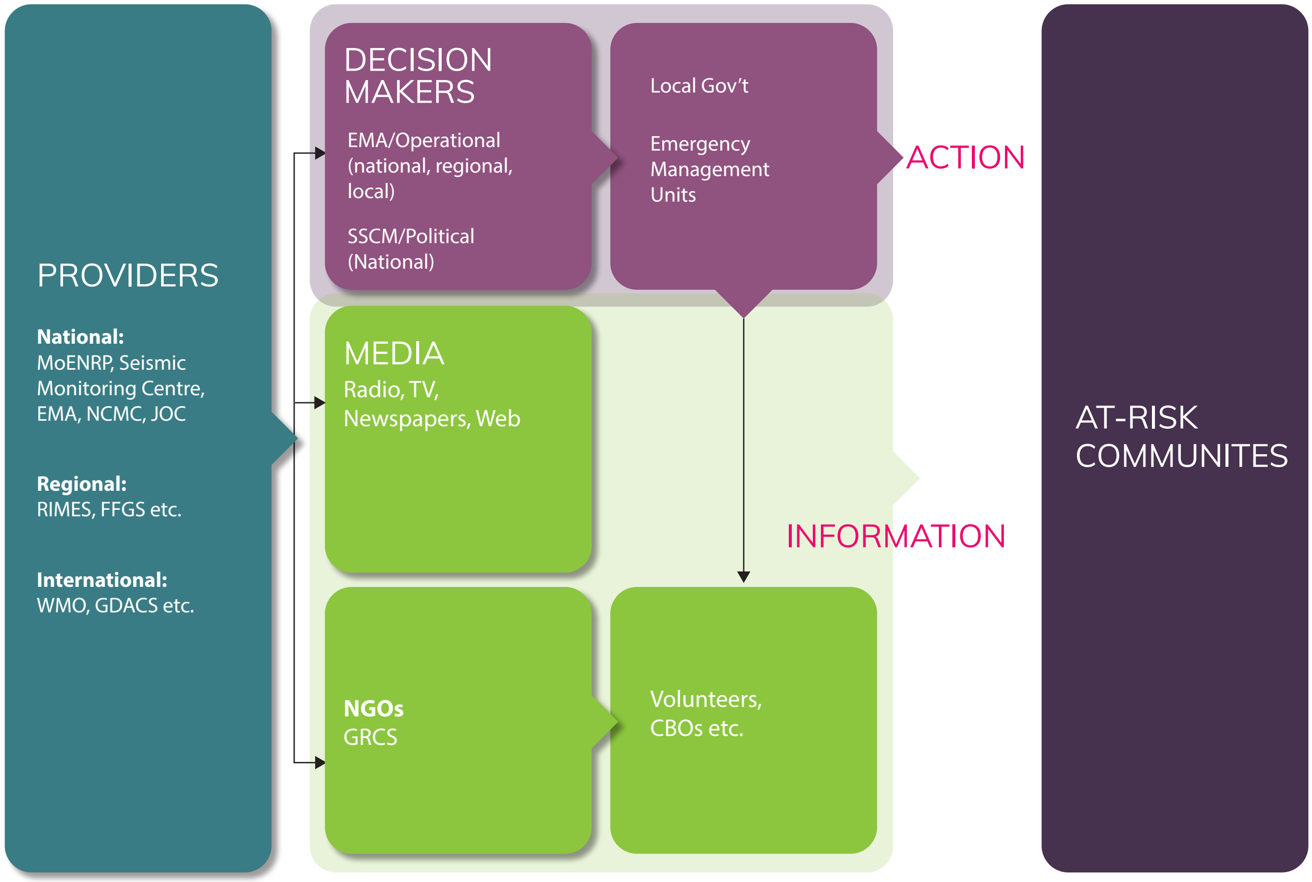
The importance of climate and risk information in the decision-making and warning communication process is also taken into consideration in the design of Georgia's multi-hazard EWS. The project aims at clarifying responsibilities and improving access to risk knowledge through upgraded systems and data sharing measures. In particular, interagency co-operation will be strengthened, and roles, responsibilities, and institutional arrangements for early warning communication and dissemination will be clarified at all levels. A particular effort will be made to make the communication lines between different agencies clearer, eliminating any redundant and duplicated channel, as well as inefficiencies. To achieve this, **Standard Operating Protocols, Communication Protocols**, and **Codes of Conduct** will be developed for each of the agencies responsible for the various elements of the early warning system. Thanks to these protocols, the roles of regional and local authorities will be made clear, and redundancies in tasks and expertise areas will be avoided.

Strengthened institutional capacity includes enhanced co-ordination and co-operation among government entities and non-state stakeholders. To achieve this, the multi-hazard EWS project in **Georgia** used Protocols as defined by UNESCO/IOC (2015):

1. The first process leads to a decision on issuing warnings and the respective warning levels. This usually takes place at the institutions responsible for hazard monitoring and warning ('provider organisations').
2. The second process leads to a decision on whether to officially call for an evacuation and helps to translate the warning message into guidance for a community at risk. In most countries, Disaster Management Organizations (DMO) are involved to disseminate warnings to the public and to take decisions on whether or not to call for evacuations.

For the case of Georgia, all types of hazards except for earthquake (handled by the seismic centre) will fall under the National Environmental Agency when it comes to hazard assessment and monitoring. For response, prevention, preparedness, and recovery, the Emergency Management Agency takes the lead (*see Figure 3*).

Figure 3. Proposed MHEWS decision making process.



2.1.2. Developing lasting capacity

The definition of capacity mentioned at the beginning of this chapter is tightly intertwined with the concept of 'sustainability'. Once the institutional framework necessary to regulate the early warning process is set up, continuous efforts must be made to maintain the newly built capacity in the long run. The value of an institution's capacity can, in fact, be measured not only by the efficiency of the institution, but also by its capability to keep its capacity over the years.

Sustaining a high capacity over years and changing conditions goes together with being able to continuously adapt and innovate the institutional framework so that it mirrors the reality that it addresses. In order to be able to intervene with specific (obsolete) institutional arrangements, it is necessary to be able to assess gaps in institutional capacity. In the capacity development process, solid **capacity assessment tools** are vitally important, as they are used over the years to monitor institutional performance (see *Table 1* below).

	CURRENT CAPACITY - HUMAN/TECHNICAL	CURRENT CAPACITY - FINANCIAL	CURRENT CAPACITY -FUNCTIONAL/LEGAL/ INSTITUTIONAL
1.1 Hazard Identification			
1.1.1. Systematic observation and monitoring of hydro meteorological parameters for strategic long-term management of hydro meteorological hazards and for underpinning FFEWS including:	Human capacities are rooted in old Soviet methods with some adoption of modern approaches. Human Capacities limited to old generation (possibly due to overall lack of interest in this field); Technology is being upgraded through the injection of modern equipment and methods (largely by donor-led projects); technical capacity needs to also be upgraded to match the new technologies and equipment being adopted.	Limited central budgets for optimisation of hydrometric monitoring network and for functions such as a fully integrated national FFEWS.	Legislative framework for the protection of citizens from natural hazards in place; Weak government budgetary commitment to optimisation and maintenance of hydrometric network. Network modernisation and improvement is largely donor-led.
1.1.2. Specification of appropriate hydrometric monitoring networks to meet all purposes (long-term monitoring, forecasting and early warning)	Hydromet experts with capacity to undertake detailed specification of equipment exist within NEA. Capacity currently sits within a small team of experts with little evidence of younger experts being trained for succession. Hydrometry experts knowledgeable of international best practice in hydrometry but little exposure to the application of best practice technologies and approaches	Limited central budgets for optimisation of hydrometric monitoring network and for functions such as a fully integrated national FFEWS.	Standards based on old Soviet standards and not focused on monitoring for FFEWS or for modern strategic approaches to FRM

	CURRENT CAPACITY - HUMAN/TECHNICAL	CURRENT CAPACITY - FINANCIAL	CURRENT CAPACITY -FUNCTIONAL/LEGAL/ INSTITUTIONAL
1.1 Hazard Identification			
1.1.3. Design installation, O&M of equipment within the hydrometric network.	Limited capacity for network design and installation for modern technology and equipment. In addition, equipment manufacturers training not systematically provided		
1.1.4. Systematic collection, management, maintenance, use, and provision of long-term and real-time data	Extensive historical data currently exists in paper format. Project-based digitisation of paper data has been undertaken (e.g. the current UNDP Rioni project), but there is little evidence of systematic digitisation of all datasets for Georgia. Project-based upgrade to and installation of new automatic hydromet stations has occurred, but further assistance is needed in developing an optimised automatic hydrometric network for all basins in Georgia. A hydrometric database is in place for the systematic storage of data. Data provision is managed by NEA and includes bulletins of hydrometric observations and forecasts, provision of data to other departments		

	CURRENT CAPACITY - HUMAN/TECHNICAL	CURRENT CAPACITY - FINANCIAL	CURRENT CAPACITY -FUNCTIONAL/LEGAL/ INSTITUTIONAL
1.1 Hazard Identification			
1.1.5. Hazard analysis and mapping	The project has introduced modern hazard modelling and mapping methodologies and has trained NEA staff in these methods.	The project has bought and installed modern software for hazard modelling and mapping. NEA (owner and custodians of the software) needs to identify and secure government budgets for long-term maintenance of flood hazard modelling and mapping software. NEA should also explore other software that might be free/ lower cost for other basins. NEA should also investigate and put in place measures to ensure that models are updated with new data on a regular basis (at least every 5 years).	Methods and technology introduced needs to be embedded within NEA and further capacity built to enable NEA to fulfil its future commitments under the EA Floods Directive (when Georgia becomes a part of the EU)

	CURRENT CAPACITY - HUMAN/TECHNICAL	CURRENT CAPACITY - FINANCIAL	CURRENT CAPACITY -FUNCTIONAL/LEGAL/ INSTITUTIONAL
1.1 Hazard Identification			
1.1.6. Forecast hazards	The project has introduced modern FFEWS systems and methodologies and has trained NEA staff in these methods.	The project has bought and installed modern software for FFEWS. NEA (owner and custodians of the software) needs to identify and secure government budgets for long-term maintenance of FFEWS software.	Methods and technology introduced needs to be embedded within NEA and further capacity built to enable NEA to fulfil its future commitments under the EA Floods Directive (when Georgia becomes a part of the EU)

Table 1. An abstract from an Institutional Capacity Assessment for flood hazard and risk management and EWS in Georgia, Hazard Identification (Georgia multi-hazard EWS project, Document, 2018). Institutional capacity assessment has been completed for the following functions/processes: hazard identification, vulnerability assessment, risk reduction, managing residual risks and risk transfer, stakeholder engagement in risk knowledge and risk assessment, monitoring, forecasting, and warning.

As part of a UNDP project that aims to develop Information and Communication Technology for Disaster Risk Reduction (ICT4DRR), **Armenia** has piloted the usage of an innovative planning methodology, developed by the UN Office for Disaster Risk Reduction (UNISDR), to identify gaps in the disaster and climate risk management capacities of municipalities and governments. The methodology, called **Local Government Self-Assessment Tool** (LGSAT), not only helps to identify gaps, but also to set baselines, plan actions, and monitor advances over time. The self-assessment, led by government, is a multi-stakeholder process which includes local government authorities, civil society organisations, and the private sector. The main advantage of this methodology is its characteristic of being a 'self-assessment', creating a procedure that can be repeated over time by the government without the need of an external consultancy. To ensure the sustainability of the toolkit replication, the LGSAT training module was localised for country-specific needs in partnership with the DRR National Platform and UNISDR Global Education and Training Institute (Incheon, Korea) and mainstreamed into the training curriculum of the Crisis Management State Academy.

Besides assessing the performance of government frameworks, it is important to also verify that the other agencies involved in the early warning process have a functional structure. In particular, national climate, hydrological, and weather services (in charge of monitoring and forecasting) and/or national media (responsible for warning communications and dissemination) have to be included in the capacity assessment process.

This aspect has been considered by a World Bank Global Facility for Disaster Reduction and Recovery (GFDRR) project in **Honduras** and **Nicaragua**, whereby an assessment of the national climate, hydrological, and weather services has been conducted within an early warning system implementation project. To assess the capacity of the hydro-meteorological services, the GFDRR reviewed their institutional arrangements, regulatory schemes, technical capacities, budget, network systems, ICT infrastructure, and data management systems, together with all other requirements for the observation, analysis, and dissemination of weather, climate, and hydrological events. The assessment was conducted on a national scale, as well as on a regional-local scale in two regions per country in Honduras and Nicaragua.

Once institutional capacity gaps are identified, **institutional capacity development plans** must be prepared to facilitate long-term capacity development within the different agencies involved in the early warning process.

A UNDP project in the former Yugoslav Republic of Macedonia (Polog region) has made a **plan to improve** the **inter-municipal co-operation capacity.** Planning for co-operation improves data collection processes, knowledge sharing, prioritisation of measures, trust building, and mobilisation for the implementation stages of the programme. Recognising the differences in capacities of municipalities to adopt and apply the principles of integrated flood risk management and DRR, UNDP explored different options for inter-municipal co-operation (IMC), considering earlier positive experiences from delivering other types of services to citizens by sharing resources. A national consultant was hired to identify procedures and prepare drafts of all legally required documents/templates for establishing the selected IMC form by the Councils of all municipalities involved in this initiative, and to facilitate consultations and the process for adoption of the decisions by municipal Councils for establishing the IMC agreement between municipalities upon adoption of the decisions. Currently, several municipalities have already adopted the decision for establishment of an IMC agreement, and the remaining municipalities are expected to complete the process by the end of the year. The inter-municipal co-operation agreement is expected to contribute to better planning and use of available funding for flood risk management at the regional level, as well as for additional resource mobilisation which can be invested in flood prevention.

Most plans address the goal of building sustainable capacity over the years through different strategies of skills and capacity development training (for an overview on which type of training can be done to increase institutional capacity, see Box 3).

As a first step, it is often necessary to clarify and refine the specific training needs through a **training needs assessment**. In **Azerbaijan**, an institutional capacity review was specifically undertaken to identify the training needs of key institutions responsible for the management and operation of the early warning system implemented by the UNDP project. As a result, a report on the review was prepared so that the needs for improvement and training were highlighted. From this basis, a comprehensive and targeted **training program** was designed.

Box 3: Institutional training needs and activities within the GCF project in Georgia

As part of **Georgia's** multi-hazard EWS project, training and institutional capacity building will address the needs identified through institutional capacity needs assessment. The training will cover the areas of risk assessment, monitoring, forecasting, information management, and warning communication as follows:

In the area of multi-hazard assessment, hydrometry, forecasting and modelling, and EWS:

- Workshops on hydrometry to include modern methods and equipment specification
- National Environmental Agency workshops for junior employees and university graduates
- Mentoring programme with younger engineers shadowing experienced staff
- Trainings in hydrometric network design and implementation
- University courses in hazard analysis, modelling, and mapping (National Environmental Agency to form links to academia and help introduce courses)
- Refresher training in hydrology, hydraulic modelling, and GIS
- Training in forecasting and warning procedures
- Training in Common Alerting Protocols
- Training of National Environmental Agency's staff in remote sensing, multi-hazard risk assessment, and mapping
- Training of National Environmental Agency's staff in landslide monitoring and operations, and maintenance of landslide monitoring equipment
- Multi-hazard EWS training on the new system for all institutions involved.

In the area of vulnerability and risk assessments:

- University courses on gender-sensitive vulnerability as well as risk assessment and modelling
- Specialist training of individuals already involved in economic assessments in the assessment of damages, losses, and risk to life

In the area of multi-hazard risk management and the use of climate information:

- Workshops to identify required changes in institutional arrangements
- Training for various sectoral ministries and institutions (National Environmental Agency, Ministry of Regional Development and Infrastructure, Tbilisi Mayor's Office) on proposed new multi-hazard risk management policy and planning
- Awareness raising workshop for all government departments. Use of the project-developed website to store hazard and vulnerability information (including maps)
- Targeted awareness and learning events on climate risk assessment and management for relevant sectoral investors (Ministry of Energy, National Environmental Agency, Ministry of Regional Development and Infrastructure, Hydropower sector)
- A series of targeted training workshops for municipalities
- Workshops and round tables on risk management financing and risk transfer instruments.

There are different types of training and competence-development strategies that can serve the scope of continuously developing capacity. The content and the modalities should mirror the need of the training's audience, which can be extremely diverse due to the different institutions managing and operating an EWS.

A UNDP project in **Bosnia and Herzegovina** focussed, for example, on the development of hydro-meteorological monitoring and modelling skills to strengthen the monitoring and forecasting component of the flood early warning system. To instruct technical practitioners, the project developed a series of **workshops** on hydrological and hydraulic modelling, assimilation of data, flood modelling and mapping, and forecasting of flood events in real time.

The multi-hazard EWS project in **Georgia** will adopt **Continuous Professional Development (CPD) methods** to address the issue of skills shortage, retention, and succession planning. CPD methods will involve the development of guidance documents, codes, and standards, and cross-fertilising of staff with skills across all organisations. The National Environmental Agency's (NEA) hydro-meteorological service will continuously be exposed to technical capacity-building activities and **training** (workshops, mentoring programs, refresher training) by the Environment Information and Education Centre (EIEC) in data analysis, forecasting, and packaging of early warning products. To ensure that technical capacity will keep pace with advancements in early warning, **Training of Trainers** will be performed internally in the EIEC. In addition, the NEA will form links to academia to introduce **university courses** in risk assessment and modelling to provide for long-term training of future employees.

2.2. Technological solutions

EWS are underpinned by institutional arrangements, human resources, public awareness and preparedness, and technology. In a world where technology has not only quickly advanced but also become ubiquitous, technological solutions offer an opportunity for low-cost advances in early warning systems, contributing to increased resilience. Technology allows, in fact, the automation and rapid processing of a series of fundamental steps within the early warning chain. In this chapter, different technological solutions will be presented to shed light on how the use of engineering or technology can solve a problem in a more efficient, accurate, and fail-safe way. For EWS, this often means that information is transferred and analysed using digital tools, or that the technological aspect of the risk assessment, monitoring, and forecasting is modernised.

This chapter explains how technological solutions provide benefits for each of the key elements of EWS. The chapter will, therefore, illustrate room for technological improvements following the four categories of EWS: risk knowledge, monitoring and forecasting, communication, and response capacity.

2.2.1. Technology for enhanced risk knowledge: risk assessment, risk mapping, risk information sharing

Risk is the combination of societal vulnerabilities, exposure to a hazard, and the probability that a hazard occurs. To be able to issue an early warning, the distribution and severity of risk must be known in detail. Since every community, nation, and region works differently and is exposed to different risks and impacts related to disasters, customised solutions are needed. Risk knowledge sets the baseline to be able to identify and design customised, locally effective EWS.

With climate change and urbanisation among the main drivers for increasing extreme weather risks, technology provides new opportunities to mitigate some risks through accurate risk assessments and hazard mapping.

Risk assessment is an important step towards enhanced risk knowledge. New toolkits and methodologies contribute to enhanced risk knowledge through risk assessments. These can include environmental and social/community vulnerability assessment toolkits which have been developed to address all aspects of the impact of hazards. These toolkits can be implemented via software and applications to facilitate standardised assessments of social vulnerability and hazard risk.

An example of a standardised methodology and toolkit to assess hazard risk is found in **Armenia**. As part of a UNDP project, a series of new **tools for multi-risk assessment** was introduced. Within the project, both a multi-stakeholder capacity assessment for developing preparedness plans and a scientific multi-risk assessment for modelling GIS-based multi-risk scenarios were performed. Between the applied tools, a **Local Level Risk Management (LLRM)** methodology to assess risk at community level was developed by the UNDP Armenia disaster risk reduction team in co-operation with the Ministry of Emergency Situations (more info at www.arnap.am). Within the framework of an ECHO-funded project, UNDP enriched the LLRM tool in partnership with UNICEF, and a child sensitive approach was mainstreamed into the methodology. Within the framework of the DRR National Platform of Armenia, the tool was tested in more than 200 communities – serving as a diagnostic and advisory tool for community risk-informed development and as a mechanism for implementation of the National Strategy on DRR and Sendai Framework for DRR. The LLRM tool was later adopted by the Government of Armenia as a unified methodology for the consolidation of key data and conclusions on community-specific risks and priority solutions obtained as a result of vulnerability and capacity assessments and planning exercises, with indications of possible future funding sources and sectors where these solutions could be accommodated.

To be able to identify the demographic and geographic areas where natural disaster and climate change-induced hazards may cause damages, **GIS tools** can be of great help. GIS provides a means of illustrating the geographical distribution of hazards and risks. One of the most well-known software applications for GIS is ArcGIS, which is proprietary commercial software - but there are also free alternatives (QGIS, GRASS GIS, R-maps, etc.). GIS tools include the ability for users to spatially visualise social and environmental vulnerability and combine this with hazard frequencies/probabilities to create risk maps for different levels of hazard intensity. Based on vulnerability and risk maps created, decision-makers can then determine adequate preparedness planning and disaster response measures.

Within the frame of ECHO and Catalytic Facility funded projects in **Armenia**, UNDP (in partnership with the National Academy of Science, Seismic Service of the Ministry of Emergency Situations and 'Georisk' a private company) conducted the 'Earthquake Scenarios Project' in the Armenian cities of Gyumri, Stepanavan, Dilijan, Goris, Sisian, and Kapan. As a result, a **deterministic assessment of seismic risk** for the target cities was conducted, and GIS-based software was developed to estimate the potential population losses, casualties, and different rates of damage that would be caused to buildings and infrastructure under the worst-case earthquake scenario. Based on the provided scenarios, city DRR plans were developed and tested during the simulation exercise in Kapan city and provided to the Government of Armenia for further replication in other cities.

Within the framework of a project in **Georgia** that aimed at improving flood resilience of communities in the Rioni river basin, UNDP developed **hazard maps** for flood risk at the basin level. Free **remotely sensed geospatial data** was used to produce maps that indicate flood risk in the Rioni river basin. The hazard prediction model was validated by comparing the modelled hazard levels with historically recorded water levels at known sites. The maps contribute to a clear picture of the geographical distribution of flood risk in the Rioni river basin and can be used for infrastructure investments, hazard evacuation, and community outreach.

Another case where mapping tools such as GIS and satellite data were successfully used is in support of the Forest Fire Information System of the former Yugoslav Republic of Macedonia. The project, implemented by the Macedonian Crisis Management Center and supported by the Japan International Cooperation Agency (JICA) in synergy with UNDP, substantially contributed to the production and dissemination of risk knowledge in the former Yugoslav Republic of Macedonia by developing, for each of four elements of risk (hazard, exposure, vulnerability, and coping capacity), various risk assessment tools and maps (see Table 2).

Risk element	Risk Assessment tool
Hazard	Hot spot map & Fire history map
Exposure	Forest vegetation map & Damaged forest value map
Vulnerability	Vegetation dryness map & Fire weather index map
Coping capacity	Topographic map & Suppression resource table

Table 2: Risk assessment tools for Forest Fire Information System

The project did not only use technology (GIS and fire forecasting models) to produce the maps but also constructed a **web-based system** (the Macedonian Forest Fire Information System / MKFFIS) to share the mapping products. On the website, it is possible to visualise hotspots of forest fires and get an overview of the spatial distribution of forest fire risk. The service also provides the opportunity to visualise single parameters, such as vegetation dryness or damaged forest (see *Figure 4*). In synergy with a UNDP project entitled 'Disaster and Climate Risk Reduction', the MKFFIS integrated web applications and databases relating to critical infrastructure, population, a registry of available resources, and the emergency management grid. With its comprehensive capabilities, the system now makes significant contributions to assessments of risks, hazards, and response.

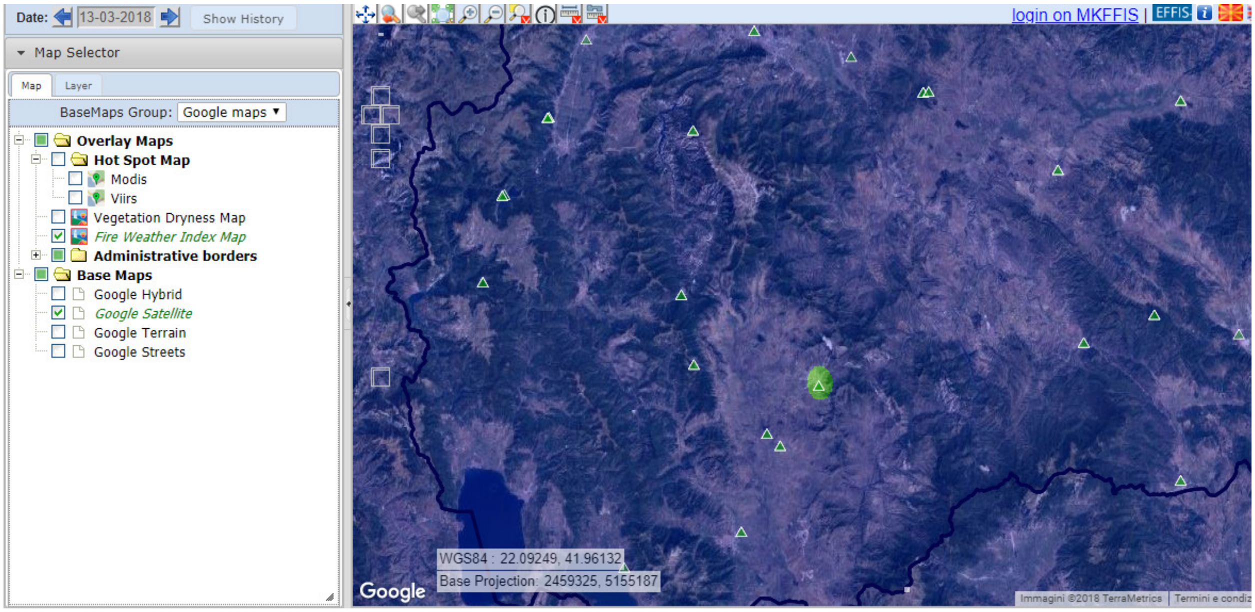


Figure 4. Macedonian Fire Information System website (mkffis.cuk.gov.mk, 2018)

The website is now used for communication between different stakeholders in fire risk management, and due to its public accessibility and visual representation it is also used to increase risk awareness for landowners and the public.

2.2.2. Monitoring, modelling, and forecasting systems under a changing climate

With climate change modifying the frequency, intensity, and distribution of future hazards, technological efforts to enhance climate information are increasingly needed in order to deal with these changing distributions and causal factors. Hydrometeorological EWS, in particular, will have to account for changing climatic conditions. Extreme value statistics (describing extreme events) of hydrometeorological events, for example, are of great importance to disaster risk reduction planning and can be combined with vulnerability metrics to set thresholds for warning dissemination. Changes in the distribution of extreme events can aggravate pressures on response systems which have to deal with increases in the frequency of extreme events and associated crises. Since human-related activities and the climate system are difficult to exactly predict, climate projections are always subject to a degree of uncertainty. Climate change impacts need to be carefully monitored, and climate scenarios need to be updated on an ongoing basis to reduce some of this uncertainty.

To ameliorate some of this uncertainty, a series of interventions can help improve weather and climate predictions (including seasonal forecasts) and climate change projections. In the first place, weather forecasts need initial data, which can be gathered through ongoing **observations**. Additionally, these observations allow forecasters to check recent weather forecasts and modify their interpretation of forecast products. Furthermore, the build-up of historical databases of observations allows for the development of statistical methods to calibrate forecasts at all timescales (weather, seasonal, and climate change). Observations can be made through several technologies, each providing different levels of accuracy and spatial coverage: remote sensing, satellite observations, and on-ground measurements (weather and hydrological stations, both manually operated and automated).

Many countries are currently limited in their climate projection capacities due to the lack of monitoring stations. Across the world UNDP has been enhancing countries' monitoring capacities by upgrading and expanding national hydrometeorological observation networks. For example, through a flagship programme of the **Zambia** Meteorological Department, UNDP in collaboration with WFP and FAO has supported the installation of

68

automated weather stations and

40

manual stations across the country. These stations also have an integrated early warning system that alerts vulnerable communities about imminent extreme weather events as well as other longer-term climate change challenges.

UNDP's work is focussing on further enhancing the capacity of the National Hydro-Meteorological Service (NHMS) to monitor extreme weather and climate change through the procurement and installation of a number of automated and manual stations (10+ hydrological, 20+ meteorological monitoring, upper air, and satellite monitoring stations) and via the training of at least 3-5 officers to maintain and repair the equipment.

To improve the monitoring capacities of an early warning system, the **re-activation and upgrading of existing observation networks** may make sense as it can be: i) cost-effective in terms of existing infrastructure and sensors; ii) it can ensure that timeseries data for the same location are continued; iii) existing trained observers are readily available. Within the ongoing SDC/SECO-funded 'Improving Resilience to Floods in the Polog Region' project in **the former Yugoslav Republic of Macedonia**, UNDP, in co-operation with the hydro-meteorological service, re-activated and upgraded systems in meteorological and hydrological stations as key elements of a flash-flood early warning and public-alert system. Existing hydrological stations along the Pena River – including the town of Tetovo and the villages of Tearce and Jegunovce - were restored (most of which had been out of operation since the early 2000s) and new monitoring sites were introduced. The re-activated and upgraded monitoring network will later be integrated with a flood information and notification system to address the need for prompt notification of flood conditions in urban and rural areas where streams rise and fall rapidly. The upgraded system will cover the entire territory of the Upper Vardar River Basin, providing timely information on possible flood events for all communities at risk.

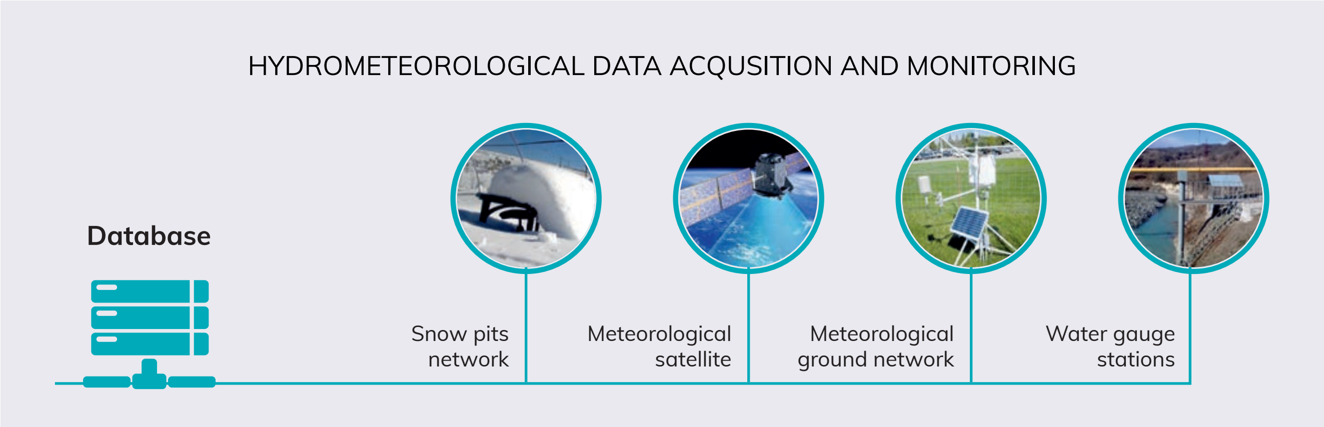


Figure 5. Hydrometeorological data acquisition and monitoring for drought EWS (Climatechange.uz, 2018)

As highlighted, observations comprise the basis of climate projections. The accuracy of the outputs of climate **models** (predictions and projections) is often dependent on the amount and quality of observed data which is used by the model. However, the complexity and the sophistication of the model also play an important role in the success of any forecasting scheme.

A challenge in climate modelling is the trade-off between spatial resolution and the ability to model global processes. Global Climate Models (GCMs) are used to understand global feedbacks and drivers of the future climate, but they have a low spatial resolution that is often not suitable to understand the climate of smaller regions or specific locations. To overcome this problem, it is common practice to use nested models, which link models of different scales within a global model. To model climate-induced hydrometeorological hazards, climate models need to not only be highly spatially resolved, they also need to be integrated with hydrological and hydraulic models.

As was evident during the 2014 floods, the Western Balkans - including Bosnia and Herzegovina - are particularly exposed to the impact of flooding. The Intergovernmental Panel on Climate Change (IPCC) projections indicate that this phenomenon will be further exacerbated by climate change. To address this pressing issue, a UNDP project in the Vrbas River Basin in **Bosnia and Herzegovina** has committed to upgrading the technological infrastructure of this river basin to better understand and predict flood events. One of the first goals of the project was to expand the hydrometeorological observation network and to develop a **model** to predict climate-driven exposure to floods in the basin and then produce hazard and flood risk maps. To be able to generate flood forecasts, different models were developed, including a geometric model of the Vrbas River terrain and a hydrological model able to simulate hydrographs using available climate scenarios. The developed models set the baseline for identifying thresholds for high/hazardous water levels and understanding flood wave propagation in the river. Additional activities to support local knowledge on climate change included the enhancement of modelling capabilities for the Bosnian NHMS, the installation of automatic stations in the catchment, the creation of a database suitable for flood early warning system purposes, and the implementation of a flood forecasting platform.

Another natural hazard which will likely be exacerbated by climate change in many places across the world is drought. Drought differs from other natural hazards in various ways. Drought is a slow-onset natural hazard that is often referred to as a creeping phenomenon. A drought early warning system is designed to identify climate and water supply trends and thus to detect the emergence or probability of occurrence and the likely severity of drought.

This information can reduce impacts if delivered to decision makers in a timely and appropriate format, and if mitigation measures and preparedness plans are in place. There are numerous natural drought indicators that should be monitored routinely to determine the onset and end of drought and its spatial characteristics. For example, the U.S. Drought Monitor Map and the European Drought Observatory combine bottom-up approaches of merging drought evaluations at national and subnational levels with a top-down approach of providing continental-scale information from meteorological networks, hydrological modelling, and satellite remote sensing. The Food and Agriculture Organization of the United Nations (FAO) Global Information and Early Warning System on Food and Agriculture (GIEWS) accumulates information from local observers, market reports, and remote sensing on evolving drought and food security conditions and provides outlooks on potential problem areas. Satellite remote sensing information has been used to measure hydrological variables at the land surface, as well as the state of natural vegetation and agriculture, often at very high spatial resolution (<1 km) and in near–real time, although their use in operational drought monitoring is still generally in its infancy, and mainly for monitoring at large scales. Drought EWS require different data inputs and modelling approaches depending on the type of drought e.g. whether it is agricultural, meteorological, or hydrological drought. In **Uzbekistan**, climate variability and climate change are causing glacier melting and changing meltwater patterns and river run-off. In concert with increasing water use, the risk of hydrological droughts has increased. This has prompted the upgrade, within the framework of a joint project of the Government of the Republic of Uzbekistan, UNDP, and the Adaptation Fund, of an existing drought early warning system (DEWS) to enable better projections of water availability in different water basins of Uzbekistan. The existing DEWS was designed and developed by the Centre of Hydrometeorological Service under the Cabinet of Ministers of the Republic of Uzbekistan (Uzhydromet) based upon mathematical models of runoff forming processes, and was explicitly designed for zones of runoff formation. The project also has to deal with downstream zones of the Amudarya river, where runoff is extensively used and dispersed, requiring the existing DEWS to be adapted. The project focussed in particular on enhancing **weather monitoring and climate modelling capacity**. It is noteworthy that the meteorological observational ground network in the Karakalpakstan region was equipped with sensor-based telemetry and with advanced communication facilities. By better understanding climate change impacts and their import for drought forecasting, the country's adaptive capacity was enhanced. Better climate modelling was achieved through improved climate data acquisition (via the upgrade and automation of hydrometeorological and climate monitoring systems), analysis, and dissemination capacity. Thanks to partnerships with different research institutions, the existing DEWS has gradually been improving, with a snow coverage mapping facility realised through remotely sensed data, regional climate change scenarios, and mapping of drought prone areas. Finally, the DEWS was upgraded with statistical-based tools to allow a qualitative assessment of water contents, plus quantitative data on water supply for specific locations. The project has therefore adapted an original DEWS system to the conditions of the region's geography in the face of climate change. Thanks to all of these interventions, the system is currently operational in two zones with different runoff patterns - upstream (Syrdarya and Amudarya) and downstream (Amudarya). For a more detailed overview of the drought early warning system's structure, see *Figure 6*.

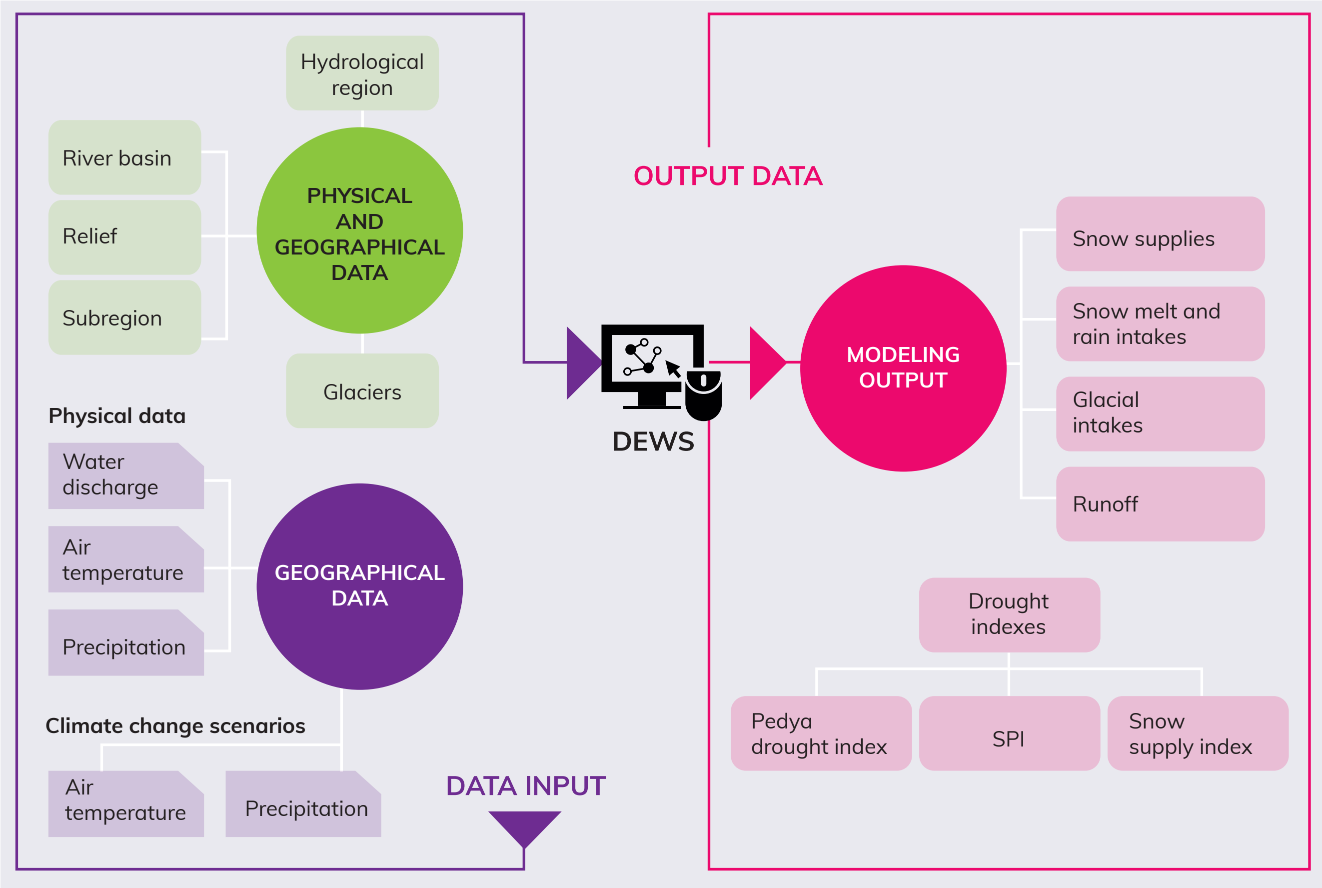


Figure 6. Structure of Uzbekistan's drought early warning system

Technological solutions are not only used to produce climate projections, but also to **manage climate data** and foster international **data and knowledge sharing**. A UNDP project in **Moldova** aimed at supporting the State Hydrometeorological Service (SHS) in producing and sharing hydrometeorological data and improving public service quality and availability. By upgrading the climate data management system, the SHS made a step forward in meeting World Meteorological Organization standards. To achieve this, the SHS was provided with climate data processing software which is linked to a server storing the data from the observation network. To embed the new system in a more user-friendly environment, the existing SHS website has been restructured to improve the sharing of information and services. Through a series of training seminars (on satellite meteorology, radar meteorology, numerical weather prediction) delivered by the Austrian Central Institute for Meteorology and Geodynamics targeting a group of SHS operative forecasters, it became possible to build the human resources necessary for running and maintaining the climate data management system. This project not only highlights how technological solutions can upgrade hydrometeorological monitoring systems, but also provides an example of how international co-operation enhanced institutional and human capacities and, thereby, makes the project more sustainable in the long run.

The ability to **forecast** a hazard is what most often comes to mind when speaking about EWS. Forecasting is often associated with weather projections. Weather forecasts have utility for a wide spectrum of interests, since rain intensity, wind speed, and air temperature are relevant for multiple stakeholders. Therefore, there are multiple organisations that provide free weather forecasts online. However, without adding locally collected data, the accuracy of these can be limited.

Other than predicting the weather, it is also possible - to some degree - to forecast geophysical events and humanitarian disasters, such as volcanic eruptions or famines. An example of a free access forecasting system is the **Famine Early Warning Systems Network** (FEWS-Net). The FEWS-Net multi-institutional partnership, primarily led by the U.S. Agency for International Development, provides routine monitoring of climatic, agricultural, market, and socioeconomic conditions in over 20 countries, mainly in Eastern Africa and Central America. This information is integrated with weather forecasts in combination with historical data and food prices to estimate when and where a food crisis may occur. FEWS-Net uses hydrologic monitoring tools to evaluate and map long-term tendencies in food security and produce high-frequency assessments from agro-hydrologic models driven by satellite rainfall estimates.

The accuracy of forecasting is correlated with data resolution, but also with the amount of historical data that is accessible. The use of modern technology is now making it possible to collect and store large-scale datasets while also using all this information for validating weather prediction software.

Georgia's multi-hazard EWS project, funded by the GCF, integrates modern technology as the core of the resilience solution. The project will deliver an extensive multi-hazard warning system (see *Figure 7*). The upgrade of the forecasting system will be undertaken both by rehabilitating, purchasing, and installing new **monitoring hardware**, and by integrating **new sources of data** into the forecasting platform. The use of additional data sources, such as weather radar data or Multi-sensor Precipitation Estimates (MPE) data, could both improve the identification of events and increase the lead-time available for the dissemination of a warning. To implement this platform, existing hydrological and meteorological **models** will be expanded to cover the whole territory of Georgia. Besides the already partially operative flood forecasting system, new systems will be set up to forecast droughts, landslides, wind, and hail storms. For each of these hazards, the project will design the **forecasting system**, collect and analyse historical data, design forecasting products and develop warning criteria.

2.2.3. Warning communication and dissemination technologies

Traditionally, warnings were issued through sirens for fast-onset hazards and through print when time allowed. Sirens can cause difficulties in giving precise orders on how to act, since the cause of the warning might be unclear for the receiver. Advances in technology have made it possible to send targeted and specific hazard warnings with no delays. Through e-mail, text messages, radio broadcasts, or mobile applications, large sections of the population can be easily reached within seconds.

Within the aforementioned project in **Georgia**, particular attention during the development of the early warning system was paid to the effective dissemination of warnings. Different activities will serve this scope, including the development of a **telecommunications system** and the integration of a telemetry system for near real-time dissemination and use of the new early warning system. To increase the warning dissemination efficiency of the community-based EWS, last-mile communication models will be included in the design of the system (see *Figure 8*). The government, besides developing communication and standard operating protocols, will work in partnership with telecommunication companies to implement technical aspects. To reach the target group of farmers and agricultural enterprises, agrometeorological services will be engaged in the generation, dissemination, and use of climate information and weather early warnings. Different communication tools (mobile phones, radio, television, dedicated web-pages, and service/local consultation centres) will be used to spread warnings of extreme events, precipitation, temperature, etc.

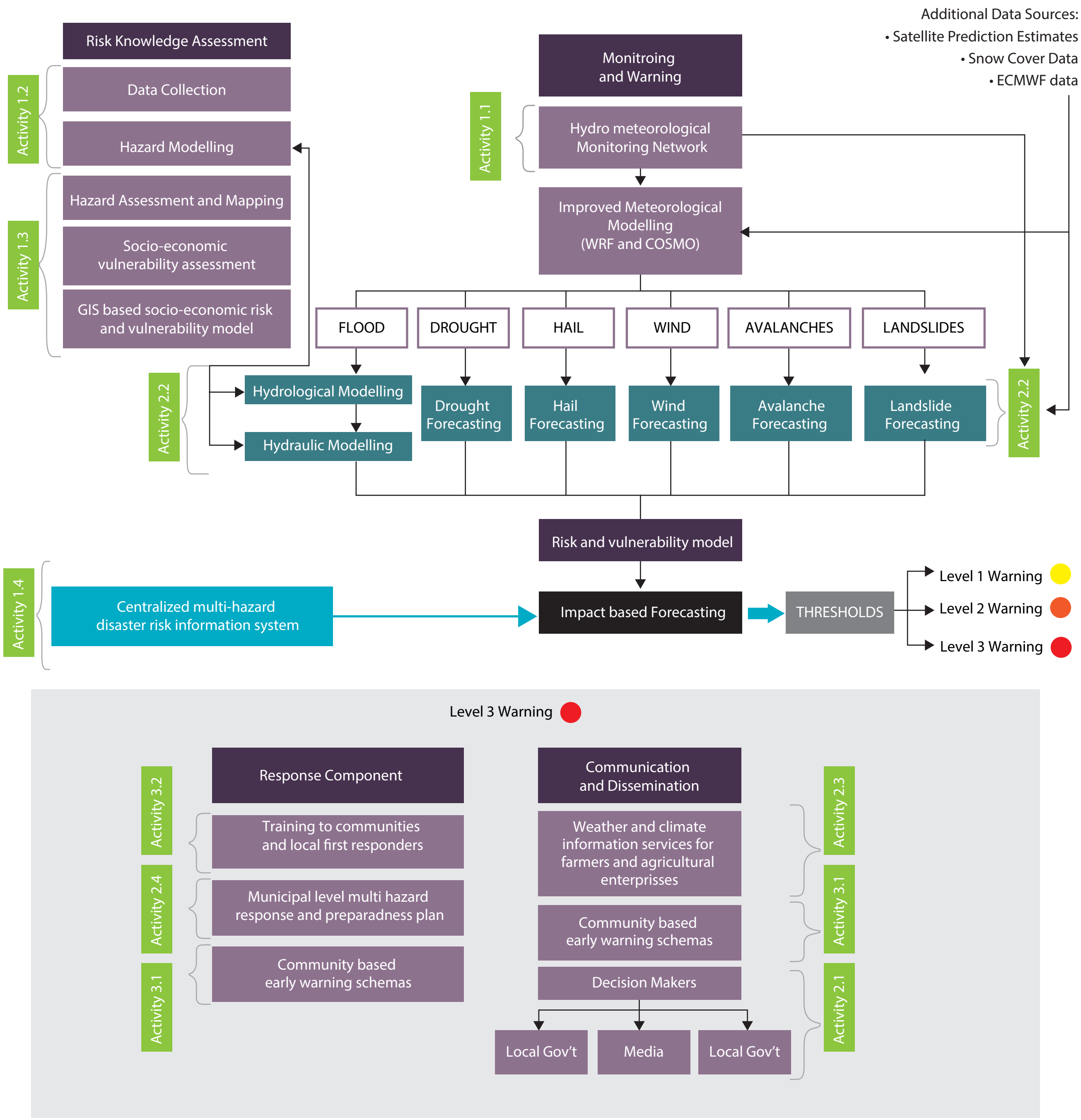


Figure 7. Operational approach to impact-based multi-hazard early warning system (Georgia GCF Project Document, 2018)

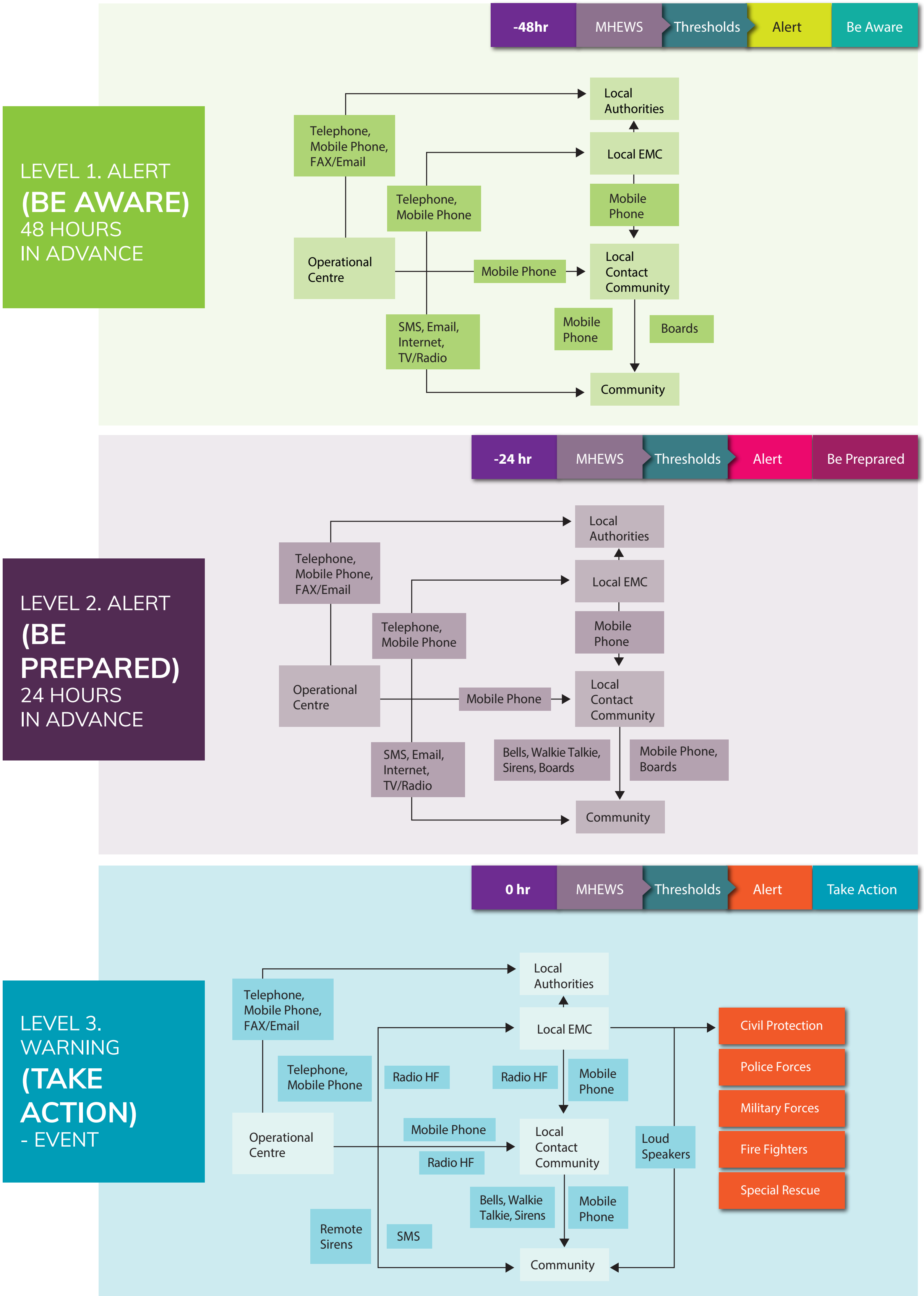


Figure 8. Warning communication flows from operational centre to community for different warning levels. (Georgia multi-hazard EWS Project Document, 2018)

One further advantage of using digital methods to disseminate warnings is the possibility of receiving information directly from the user of such communication streams.

A project in **the former Yugoslav Republic of Macedonia**, later expanded to **Kosovo**3, addressed the recognised gap in the capacity for response operations during disaster and crisis. With support from students from a national university, the UNDP country office of the former Yugoslav Republic of Macedonia built a **mobile phone application** to overcome this gap. The application (available for Android, IOS, and Windows Phone) gives access, through an interactive interface, to detailed information on events like floods, fires, power cuts, and heavy snowfall. When major floods hit the country in 2013, communities were continuously updated on the weather to expect, what safety precautions to take, and the progress of relief efforts. At the application's core is a digital infrastructure on which the emergency service bodies can quickly update information for ongoing events as well as transmit early warnings. This also had the benefits of standardising reporting over the sector. Despite its initial success, difficulties with sustainability resulted in a lack of regular updates and its full integration in the system. However, in Kosovo, where the implementation was done by the Emergency Ministry, centralised management guaranteed a full uptake and the application remains fully operational.

In **Lebanon**, an early warning system named LARI was developed to increase farmers' access to information on climate-induced hazards. The system used to provide agro-meteorological information to farmers via SMS but when in 2015 it shifted its information channel to a **smartphone application,** uptake increased from 2,000 recipients to 14,000. The transition to a mobile application made it possible not only to reach a larger community, but also to upgrade the content of the messages. Currently, the LARI app efficiently distributes information such as:

- Weather forecasts up to ten days in advance
- Advice on irrigation periods and recommended methods
- Alerts on disease and pest outbreaks as well as appropriate control measures.

Although app redundancy and a lack of information centralisation can result in inefficient investments in novel warning dissemination systems, the success of these examples sheds light on how disaster risk reduction, to be effective, must mirror the needs of a changing, increasingly technological society.

2.2.4. Information technologies for emergency response

To improve emergency response, technology can provide solutions which range from automatically cutting the gas supply when an earthquake is detected to effectively educating on what to do if a disaster strikes. The speed of action particularly affects the success of emergency response activities. This speed can be achieved in several ways, not least through the rapid distribution of warnings. But rapid distribution of warnings is not in and of itself sufficient unless stakeholders are well informed about actions to take in an emergency.

Commonly, disaster responses are co-ordinated by an entity (in most cases the national agency for emergency response) specifically appointed to the task. With the growing reach of mobile technology and the use of social media, this landscape is now gradually evolving. **Online platforms** such as Facebook and Google help people connect and co-operate without a central mandate.

One of the most commonly used platforms for emergency response is **Facebook,** where the specific function is called **Crisis Response**. The ability to monitor and administer during emergencies resides outside of the proprietary/commercial social media provider; Facebook solely provides the specific digital infrastructure. Its working principle is simple yet very effective: when enough users have reported on an event in a specific area, the crisis response function is automatically activated. As a result, all Facebook users within the area are reached with a push notification where they are encouraged to indicate if they are safe. After giving feedback on one's safety status, friends and relatives are then informed through a notification. Moreover, a dedicated Facebook page is activated where individuals can request assistance and provide help both in the form of actions and resources.

3 References to Kosovo shall be understood to be in the context of Security Council Resolution 1244 (1999)

Building a dedicated application for the purpose of warning does come with the advantage of being able to verify all information that is posted. If mandates are clear, it can also lower the probability of contradicting information from authorities.

There have been several efforts towards developing such mobile phone applications. One example is **Armenia**'s '911 SOS' application. The **application** was part of a larger project entitled 'Risk-Informed Urban Development' implemented by UNDP in collaboration with the Ministry of Emergency Situations. The main objective of the application is to organise the targeted and rapid response of citizens in emergency situations. Additionally, the service provides medical and psychological support during an emergency. By pushing an 'SOS' button, the app triggers a call to the national emergency call centre, together with the exact location of the help request. In this way, people with disabilities or people who are not able to describe where they are can be easily located and assisted. The application also provides possibilities to connect and find the status of family members and friends.

In areas where internet and/or smartphone access is sparse, emergency response tools are being designed to specifically reach underserved users. Often these systems are based on response recommendations being transferred using **SMS** technology and then further forwarded through **phone trees** or village **representatives**. A project which uses SMS to organise emergency response is the 'Rapid SMS Community Vulnerability Surveillance Project' in northern **Uganda,** that was implemented by UNICEF and ACTED. The messages are generated from location-specific warnings and come with basic information on hazards and what actions to take.

2.3. Public involvement and community-based solutions

We must increase investment in community resilience, with the full participation of women, young people, and other groups in society. Follow the rule: as local as possible; as international as needed. Local action must be driven by local needs and complemented by regional and international support.

-Ban-Ki Moon,
then-UN Secretary-General, 2016

EWS are useful only as long as they stimulate an appropriate response which empowers people to mitigate the impacts of a disaster. If the community is not reached, involved, or aware of the EWS, maintenance, sustainability, and effectiveness will be negatively affected. People are the last-mile actors in emergency situations, hence it is important that EWS are built on existing capacities and coping capabilities within the community. To achieve this, EWS should be designed and implemented in close collaboration with communities, vulnerable groups, and individual needs in such a way that disaster risk reduction intersects with development. With this approach, EWS can stimulate wide acceptance and provide for long-term sustainability.

To be effective, community-based EWS must tackle the challenge of combining 'bottom-up' with 'top-down' elements. Community participation and empowerment is vital to understand the needs, risks, and vulnerabilities of the community. EWS have to mirror the priorities of a community, as well as to actively involve the community through ownership or legitimacy. One good practice is to involve the community in the use and operation of accessible technology for the early warning system.

Communication also plays a key role in community-based EWS. Communication is decisive for the success of an early warning system since it allows co-operation between key actors, sets the foundations for risk knowledge and response capability, undergirds effective delivery of the warning message, and influences how ordinary people take actions to reduce risk in their everyday lives. Although its importance is well recognised, EWS tend to fail mainly in this component. To effectively be able to reach and communicate with a threatened community, the agency which issues the warning must be aware of which kind of language, register, content, channel, and packaging should be used to communicate risk.

This section will show how threatened communities and people can be empowered, across each component of an early warning system, to reduce risk.

2.3.1. Raising public risk awareness

Risk knowledge is the fundamental requirement of each user-oriented early warning system. Without widespread education on risks, warnings, and how to react to them, EWS lose their fundamental mandate to prompt a mitigating action by endangered communities. For this reason, increasing public risk awareness is an activity often included in the development plan of community-based EWS.

Public risk awareness is defined by the International Federation of Red Cross (IFRC, 2011) as 'the extent of common knowledge about disaster risks, the factors that lead to disasters and the actions that can be taken, individually and collectively, to reduce exposure and vulnerability to hazards'. There are four major types of approaches that can be used to educate the public and raise risk awareness: campaigns, participatory activities, informal education, and school-based education. Best results are achieved through a mixture of different approaches and through redundancy in the communication of messages.

On an international, national, or local level, campaigns can be undertaken to provide uniform, large-scale impacts with standard messages. Campaigns are comprehensive efforts that include multiple components to help reach a specific goal.

In **Moldova**, UNDP is assisting the Civil Protection and Emergency Situations Service (CPESS) in developing communication and outreach strategies to improve public risk awareness and education. The plan includes a series of seasonal **campaigns** to increase awareness of floods, earthquakes, heat-waves, freeze, and wildfires. These broad-scale campaigns encompass a series of activities to not only inform citizens about hazard risks, but also to train them regarding their duties in the event of crises. The activities range from public events, training and drills, information booths, media and cultural events, to activities targeting children.

In the **Philippines**, the Weather Philippines Foundation (WPF) provides weather services to the population and has developed a strong public outreach **campaign** characterised by the hashtag *#WeatherWiser*. The *#WeatherWiser* programme aims at informing the public on the weather services provided freely by the foundation, on how to understand the weather information provided, and on how to apply the information properly during severe weather events. To reach this goal, the WPF uses several platforms, such as a mobile application, a webpage, a dedicated TV channel, and several forms of social media, where diverse educational weather content (articles, videos) is uploaded and shared.

The 12-episodes series

'#WeatherWiser Ka Na Ba?', for example, focusses on explaining weather through simple concepts. Through another five-episode animated series, entitled 'Weather Wizards', WPF engages with the younger segment of the public to increase children's awareness of weather impacts.

In the examples above, campaigns often encompass a broad range of activities, such as participatory activities, informal learning, and school-based learning. **Participatory learning** activities are often included in public awareness-building strategies. Thanks to the active engagement of the public, they are usually very effective in developing a culture of prevention. Simulation and drills, for example, not only teach people how to behave in an emergency situation, but they also contribute to identifying fallacies in emergency plans. More importantly, active engagement strengthens in the public a sense of empowerment towards emergency situations.

In the **Hindu Kush Himalayan** region, the International Centre for Integrated Mountain Development (ICIMOD) has developed a project that will implement a community-based flood early warning system. To improve the effectiveness of the system, the project also focuses on providing comprehensive technical and theoretical knowledge on flood risk to the affected community. To achieve this, ICIMOD has developed **hands-on training** on flood risk management and the local early warning system. This was done through a five-day course to let the communities familiarise themselves with the instrumentation and the process of the flood EWS. The course not only provides lectures on how it works, it also gives all participants the chance to operate the early warning system through practical sessions and fieldwork.

Cuba provides a good lesson on how to actively involve communities and people in risk awareness activities. Cuba's high exposure to tropical cyclones has made the country particularly advanced in the matter of public awareness initiatives. Particular emphasis is given to the role of **school education**. In the national education system, subjects dealing with civil defence are mandatory at multiple stages across primary and secondary school. Additionally, a civil defence module is mandatory in all programmes of the higher education system.

Not all school-based risk awareness-raising initiatives are limited to school subjects or university modules. In the above-mentioned risk awareness-raising programme in **Moldova**, for example, youth are targeted through a series of diverse school-based activities. Not only do some school lessons focus on disaster and climate-related risk, but children are also engaged through firefighters' interventions in schools and creativity competitions. In co-operation with the ministry of education, the civil protection authority launches an annual national contest of photos and drawings on natural hazards and their mitigation for children in school. Similarly, it also launches a short film contest for children to promote prevention and response measures. Co-operation with schools is also established through collaborations with school-radios and newspapers. Moreover, teachers are encouraged to tackle awareness during meetings with parents. To ensure that a culture of risk awareness permeates society, the Ministry of Education and civil protection authorities are aiming at including subjects of civil protection and relevant innovative teaching methods in the curriculum of teacher education.

A further approach to increase public risk awareness, undertaken by non-governmental organisations or research centres, is **informal education**. This approach is flexible with respect to methods, channels, type, and size of the audience. The underlying principle is to take advantage of brief encounters with the public to stimulate awareness and engage in the discovery of appropriate behaviours to increase resilience. Favourite channels are therefore traditional media and social networks as well as public events.

The education channel of the **Cuban** national TV broadcasting authority, for example, broadcasts short courses of

30 lessons

where meteorologists educate the public on hydro-meteorological hazards, with a focus on hurricanes. During hurricane season, these short episodes are transmitted during breaks between regular programming.

2.3.2. Strategies for 'last-mile' communication and dissemination of information

When dealing with customised, community-based EWS, last-mile risk communication is always an important element. Risk communication is the process of delivering multiple messages about the nature of the risk - and practical actions to undertake - in case of an emergency (National Research Council, 1996). Recently, the international community has undertaken a series of commitments to improve risk communication through **protocols and guidelines**. The United Nations International Strategy for Disaster Reduction (UNISDR), for example, published a series of guidelines for public risk communication. These are centred around two pillars: address the right public, and issue an engaging and practical message that prompts an action in the recipient. The World Meteorological Organization (WMO) has addressed these recommendations by developing a Common Alerting Protocol (CAP) (WMO, 2006). This is an international standard format for risk communication designed for all hazards and all media. While facilitating the issuance of warning messages and making the whole process smoother through national structures, the CAP lacks the ability to personalise the message and dissemination channels to address threatened communities.

'Last-mile' communication is a communication strategy specifically targeting communities through well-tailored dissemination mechanisms. 'Last-mile' communication is intrinsically audience-targeted. The public must be known not only in its demographic details, but also in the way it perceives and comprehends risk. To overcome these obstacles, a good practice is to perform **audience research** when designing community-based EWS.

A UNDP project in **the former Yugoslav Republic of Macedonia**, aiming at improving resilience to floods in the Polog region, will help increase the overall resilience of communities at risk of future floods. Activities have been undertaken to review the institutional framework and existing EWS, including management responses and the roles of different institutions. Additionally, **sociological research** was conducted in order to provide information on demographic and socio-economic characteristics of the local population, as well as information on their knowledge, views, and perceptions about floods. The information collected through this sociological research will help in designing the campaign and improving the overall awareness of the occurrence of floods, their causes, management responses, and the roles of different institutions. It focusses on the key preconditions and benefits of introducing early-warning and public-alert systems for different types of floods, including the flash floods that are typical for the Polog Region. In this way, the activity will help create the requirements for the institutionalisation of the early warning system, including the facilitation of co-operation between different responsible institutions. The project supports the design and testing of different plans of action in emergency situations, facilitating collaborative efforts among multiple institutions and at-risk communities.

Addressing the right audience can be done in various ways: by issuing warnings in a specific language or dialect, by modifying the content to respond to community necessities and by using specific dissemination channels. Rural communities are often hard to reach because of cultural and infrastructural isolation. Therefore, customised solutions have to be identified based on the needs of the community.

Although communication is fundamental to all aspects of drought cycle management, communication can be very difficult in drought-prone areas. In **Kenya**, for example, the vast drylands have few roads, uneven electricity access, and sparse telecommunications infrastructure. Postal services are slow and unreliable. Local people speak different languages and dialects, and literacy rates are very low. To address this problem and minimise the impacts of droughts, a community-based warning dissemination and response organisation tool was successfully implemented in the Garba Tulla region in **Kenya** by the local development office (Garba Tulla Development Office). The system disseminated warnings using **local (community)**

radio stations

in the **local language**. Initially, the community radio initiative began with one base station and one mobile VHF radio operation to co-ordinate emergency relief intervention during the severe drought of 1992. The mobile station visited remote communities to collect data on their needs. The information was then relayed back to the base station, which compiled a report and sent it onwards to the relevant authorities for action. The radio station used for the transmission not only made it easy to identify the locations most in need and to act swiftly with an appropriate response, but also became a channel to inform villages of threats and appropriate actions. Over the years, more radios were added, contributing to a network of nine connected villages. The radio station was popular among small rural communities where radio receivers were better dispersed than other communication technologies.

A similar, audience-customised approach was used within a UNDP project in **Zambia**. The project is part of a larger programme on 'Climate Information for Resilient Development in Africa (**CIRDA**)' that has been ongoing since 2014. One of the project components is the digitisation of old weather archives to improve forecast accuracy. Thanks to this effort, more accurate weather warnings can then be disseminated through **mobile phones** and **solar-powered radios** to those most in need of said information, such as farmers. In this way, farmers can now be informed about upcoming storms or droughts as the weather events occur around the country. Moreover, to overcome the high rate of illiteracy and to increase trust in information, warning messages are primarily disseminated orally (via radio or phone calls).

There are different strategies to face difficulties stemming from the disparity between experts disseminating warnings and their lay recipients. In **Moldova**, the General Inspectorate of Civil Protection, supported by UNDP, has upgraded its communication strategy by addressing the use of technical terms within risk communications. The civil protection plans to develop **expertise in communication** by employing specialised staff, training existing staff, and assigning responsibilities in emergency communication. To achieve this, the department responsible for mass communications was formed at headquarters, where specialists in communication and public relations have been hired, together with consultants, for the coaching of civil protection staff.

In **Cuba**, the government adopted a different strategy. Instead of educating the civil protection in the matter of communication, they are training mass media personnel in disaster risk reduction. Every year, mass media staff members have to attend updating training courses and a national workshop on disaster reduction. The same workshop is also taught at a provincial level, whereby provincial and municipal media are targeted. Community outreach is possible because there are numerous television and radio stations at the municipal and community level. Since the government directs media operations, these local outlets are comprehensively used to spread information and directions during and after disasters. To better reach smaller communities and rural areas, the communication strategy adopted is not solely top-down. Through grassroots organisations, social workers, and local leaders, warnings and risk communication are often transmitted face-to-face.

2.3.3. Community preparedness and response capacity building

Once a hazard has been detected and the warning disseminated to the community at risk, the success of the early warning depends on the community's preparedness for response. The community plays a key role in the response since the local residents of a community are the people most qualified to understand local opportunities and constraints. Moreover, the first and quickest response to a disaster in any community will always come from the community members themselves.

Community-based disaster preparedness is a process that mobilises a group of people in a systematic way towards achieving a safe and resilient community. Important elements are balanced power relations, coherence in the process of decision making, and co-operation in dealing with issues, conflicts, and individual and collective tasks. To be effective, response initiatives have to be inclusive. Throughout the whole preparedness process, it is fundamental to include those that are more vulnerable in case of disasters, such as women, children and people with disabilities. This can be achieved by including vulnerable groups in the design of emergency plans, and through the assignment of special assistance tasks in the community.

Once the warning has been received, the time for reaction must be capitalised upon as effectively as possible. **Evacuation plans** are an effective strategy to strengthen preparedness and make the community aware of emergency procedures. However, evacuation plans must be customised for each hazard. For example, while, during floods, the evacuation often directs people to elevated grounds, the same measure would be counterproductive in the case of a thunderstorm or strong winds. To fill the gap between the development of plans and the actual ability of communities to follow them in hazardous situations, it is vitally important that the community has been **trained** to appropriately respond to the warning.

In **Cuba**, the government is aware of the importance of preparedness for the smooth functioning of its cyclone early warning system. To keep the preparedness of both civilians and institutions high, the Cuban civil defence authority each year promotes a two-day long **emergency case exercise** called Meteoro National Exercise for Disaster Case Actions. The first day focusses on governmental agencies and civil defence preparedness (institutional response capacity building), while the second day targets workers and the wider population. Drills, simulations, and training are carried out at national, municipal, and community levels. The Meteoro exercise not only assists authorities and the population to prepare for disaster situations, but it is also used to test the warning, communication, and information systems within the larger EWS infrastructure.

In most emergency response plans, roles and tasks are established in a hierarchical way, with institutions and governments taking the lead. On the community level, the roles are more flexible, and allow each family or community to adapt plans to internal structures. Either way, the different actors have to co-operate both to help others and to make sure that no counterproductive actions are taken. To streamline the functioning of the various roles, **training, simulation exercises,** and **drills** can be helpful not only to train each individual in his or her specific task, but also to identify fallacies in response plans.

A community-based flood early warning system in the **Hindu Kush Himalayan region** was able to strengthen the response capacity of communities in dealing with floods. This was made possible through the creation of **task forces and groups** where specific responsibilities were assigned, such as early warning, evacuation routes, shelter zones planning, search, and rescue. To keep the readiness of the community high, **tests, training,** and **drills** are undertaken on a regular basis. All task forces co-operate to make sure that aid facilities and relief materials are ready.

Besides training, a written **checklist** is a good way of making sure that individuals in a high-stress situation act more rationally. By checking the list and following **standard operating procedures**, the likelihood that something – or someone - is missed, is reduced. An example of such a standard operating protocol is the one shown in the diagram below (*Figure 9*).

The MHEW stages:

- Normal situation
- Alert: take closer look and continue monitoring
- Warning: thresholds exceeded, issue the warning

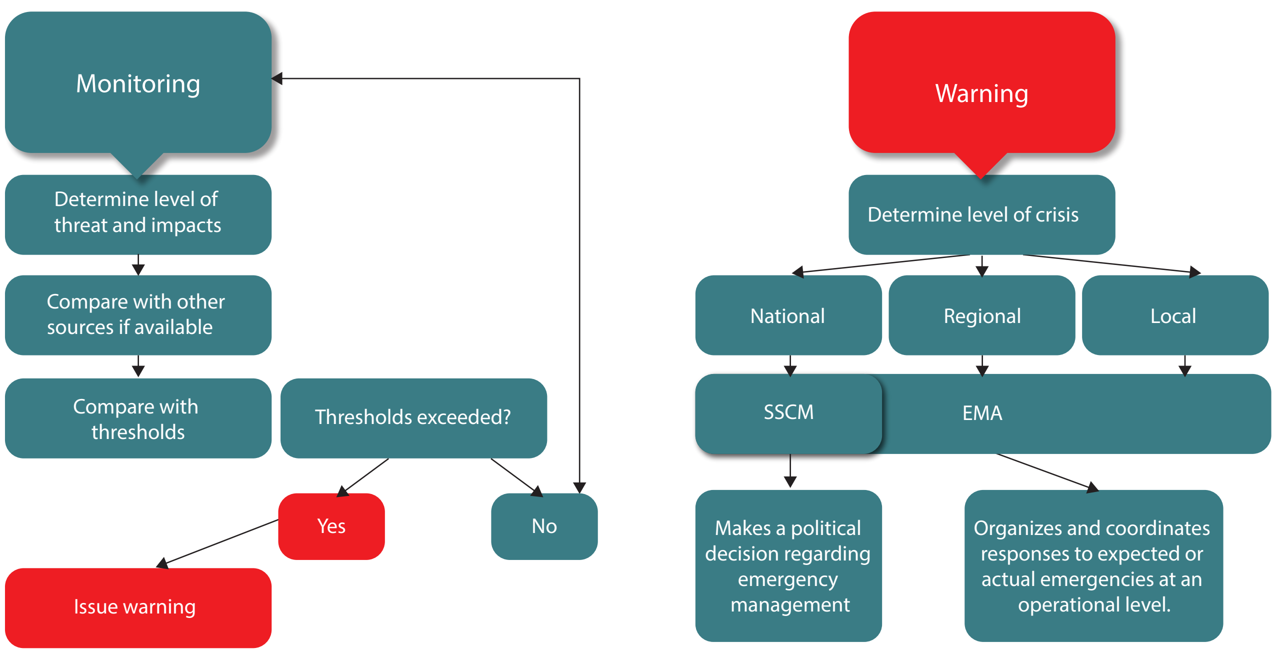


Figure A. Standard Operating procedures for provider organisations.

Figure B. SOPs for decision making based on the warning

Figure 9. SOPs for provider organisations (left) and decision making based on the warning (right), (Georgia GCF Project Document, 2018)

2.3.4. Case study: how to build a community-based early warning system

To give an example of how an early warning system can be designed and developed to target and reach out to a community, two case studies from the region will be analysed in greater detail. One focusses on climate change resilience, while the other one focusses mainly on flood and earthquake early warning.

Box 4: Community-based early warning system and last-mile communication within the Georgia multi-hazard EWS project

Climate change and climate-induced disasters often greatly affect the poorest and most isolated communities. They often lack the financial resources to prepare and cope with disasters and have a limited awareness of early warning. The lack of watershed management plans reduces their ability to address the impacts of climate change such as increased flood frequency, damage, and other extreme weather events. A number of communities in the Caucasus region are becoming more and more vulnerable to climate-induced flooding and water stress. UNDP has developed several projects to increase the climate resilience of these mountainous groups in Armenia, Azerbaijan, and Georgia and thereby reduce their exposure to climate-induced disasters.

Community resilience through the UNDP-managed GCF project in Georgia will be achieved through the implementation of community-based early warning and climate risk management schemes, through public awareness and capacity building programmes, as well as through risk reduction structural measures. In the following section, we will concentrate on project activities regarding the community-based early warning systems, leaving structural interventions aside for the purposes of this case study.

In the Georgia project, community-based EWS will be implemented based on full community engagement and participation. **Participatory methods** will be used as much as possible, and the inclusion of women and youth will be a priority. The choice of the 100 communities (villages) will be made based on the risk assessment and mapping exercise completed under an earlier output of the project, so that the early warning system will be developed in the communities most at risk. Communities' willingness to participate and actively engage in early warning activities will be one of the key criteria for the final selection of beneficiaries under this activity.

For mountainous upstream communities that are affected by short lead-time events, the project will provide at least one telemetered rain gauge in the headwaters to provide backup and **additional information at a national and district level** (unless there are opportunities to share gauges between schemes), and with communication equipment. As a first approximation, the sensors will be deployed as high up in the catchment as possible in order to provide the longest lead-time possible. These rain gauges will communicate real-time precipitation information to the operational centre. Some schemes are also likely to include river gauges connected via telemetry in the lower reaches of the catchment (for measuring river levels), coupled with color-coded gauge boards for better visual markers of flood risk levels. The downstream communities may not require additional local monitoring equipment (as the national EWS will be capable of providing timely warnings) but will be equipped with the suite of warning communication tools.

The system will be community-based not only because the monitoring and communication infrastructure will be available at the community level, but also because the **community** will be **actively involved in the design of the system**. Local authorities and community leaders will be consulted on the scheme and on hazards experienced, for example through walkover site visits and through feedbacks on the estimates for the numbers and locations of households at risk. Special attention will be given to vulnerable groups (elderly, disabled, children, seasonal workers, schools, fishing communities, etc.). Special assistance required during hazard events/ disasters will be planned using risk modelling, vulnerability mapping, and community surveys.

Thanks to a GIS-based approach, warning and evacuation maps showing evacuation routes, shelters, the locations of vulnerable people/groups, critical infrastructure, NGO/Community Based Organisations (CBOs) offices, health facilities, and other operationally useful information will be developed. Local communities will be assisted in the installation and operation of the EWS. Guidance on the numbers and locations for the installation of manually-operated rain gauges and river gauges will be provided together with advice on the procurement and installation of telemetered radar level gauges and rain gauges. Each community will develop site-specific warning thresholds.

The project focusses also on actively **engaging communities in the early warning process**. Through community-specific engagement programs (e.g. meetings, plays, leaflets, posters, school classwork) and the development of simple forecasting tools at district and community levels, citizens will be able to understand the basics of disaster forecasting and engage with warning issuance. As part of these activities, for example, a series of simple tools to understand the correlation between rainfall and floods will be prepared. These will consist of, for example, maps showing the extent of flooding for different river gauge heights, rainfall depth duration criteria for initial flood watches, or look-up charts showing the travel times of flood waves and correlations between peak levels at river gauges. A volunteer observer or 'spotter' training and recruitment programme for rainfall, river conditions, and flood extent will be established, initially starting with schools, NGOs/CBOs, and other interested parties. This will include instructional material, guidance on recruiting volunteers, health and safety aspects, and provision of manually operated rain gauges.

Last-mile communication strategies will also be part of the development of community-based EWS. The project will ensure that central observations and forecasts are available at district and community levels (e.g. via text message and a website), and that training is provided on how to interpret the information. A standard set of warning messages, codes, icons, colour-coding etc. will be designed for issuing warnings in future schemes, based on a review of the national warning messages currently used. The format and content of text messages triggered directly from gauges will be decided. Local staff will relay information on rainfall, river levels, and flood conditions to the national and district level.

The **preparedness of communities** will be enhanced through extensive campaigns on EWS and multi-hazard risk management. As such, the focus will be in particular on gender-responsive and youth-engaging practices. These campaigns will make use of social media, TV and radio talk shows, media coverage of project activities, production of footage and short documentaries, training for media on EWS, and annual media competitions. Youth will be additionally engaged through training programmes, the development of manuals and informal education materials for schools and youth clubs, and through the inclusion of educational modules on disaster risk reduction in certain university courses.

Box 5: Strengthening community-based resilience and environmental emergency preparedness capacities in Armenia

Within the framework of an extensive disaster risk reduction and climate change adaptation project of UNDP in **Armenia**, a **community-based early warning system** was established in three cities and 22 communities. The project aimed at strengthening community resilience through a multi-hazard approach.

The project was designed to pose a solution to the centralised approach to EWS that dominated during the Soviet era. A national multi-hazard system already exists in Armenia, yet isolated mountain communities are often not reached by the main warning dissemination channels.

To identify a solution to this problem, UNDP conducted a needs assessment on a local scale. Besides needs in terms of human resources and institutional capacity, some key communities, which did not have a targeted warning dissemination system were identified as highly exposed to multiple hazards.

Within the frame of ECHO-funded and UNDP Catalytic Facility projects in the cities of Kapan, Stepanavan, and Dilijan, as well as in other 22 small communities, the following activities were undertaken to create a community-based early warning system:

- Technical specifications and locations were identified for the installation of an early warning system
- The early warning system's hardware was procured and installed in targeted communities. This phase was done in partnership with the regional Crisis Management Center and local municipalities
- Early warning systems were connected with regional and national EWS
- EWS were included in existing emergency plans, and implementation mechanisms were formulated for effective population protection and evacuation
- In the city of Kapan, a city resilience team was established to strengthen and consolidate public and private co-ordination for disaster risk reduction, preparedness, and response capacity.

The technical components consist of a network of local monitoring stations that communicate through telemetry with the national civil protection agency that then disseminates warnings through a series of sirens located in key locations within affected communities. In parallel, the co-ordination system can also spread the warning through national TV.

The project has successfully built a large user base that can now benefit from these interventions. For this reason, the government and 28 new communities have fostered a replication of the project that UNDP will support in a similar way.

2.4. Private sector engagement

The private sector is the perfect advocate for resilient thinking because of its direct relationship with consumers, customers and suppliers and can steer public demand towards risk-sensitive products and services. A new collaborative approach between governments and private enterprise based on trust will build disaster resilient communities.

Margareta Wahlström, UN Special Representative of the Secretary General for Disaster Risk Reduction, 2015

Engaging the private sector in emergency response and disaster is important, since building resilience to natural disasters is both an economic imperative and a humanitarian mandate. Post-disaster statistics provide a clear message on disasters affecting livelihoods, as well as business essentials like power access and transportation infrastructure, and providing incentives for private sector engagement in EWS.

Some sectors, such as the insurance business, have an obvious interest in reducing the number of incidents. This interest provides an incentive for their engagement in risk-reducing initiatives. Other sectors are motivated by Corporate Social Responsibility (CSR). CSR refers to a corporation's initiative to take responsibility for their impacts on social and environmental well-being by offsetting some of their negative externalities (or bolstering positive ones). This is usually done by actively engaging in projects and initiatives that prompt a positive change.

Another motivation for investment in disaster reduction projects is the will to test innovative solutions. Investing in research and development of sustainable solutions can lead to long-term benefits for the private sector, even when they do not lead to any immediate increase in profit.

Finally, engagement in services to help society always comes, at least to some degree, with an opportunity to spread knowledge about the company or its brand.

2.4.1. Services and technology to implement early warning systems

One of the ways the private sector may participate in building a more resilient society is through its expertise in infrastructure and technology. The private sector can engage in different ways: by providing early warning projects with free or discounted services, by delivering technological infrastructure, and by sharing its expertise.

To easily engage in humanitarian actions, some companies allow the **use of their services for free**.

The leading company in GIS (Esri), for example, grants ArcGIS licenses to non-profit organisations within the so-called **Nonprofit Organization Program**. Qualified members of the Nonprofit Organization Program receive the ArcGIS software at no cost to be used as a tool for risk assessment and mapping phases of EWS.

One sector that has a relatively high level of engagement in EWS is telecommunications. Telecommunication companies are often vital in order to communicate warnings while also being the main channel for finding further information for those at risk. An example where such a company offered their service for philanthropic reasons is the case is of KDDI, a **Japanese telecommunications company**. Together with the Japanese **Fire and Disaster Management Agency** (FDMA), they built a system to warn of earthquakes and missile launches. In this collaboration, KDDI is responsible for a disaster message board service, emergency email service, and disaster voice message in the event that a disaster occurs.

The **Philippines** is an island nation particularly susceptible to climate-related disasters. To address this issue, the **Weather Philippines Foundation (WPF)**, a non-profit organisation funded by the Aboitiz Group, has installed and maintains a modern network of nearly 1,000 automatic weather stations to monitor weather metrics used for forecasting and damage control. The co-operation between the WPF and the private sector extends not only to the network's funding, which is provided mainly by the Aboitiz Group; the private firm **MeteoGroup**, for example, shares with WPF its expertise in weather forecasting by processing the collected data and elaborating forecasts and bulletins. This collaboration means that in exchange for being allowed access to the weather data to be used for global weather reports, local forecasts are delivered for free. Other innovative arrangements include an agreement with **Cebu Pacific Airlines** that is providing free flights for weather station technicians in exchange for access to high-resolution weather forecasts.

A common partnership in early warning projects is with **private-sector media**, such as television, radio channels, and newspapers. This collaboration offers opportunities for expanded distribution of early alerts. When creating **Private-Public Partnerships** (PPPs) with media, it is important to have a clear response matrix that assigns roles and responsibilities like when, how, and who does what to interrupt broadcasts for the issuance of early warnings.

A good example of such early warning collaboration is the Asia-Pacific Broadcasting Union (ABU) that makes sure that warnings reach those in danger. The organisation currently comprises

272 member

broadcasters (from major national channels to small private ones) spread across

69 countries

from Turkey in the west to Samoa in the east. Thanks to this very broad coverage, the organisation has emerged, in recent years, as a regional leader in early warnings and disaster preparedness through the media.

In 2006, under a partnership with UNISDR, it adopted the 'Declaration of the Implementation of Emergency Broadcasting Systems in the Asia-Pacific region'. This is a call to action to the different members to unite and organise in order to use the broadcasting potential of the Union to minimise the impacts of disasters. One of the projects implemented through these efforts was the **Early Warning Broadcast Media Initiative**. Through this initiative, broadcasters and media were informed about the need for communication systems between authorities and the public. Moreover, internal Standard Operating Protocols were developed as well as a Broadcast Plan. The latter standardised the training of editors and reporters about the role of media before, during, and after disasters. All these activities contributed to creating a culture of early warning and preparedness within the target Asian-Pacific countries of the project (Malaysia, Thailand, China, Philippines, Vietnam, Cambodia, Indonesia) and succeeded in training over 500 broadcasters.

EWS are not solely comprised of monitoring, forecasting, and communication infrastructure. The human resources who operate and maintain the systems also play a vital role. In order for an early warning system to be resilient, updated, and effective, the beneficiaries must feel ownership of it and, therefore, the implementation should always come hand in hand with education and training. This whole process, which falls within the broader spectrum of **capacity development**, can enormously benefit from private sector involvement. The private sector can address the lack of human resources through expertise sharing and other educational initiatives.

2.4.2. Funding early warning systems: multiple benefits for the private sector

Some sectors decide to **fund** external projects rather than having an organisational involvement. The aforementioned **Weather Philippine Foundation**, for example, was founded in 2012 with the mission of providing free and accurate climate information to the public thanks to the funding of the Aboitiz Group and Union Bank. Other companies have additionally provided funds to the foundation in exchange for being provided with better weather forecast coverage in their area of interest.

The private sector does not only benefit from tailored weather information for the protection of human and material resources, but it is also to a high degree dependent on climate-smart business decisions. Sectors such as agriculture, power production, aviation, and mining all have a large interest in being warned about weather phenomena such as strong wind or lightning, and to maintain regular water flow.

The **hydropower sector** is an important partner for hydrometeorological risk management and EWS. With climate change bringing greater uncertainty and frequency of precipitation extremes, intense runoffs and increased peak river flows may result in reduced power production and damage to hydropower infrastructure. The hydropower sector is therefore an important stakeholder for flood risk management, and a beneficiary of enhanced hazard and risk information whilst climate-proofing their operations. UNDP has been engaging with hydropower stakeholders to facilitate co-operation along river basins on core aspects such as: generation and management of weather and climate information, hazard assessments, EWS, and flood risk management.

A sector that is, out of obvious interests, heavily inclined to reduce the number of disasters is the **insurance** sector. The fewer disasters there are, the less money they need to pay out to premium holders. Therefore, many insurance companies get involved in projects to increase societal resilience. In 2013, the **Zurich Insurance Company** made a **monetary commitment** of up to USD 22.7 million over five years to support the creation of a flood resilience model together with the International Federation of Red Cross and Red Crescent Societies. The model is based on innovative pre-event mitigation measures and targets poor communities around the world. As part of this effort, a successful activity is the implementation of the mobile application Z-alert in Indonesia. Today, Z-alert provides notifications on various hazards such as fire, typhoons, and tsunamis with the ability for private citizens to add and verify warnings (see *Figure 10*).

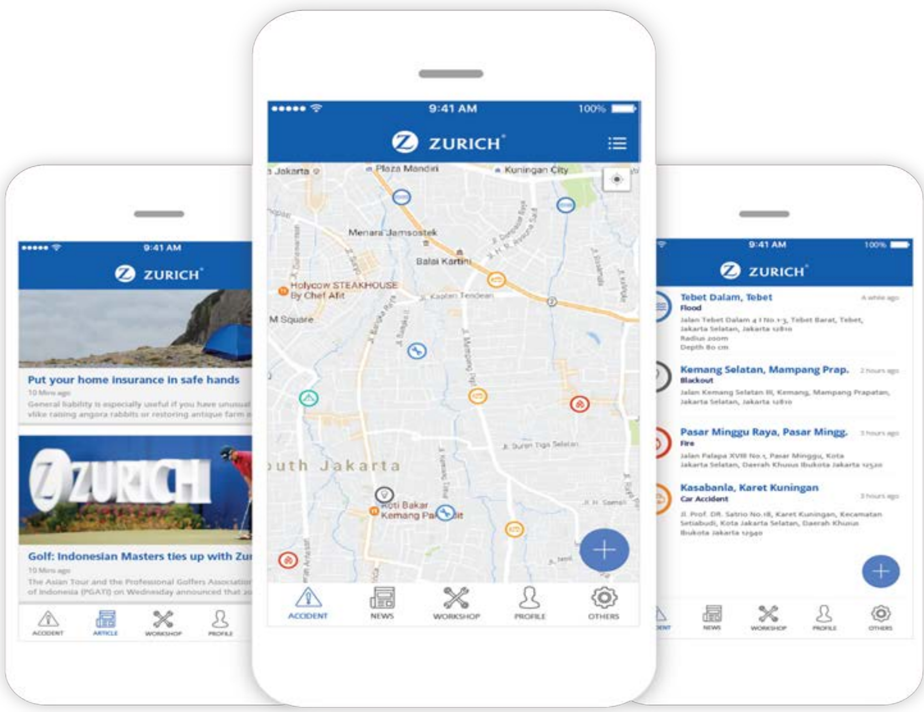


Figure 10. Overview of Z-alert application (neofusion.com, 2018)

2.5. International co-operation and data-sharing

We will work to strengthen international cooperation on managing disaster risk, reducing mortality, reducing the numbers of people affected by disasters, reducing economic losses, and reducing damage to critical infrastructure.

António Guterres, UN Secretary-General

There are as many national warning systems as there are countries. National to local EWS are easier to implement and maintain since they are customised for national conditions and needs, and because they can be managed by mandated governmental agencies. At the same time, global or regional warning systems - even if smaller in number – also play a significant role, since they can have the capacity to cover larger areas and multi-country hazards, which are dependent on conditions in more than one country.

Regional and international co-operation add to national EWS by providing improvements on the accuracy of warnings and by spreading knowledge. Multi-national EWS can offer not only improved performance, but they also are in some cases a requirement for the success of the early warning process. Within vast river basins, for example, cross-boundary collaboration entails a mandate to forecast and manage flood risk. The share of information between up- and downstream countries regarding rainfall measurements and runoff forecasts not only improves the accuracy of the predictions, but is also necessary to issue flood warnings downstream.

By sharing expertise and merging efforts into one early warning system, countries also contribute to the development of the whole region. Working together across national borders increases the possibility of co-ordinating joint response operations, and of spreading new knowledge faster to a greater number of stakeholders. This chapter will explain in greater detail how international co-operation and data sharing can enhance EWS.

2.5.1. Data sharing and infrastructure co-ownership for better warning issuance

For many hazards, effective warnings and adequate forecasts are difficult to issue if limited to the national level. To forecast tsunamis, for example, it is necessary to know the position of the epicentre, which often lies in international waters. Relying solely on nationally owned seismic centres leads to a delay in the detection of the epicentre, and therefore in knowing when and where the tsunami wave will reach the coast.

To address this problem, co-ordination and collaboration must underpin the whole process of issuing a warning, from monitoring and data sharing through to forecasting.

In some cases, the **monitoring infrastructure** has to be designed and installed on an international level. That is often the case for remote sensing and satellite observations. The European Space Agency owns, for example, a family of satellite missions called the Sentinels, many of which produce data that can be used to issue weather-related early warnings.

An extensive project aiming at enhancing international co-operation for meteorological data production and sharing is **Eumetnet** (the European Meteorological services Network). Eumetnet is a group of 31 European national meteorological services that provides a framework to organise co-operative programmes between its members in meteorology and related fields. These activities include observing systems, data processing, basic forecasting products, research, development, and training. One important component is the **Eumetnet Composite Observing System** (EUCOS). Including its series of different weather and climate observation projects, EUCOS has contributed substantially to the upgrade of the European-owned observation infrastructure for weather forecasting and climate monitoring over Europe.

After the devastating effects of the 2004 Tsunami in the Indian Ocean, UNESCO supported the development and installation of the **Indian Ocean Tsunami Warning System**. Within the project, 25 seismographic stations and six deep-ocean buoys for the assessment and reporting of tsunamis were installed in the Indian Ocean to provide seismic event alerts to scientists and NHMS through SMS and email. This new monitoring instrumentation is relaying information to 26 national tsunami information centres.

In the example of the Indian Ocean Tsunami Warning System, most facilities had to be built from scratch, but in many less-complex cases, the instruments needed to monitor hazards are already available on a local or national level. When instruments exist, however, forecasts can be limited because local or national data is not sufficient to provide a comprehensive overview of a particular event. In these cases, **cross-boundary data sharing** is an easy yet effective practice to increase the reliability and accuracy of forecasts. In the field of meteorology, data sharing has been a common practice for many years, mainly thanks to the global efforts made by the World Meteorological Organization (WMO). Under the WMO umbrella, partner countries have stipulated formal agreements on the type of data that are routinely exchanged to issue weather forecasts (Basher, 2006).

In **Europe**, the European Commission's Joint Research Centre (JRC) has achieved a lot in terms of international data sharing and forecasting efforts for its member countries. In particular, the JRC's Disaster Risk Management Knowledge Centre focusses on providing a platform for information exchange to achieve a harmonised approach to disaster monitoring. As part of this effort, the **European Flood Awareness System** (EFAS) collects hydrometeorological information from different national hydrometeorological services to model and forecast the dynamics of floods on a cross-boundary level. Thanks to EFAS, flood early warnings are issued up to

10 days in advance

to national hydrometeorological services and to the European Response and Coordination Centre. JRC have also developed **ASAP** (Anomaly Hotspots of Agricultural Production) that by summarising information from various data sources - such as precipitation measurements, satellite imagery, and modelled soil moisture content - can elaborate different information tools, such as graphs, drought maps, and country-specific drought alarms.

The **International Sava River Basin Commission** (ISRBC) was established in 2004 to support co-operation by riparian countries on sustainable water management, sustainable navigation, and reducing the impacts of hazards including floods and droughts. A joint Flood Forecasting and Warning System in the Sava River Basin (Sava FFWS) has been established via the framework of a World Bank project supported by the Western Balkans Investment Framework. The integrated forecasting system covers the Sava River Basin and the beneficiary countries of Bosnia and Herzegovina, Croatia, Montenegro, Serbia and Slovenia. The system was created by the Protocol on Flood Protection signed in 2010 by the Parties to the Framework Agreement to the Sava River Basin (2002) - Bosnia and Herzegovina, Croatia, Serbia and Slovenia. The system allows the member countries to maintain their autonomy in monitoring, modelling, and forecasting, while a common flood forecasting platform provides for better preparedness and optimised mitigation measures (ISRBC). Sava FFWS utilizes a Delft-FEWS platform based on HECRAS software, with the main server in Slovenia and with back-up servers in Croatia, Bosnia and Herzegovina, and Serbia.

Independently from the source of the data, whether it is produced in the framework of an international monitoring co-operation agreement, or merged together from different sources thanks to international data sharing, international co-operation is at the heart of issuing international to global level forecasts. For most international EWS, there are two main strategies used to forecast disasters: set up an international forecasting centre or utilise existing local expertise in modelling and forecasting and then disseminate the warning at the international level.

The importance of international co-operation and of sharing of information, skills, and resources for wildfire early warnings has been increasingly recognised as a result of the exacerbated severity of fire seasons caused by climate change. Under the support of the UNISDR, a global fire early warning system project (**Global EWS-Fire Project**) has been developed to globally produce a suite of fire danger and early warning products. The project delivers early warning products at different time resolutions, from long-term/seasonal fire forecasting, through medium-term early warnings (1-2 weeks), to short-term forecasting (1-7 days). Fire danger indices are specific for the region for which they are calculated, since they depend on the type of vegetation, soil, and climate. The Global EWS-Fire Project is innovative in the way it overcomes this problem while producing global fire probability maps and indices: ground-based and satellite observation are processed by the Canadian Meteorological Centre, which produces a series of indices. These link the wide range of uniquely calibrated, national fire danger rating systems with a single set of fire danger indices that have globally-consistent calibration. Thanks to these global indices, it is possible to make comparisons of fire danger across national borders, making available fire early warnings for many developing countries that do not have the internal capacity to develop a national fire danger rating system.

2.5.2. International co-operation for effective response

As the world is getting more and more connected, it is easy to imagine a greater sharing of warnings when hazards are detected. When speaking about EWS the hazard warnings can be divided into two different categories: fast- and slow-onset hazards. For fast-onset hazards such as tsunamis, earthquakes, and flash-waves, the warning needs to travel instantly in order to spark a useful reaction. This puts high demands on communication channels and requires trust from the receiver.

An example of a well-functioning network is the **Pacific Tsunami Warning Center** (PTWC). PTWC collects data from seismometers spread all over the globe registering movements in the earth's crust. This information from the seismometers is transferred to a central location through a combination of radio links, phone lines, internet, and satellite communication. The collected information about ground movements is then

analysed in real time

to rapidly determine the location and magnitude of the event and how tsunami waves are expected to propagate. Once this is determined, the information is published online and sent to the threatened nation's focal point so that an evacuation alarm can be triggered. When in 2012 the Banda Aceh earthquake (8.4 magnitude) struck the Indian islands of Andaman and Nicobar, the early warning system managed to warn a large share of the threatened public within eight minutes. This early warning allowed enough time for a successful evacuation.

As discussed in the previous section, sharing data between nations improves national abilities to mitigate natural disasters. Consortia which unify different countries' institutions are highly beneficial to **communicate and disseminate warnings** about disasters that might not be geographically constrained to a single country. Through this type of association, information sharing becomes a practice of regional or international co-operating entities. Two good examples from Europe are **SEE-MHEWS** (South-East European Multi-Hazard Early Warning System) and **EMMA** (European Multi-Services Meteorological Awareness). Both consortia work with national civil protection organisations to provide timely and accurate warnings of hazardous events to reduce losses. The two networks are both collecting and distributing warnings to national authorities. EMMA additionally communicates its warnings to the broader public through the **meteoalarm.eu** website, where information is displayed in

31 languages

together with expandable information on events and links to the web pages of involved national civil protection agencies.

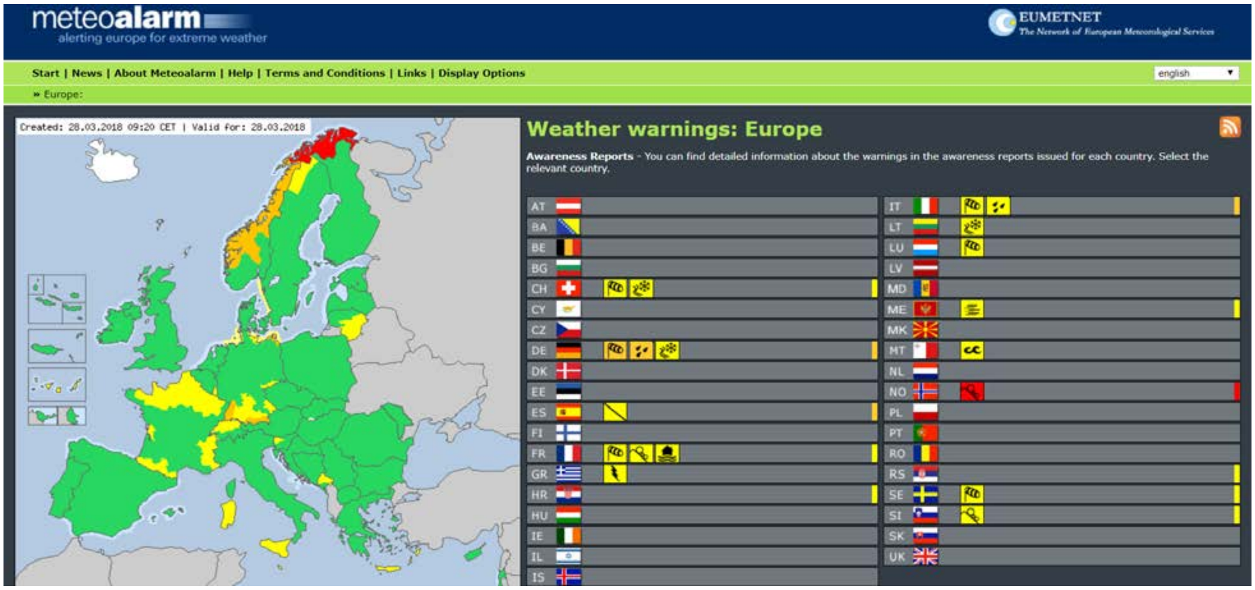


Figure 11. Meteoalarm website: through the expandable map, specific warnings about the individual countries in the EU can be easily found. (meteoalarm.eu, 2018)

Creating extensive **partnerships** to build multi-national warning dissemination platforms requires international co-ordination and multilateral revision of policies. In this matter, the UN system can provide broad assistance to different countries seeking partnerships.

In 2016, UNDP, together with **Moldovan** authorities and funding from the government of Austria, undertook a project to upgrade Moldova's risk reduction and climate change adaptation capacity. Via this project, UNDP set up a national adaptation plan for medium- to long-term climate and disaster vulnerability reduction. One of the outputs of this project was to create **institutional and technical capacities** that would make it possible to participate in Eumetnet, a prerequisite for also participating in the warning platform of EMMA.

3. SUMMARY

Throughout the years, the various United Nations agencies, funds, and programmes have played an important role in promoting and developing a culture of preparedness and prevention. The UN has underlined the value of prevention strategies on multiple occasions, not only by encouragement, but also through a number of projects, conferences, and platforms. As climate change and its consequences are becoming ever more evident, the private and public sectors are now counting on the assistance of academia and international organisations to support prevention strategies and build a more resilient society.

Early warning is a major component of prevention and, thanks to the Sendai Framework for Action 2015-2030, it has gained a prominent place in the agenda of the international community. This has led, in the past few years, to a growing number of projects aiming at implementation or upgrades of regional, national, and local EWS. However, there are frequently difficulties related to the implementation of EWS that span a wide range of sectors, actors, and processes, and that involve various levels of infrastructure and technology. For these reasons, and given that each country/community context is different, it is not usually possible to provide standardised solutions or recommend standard means of implementation. However, as highlighted in this publication, it is possible to bring some of these important lessons and best practices to bear when designing projects to strengthen EWS.

Through a preliminary analysis which supported this publication, qualitative interviews with disaster risk reduction experts from UNDP country offices in the region, as well as through desk research, some of the main challenges in the field of early warning have emerged.

This publication has highlighted innovative approaches to tackle these challenges through solutions focused on:

1. Institutions, regulations, and capacity development
2. Technological solutions
3. Community outreach and community-based solutions
4. Private sector engagement
5. International Co-operation and Data-sharing

These solutions have been found to be applicable to most of the broad challenges in the regions discussed (South-East Europe, South Caucasus, Central Asia). The first three intervention areas of this publication describe how to specifically build the elements necessary for EWS: developing institutional capacity; upgrading technological infrastructure for better monitoring, forecasting, and dissemination; and building community-based solutions which engage the population and reach out to it through innovative communication strategies.

The last two areas of intervention are cross-cutting approaches that help improve the performance of EWS throughout all their components: i) engaging the private sector in the early warning process, and ii) cooperating internationally to raise funds, reduce costs, share knowledge, develop institutional capacity, and make solutions more sustainable.

The aforementioned solutions and examples underscore the fact that setting up an early warning system is a long and complex process that requires attention to each segment of its function; an EWS is only as effective as its weakest component. Recognising EWS complexity, this publication can be used in two ways: Firstly, to understand which necessary components are to be implemented and which cross-over elements should be present for the system to work. Secondly, to identify strategies addressing specific challenges that have proven to work successfully elsewhere. This strategy reflects the ethos behind this publication, which is built on a challenge-solution approach, whereby for each challenge it is possible to identify different solutions. Although the publication does not cover all possible challenges and solutions, it allows the reader to identify quickly areas which have not been considered in the design of an early warning system; to be inspired on how to upgrade an early warning system by acting within a specific area of intervention; and to find answers to challenges and problems encountered in the implementation of such systems.

An average of 24 million people are pushed into poverty every year by disasters. Many millions are forced to leave their homes. If vulnerable countries are in a constant struggle to rebuild and recover after catastrophic events, we will never achieve the 2030 Agenda for Sustainable Development.

António Guterres, UN Secretary-General

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V. PROJECT INFORMATION

V.I. Institutional Regulations and Capacity Building

Azerbaijan
https://undp-adaptation.exposure.co/land-of-fire

Bosnia and Herzegovina
http://www.ba.undp.org/content/bosnia_and_herzegovina/en/home/operations/projects/environment_and_energy/technology-transfer-for-climate-resilient-flood-management-in-vr.html

Georgia GCF
http://www.adaptation-undp.org/explore/western-asia/georgia

Uzbekistan
http://www.uz.undp.org/content/uzbekistan/en/home/operations/projects/environment_and_energy/developing-climate-resilience-of-farming-communities-in-the-drou.html

ICT4DRR
https://www.preventionweb.net/news/view/43250

Honduras & Nicaragua
http://siteresources.worldbank.org/INTLACREGTOPURBDEV/Resources/840343-1319499018982/DRM_CENTRAL_AMERICA.pdf

The fYR Macedonia (Polog region)
http://www.mk.undp.org/content/the_former_yugoslav_republic_of_macedonia/en/home/operations/projects/environment_and_energy/reducing-flood-risk-in-the-polog-region.html

V.II. Technological Solutions

Armenia
http://www.undp.org/content/dam/undp/library/crisis%20prevention/disaster/europe/Armenia_Strengthening%20of%20National%20Disaster%20Preparedness%20and%20Risk%20Reduction%20Capacities.pdf

Georgia Rioni River
http://www.ge.undp.org/content/georgia/en/home/ourwork/environmentandenergy/successstories/flood-management-in-the-rioni-river-basin.html

MKFFIS (The fYR Macedonia)
http://mkffis.cuk.gov.mk/broshura/MKFFIS-en.pdf

Georgia GCF
http://www.adaptation-undp.org/explore/western-asia/georgia

Zambia
http://www.adaptation-undp.org/resources/brochures-posters-communications-products/zambia-climate-information-and-early-warning

The fYR Macedonia (Polog region)
http://www.mk.undp.org/content/the_former_yugoslav_republic_of_macedonia/en/home/operations/projects/environment_and_energy/reducing-flood-risk-in-the-polog-region.html

Bosnia and Herzegovina
http://www.ba.undp.org/content/bosnia_and_herzegovina/en/home/operations/projects/environment_and_energy/technology-transfer-for-climate-resilient-flood-management-in-vr.html

Uzbekistan
http://af.climatechange.uz/index.php/en/

Moldova
http://www.md.undp.org/content/moldova/en/home/operations/projects/climate_environment_energy/proiecte-finalizate/disaster-and-climate-risk-reduction-in-moldova.html

FEWS-Net
http://fews.net/

The fYR Macedonia App
http://www.mk.undp.org/content/the_former_yugoslav_republic_of_macedonia/en/home/ourwork/environmentandenergy/successstories/disaster--there-s-an-app-for-that-.html

Kosovo App
http://www.ks.undp.org/content/kosovo/en/home/presscenter/articles/2013/05/28/mobile-app-to-reduce-the-risk-of-disasters.html

Lebanon
http://www.climasouth.eu/sites/default/files/LARI%20EWS%20project%20proposal%20FINAL%20feb17.pdf

Facebook Crisis Response

https://www.facebook.com/about/crisisresponse/

Armenia 911 SOS App
http://www.mes.am/en/news/item/2017/06/15/sos/

Uganda
http://www.acted.org/en/writing-sms-can-save-lives-northern-uganda

V.III. Public involvement and Community-based Solutions

Moldova
http://www.md.undp.org/content/moldova/en/home/operations/projects/climate_environment_energy/proiecte-finalizate/disaster-and-climate-risk-reduction-in-moldova.html

Philippines
https://weatherph.org/

Hindu Kush Himalaya
http://lib.icimod.org/record/32318/files/icimodCBFEWS016.pdf

Cuba
https://www.american.edu/clals-old/upload/CIP-Disaster-Relief-Management.pdf

WMO Common Alerting Protocol
http://www.wmo.int/pages/prog/amp/pwsp/CommonAlertingProtocol_en.html

The fYR Macedonia (Polog region)
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Zambia
https://reliefweb.int/report/zambia/real-time-weather-forecasts-are-helping-zambian-women-farmers-win-their-battle-against

Azerbaijan
https://undp-adaptation.exposure.co/land-of-fire

Georgia GCF
http://www.adaptation-undp.org/explore/western-asia/georgia

Armenia
http://www.am.undp.org/content/armenia/en/home/projects/disaster-risk-reduction-.html

V.IV. Private Sector Engagement

Esri
http://www.esri.com/nonprofit

KDDI Japan
https://www.centreforpublicimpact.org/case-study/disaster-technology-japan/

Weather Philippines Foundation
https://weatherph.org/

ABU

http://www.abu.org.my/Latest_News-@-Climate_Risk_Early_Warning_Systems_initiative_launched_at_COP21.aspx

Uganda
http://www.adaptation-undp.org/resources/planning-meeting-presentations/cirda-ppp-workshop-uganda-action-plan

Zurich Insurance
https://www.zurich.com/en/corporate-responsibility/flood-resilience

V.V. International Co-operation and Data-Sharing

ESA's Sentinels
https://www.esa.int/Our_Activities/Operations/Sentinels

Eumetnet
https://www.meteoalarm.eu/

Indian Ocean Tsunami Information Center
http://iotic.ioc-unesco.org/

European Flood Awareness System
https://www.efas.eu/

European Drought Observatory
http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000

Global Fire-EWS
https://www.fire.uni-freiburg.de/fwf/Global%20Early%20Warning%20System/EWC-III-Wildland-Fire-EW-System-10-Proposal-Text.pdf

Pacific Tsunami Warning Centre
https://ptwc.weather.gov/

SEE-MHEWS
https://public.wmo.int/en/projects/see-mhews-a

EMMA
http://eumetnet.eu/activities/forecasting-programme/current-activities-fc/emma/

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