Forecasting, hazards, averting disasters: Implementing forecast-based early action at scale

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Implementing forecast-based early action at scale

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Cover photo: Men cover the windows of a car parts store in preparation for Hurricane Irma in San Juan, Puerto Rico ©2017 Alvin Baez / Reuters Pictures

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Contents

List of boxes, tables and figures

Boxes

Tables

Figures

Acronyms

ACAPS	Assessment Capacities Project
ARC	African Risk Capacity
ARDIS	African and Asian Resilience in Disaster Insurance Scheme
DFID	UK Department for International Development
DREF	Disaster Relief Emergency Fund
DRR	disaster risk reduction
EAPs	Early Action Protocols
ECMWF	European Centre for Medium-Range Weather Forecasts
EENIP	Extreme El Niño Insurance for Climate Change Prevention and Adaptation (Peru)
FAO	Food and Agriculture Organization
FbA	forecast-based early action
FbF	forecast-based financing
FEWS NET	Famine Early Warning System Network
FFP	USAID Office of Food for Peace
HSNP	Hunger Safety Net Programme (Kenya)
IASC	Inter-Agency Standing Committee
INFORM	Index for Risk Management
IPC	Integrated Food Security Phase Classification
IPCC	Intergovernmental Panel on Climate Change
IRI	International Institute for Climate and Society
LEAP	Livelihoods, Early Assessment and Protection (Ethiopia)
MFI	microfinance institution
NDMA	National Drought Management Authority (Kenya)
ROI	return on investment
SST	Sea Surface Temperature
SOPs	Standard Operating Procedures
WFP	World Food Programme

1 Introduction

Donors and humanitarian agencies are thinking carefully about how to use forecasts to provide earlier support to at-risk communities before a disaster occurs. While this interest stems from a desire to reduce the growing humanitarian burden and reconsider how aid is spent on humanitarian crises, forecast-based early action is also of interest to development professionals operating in social protection, disaster risk management and risk financing: preventive action should happen anyway, but in a context of limited resources forecast-based early action can help with decisions about how to best allocate funds in advance of an imminent impact.

While practitioners agree on the importance of early action, there is a wide interpretation of what this means and when it can occur. Forecast-based early action (FbA) initiatives are diverse, with very different approaches to the timing of decisions and actions, and to the types of forecast, monitoring data and delivery mechanisms used. They are similar in design to early warning systems: both are set up to minimise and prevent the impacts of imminent threats by providing information and support to at-risk communities.[1] Forecasting and communication of early warnings have improved significantly in recent years, but action based on those warnings has not kept pace due to a lack of readily available resources and internal inefficiencies in NGOs and UN and government agencies. FbA mechanisms respond directly to this challenge by placing considerable emphasis on decision-making protocols, so actors know what to do on the basis of a forecast; on *ex ante* financing of early action; and by using cost–benefit analysis more rigorously to help promote *ex ante* investment in disaster risk reduction (DRR). As such, FbA has the potential to revolutionise disaster risk management in a way that previous efforts to improve the links between early warning and early action have not.

This paper identifies the core features of over 25 FbA instruments designed to anticipate and reduce the impacts of natural and man-made hazards (see Annex 1). It outlines how, by integrating forecast-based decision-making in existing national and international organisations and NGO delivery systems and in international humanitarian financing mechanisms, forecasts could play a more significant role in humanitarian practice and disaster risk management. As referred to here, forecast-based early action initiatives[2] are specialised mechanisms linking financing and early action to forecasts of hazards and disaster impacts. No one definition of FbA has been agreed, but to help distinguish it from other risk financing arrangements and humanitarian and disaster risk management practices we refer to the use of climate or other forecasts to trigger funding and action prior to a shock or before acute impacts are felt, to reduce the impact on vulnerable people and their livelihoods, improve the effectiveness of emergency preparedness, response and recovery efforts, and reduce the humanitarian burden.

While the paper draws on evidence from a wide range of FbA initiatives over the last five years, it is not intended to provide a comprehensive review, but rather draws out some of the commonalities and differences between these initiatives within what is a disparate field of practice. The paper situates FbA innovations within broader humanitarian, disaster risk management and development agendas and reform processes. The authors examine the full chain of data use and decision-making: from decisions about the forecast and monitoring data to be assessed to the selection of triggers and thresholds (and methods for integrating bio-physical and socio-economic impact data), protocols for action and the financing mechanisms needed to deliver support to communities before a disaster happens.

This has resulted in a typology of forecast-based early action. The typology includes questions around:

1. **Forecasting and decision-making:** FbA involves a range of forecasts, indicators and decision-making mechanisms, from automated triggers to forecast-informed decision-making.
2. **Timing and planning early actions:** FbA mechanisms are designed to trigger and inform action across multiple time-scales before a disaster occurs, ranging from several days (for a cyclone) to a year (in advance of an acute drought).
3. **Financing:** Forecast-based action programmes have applied a variety of financing tools, including dedicated funds, specific windows in emergency response funds, insurance and direct links to regular resource allocation processes.

1 UNISDR (2017) defines an early warning system as: ‘An integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities, systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events’.

2 What is referred to here as FbA overlaps with other concepts such as early warning/early action and Forecast-based Financing (FbF).

4. **Delivery:** FbA mechanisms can be deployed through a range of delivery channels, including community-based emergency preparedness processes and social protection systems.

The paper concludes by considering the potential for FbA mechanisms to be adopted at scale in humanitarian and disaster risk management decision-making through the use of different sources of risk financing and national and international delivery mechanisms. There are significant challenges associated with using forecasts systematically to trigger the release of international and national humanitarian funds – and hence taking some control over allocation away from donors, governments and NGOs – but this kind of step change is necessary if FbA is to have a significant impact on the lives of vulnerable populations.

1.1 Methodology

This paper draws on data from a selection of operational or piloted FbA mechanisms (see Annex 1). These were selected to ensure wide coverage of the various types of mechanisms, with different objectives, technical designs, operational contexts, governance arrangements, scales of operation, implementation location and hazard type.

Humanitarian organisations that have developed and piloted forecast-based early action mechanisms understand and use the concepts of 'forecast' and 'early action' very differently (see Annex 4). Early action is relative to the baseline of the implementing organisation (the kind of action they were undertaking before) and the type of hazard, whereby 'early' means something very different for drought than it does for flooding. Similarly, the type of forecast used depends very much on the context (what kinds of risks are faced), the relationship with monitoring agencies and the mandate of the organisation (whether it can support communities it does not already operate in).

To date, most – but not all – FbA initiatives are concerned with forecasting extreme weather-related events that will have a negative impact on vulnerable populations, so the analysis of FbA mechanisms in this report focuses on these.

The report draws on project documentation and grey literature, as well as 14 key informant interviews with representatives of FbA initiatives (see Annex 3), to extract relevant technical information on the nature of the forecast and impact information used, the design of triggers and decision-making protocols and the delivery systems through which support is provided to communities in advance of a disaster.

Figure 1 Map showing FbA initiatives and short descriptions of selected pilots

Note: please see Annex 2 for full details on the selected pilots.

2 Forecasting and decision-making

Understanding hazards and their potential impact is central to promoting early action. This section describes attempts to forecast hazards, and to use vulnerability and exposure information to predict disaster impacts and develop triggers for action. As FbA is born out of a desire to more effectively translate early warning information into concrete action, these initiatives pay a great deal of attention to the decision-making processes needed to generate early action. Two principal approaches to decision-making dominate forecast-based action initiatives: automated triggers and forecast-informed decision-making. These are discussed below.

2.1 Characteristics of hazard information

Forecast information comes in many forms, from raw data to qualitative statements such as bulletins from national meteorological services.[3] FbA mechanisms typically require quantitative information to define objective triggers for decision-making. FbA mechanisms must consider the hazards that need to be forecast and the forecast data required (or monitoring data in some cases, for slow-onset events), the source of that information, whether the spatial/temporal scales and lead-times and the forecasted variable meet their requirements, whether the reliability of the forecasts (known as 'forecasting skill')[4] is well established and whether deterministic or probabilistic forecasts are required. The Red Cross/Red Crescent Forecast-based Financing (FbF) manual provides guidance on this process.[5]

2.1.1 Hazard forecasts and monitoring data

Most of the FbA mechanisms reviewed in this report focus on the hazards posed by extreme weather and climate, and so incorporate forecasts of extreme weather and climate variables (such as precipitation and temperature), as well as river levels for flooding. For drought, many also use real-time monitoring of soil moisture and vegetation conditions from satellites, and assess food security status using in situ reports.

Around half the systems reviewed in this research use probabilistic forecasts (including all the Red Cross pilot systems, the World Food Programme (WFP)'s FoodSECuRE programme and the Inter-Agency Standing Committee (IASC) El Niño Standard Operating Procedures). Several mechanisms use real-time monitoring data rather than forecasts, which can provide advance warning of socio-economic and humanitarian impacts of drought. These include social protection systems (the Hunger Safety Net Programme (HSNP) in Kenya and the Livelihoods, Early Assessment and Protection (LEAP) project developed by the government and WFP in Ethiopia); insurance-based systems such as African Risk Capacity (ARC) and the Extreme El Niño Insurance for Climate Change Prevention and Adaptation in Peru (EENIP); and the Start Drought Financing Facility. For slowly evolving drought hazards, real-time monitoring of impact precursors is clearly favoured over forecast information. A few systems involve a hybrid of both real-time monitoring and forecast information, including the USAID Food for Peace's use of the Famine Early Warning System Network (FEWS NET) Food Assistance Outlook Brief, the Food and Agriculture Organization (FAO) Early Warning-Early Action system and the Start Fund's Anticipation Window.

2.1.2 Sources of forecast information

FbA uses a wide range of climate forecast information, based on what is available and appropriate. Systems using probabilistic forecast information typically draw

3 Weather and climate forecasts vary in terms of their lead-times (e.g. forecasts for days, weeks, months and seasons ahead), their spatial coverage and their detail. The more comprehensive and coordinated forecasts are obtained from numerical models of the atmosphere and/or the climate system. These weather and climate forecasts are combined with bio-physical impacts, such as river flow, crop yields and fodder quality, to create a hazard forecast. The Global Flood Awareness System (GloFAS), for example, couples weather forecasts with a hydrological model, with lead times of up to 15 days to forecast river flow and flood risk globally.

4 A brief example of how to assess forecast skill is provided at https://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/gpc-outlooks/user-guide/interpret-roc

5 http://fbf.drk.de/fileadmin/Content/Manual_FbF/01_Manual/01_Manual_For_Forecast-Based-Financing.pdf

on products from international, regional and national forecasting centres. Products from international and regional forecasting centres are most common as these are freely available and considered reliable. Where appropriate, these are complemented with products from national hydrological and meteorological services. The Red Cross FbF pilots for flooding in Bangladesh and Togo, for example, use forecasts produced and used by national early warning systems in those countries. Drought/food security hybrid systems typically use a range of information on food production, access and livelihood outcomes from national agencies and international assessments (e.g. FEWS NET, Integrated Food Security Phase Classification (IPC)), and merge these into an assessment of food security status and likely risk.

2.1.3 Spatial scale of operation

The scales at which forecast information is assessed range from districts to counties/provinces and the national level. Actions need to target specific places and people that are vulnerable to climate extremes. This can present problems for the application of climate forecasts, particularly seasonal ones, as these forecasts tend to be made at a coarse scale with limited information for very local decision-making.[6] The type of forecast information required depends on the hazard; while coarse resolution forecasts may be suitable for droughts or heatwaves, which are spatially extensive, forecasting flash floods requires very high-resolution modelling. There is a clear role for national meteorological and hydrological services in providing such detailed information.

2.1.4 Forecast lead time

Forecast lead times in the systems surveyed vary from days through to seasons (and up to 12 months in advance of acute humanitarian impacts of drought). The lead time depends in part on the hazard system under study, with short lead times (typically days) for pluvial flooding from heavy rain and heat/cold waves, days to weeks for fluvial flooding, depending on river basin size, and months for drought and food security hazards. Systems using forecasts can generally provide longer lead times than those based on monitoring information, although monitoring can provide usefully long lead times in more slowly evolving systems, for example in larger river basins (the Mono river in Togo is one example), and for drought/food security.

A small number of systems operate over a range of forecast lead times, drawing on forecast information from seasons through to days. This can allow for the progressive staging of actions. A notable example is the Red Cross extreme rain/flood hazard system in Peru (see Figure 2), which involves preparedness actions triggered automatically by forecasts at various lead times (days/month/season).

2.1.5 Degree of recognition and application of forecast skill

Limited detail on the design of FbA systems makes it difficult to determine how much forecast skill is directly taken into account in agreeing triggers for action, although the Red Cross FbF Manual does encourage this. Other examples of initiatives that

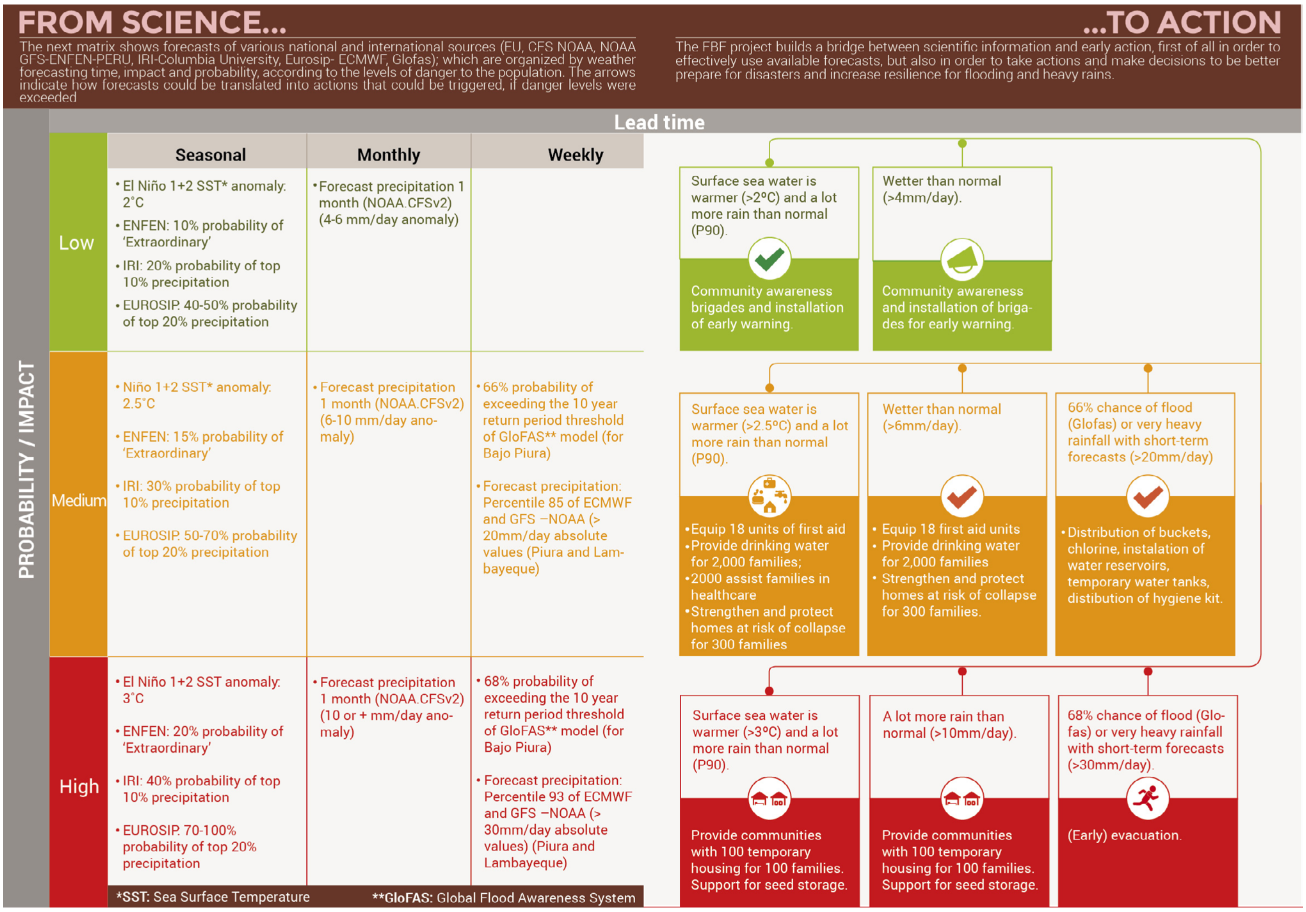
Box 1 Probabilistic forecasts and statistical methods for FbA

Weather forecasts are usually accurate for hours or a few days ahead, but it might not be possible to predict exact conditions at precise times. Nevertheless, it is possible to make forecasts of the *statistics* of atmospheric conditions over an extended period of time (a month or a season), with a longer lead of up to many months, e.g. a forecast of monthly or seasonal rainfall *totals* a few months ahead. These monthly/seasonal forecasts from models are probabilistic, meaning that they typically come from multiple runs of the model (an 'ensemble'). Ensemble forecasting is now the standard approach used in major modelling centres and accounts for inherent uncertainty in both the climate system and the models themselves. Probabilistic forecasts provide an estimate of the likelihood of some event occurring, e.g. a 30% chance of rainfall greater than some value.

Monthly/seasonal forecasts can also be derived using statistical approaches such as regression equations, predicting climate some months ahead, and Sea Surface Temperatures (SSTs), where a strong relationship exists in historical data. This is a standard method used by many African national meteorological services. This type of local approach is more appropriate for the context and can have greater skill (i.e. get it right more often) than global models. The forecasts are often expressed as probabilities, reflecting uncertainty in the statistical relationships. Statistical 'calibration' of numerical models can improve forecast skill: a good example is the calibrated multi-model system used by WFP to derive drought forecast triggers, developed by the International Research Institute for Climate and Society (IRI) at Columbia University. Multiple forecast products can also be merged using an 'expert judgement' system, e.g. the consensus products of the Regional Climate Outlook Forums.

6 The resolution of numerical forecast models remains relatively coarse (at best ~40km grid cell). The most commonly used IRI multi-model processed product is available on a 1-degree grid (~111km at the Equator), while some of the consensus products (e.g. from regional climate outlook forums) provide only very broad regional distinctions. Tools are available to statistically downscale these forecasts (e.g. the Fact-Fit tool), although these are not typically used in the systems we surveyed. For that reason, some smaller-scale systems use local hazard risk forecasts from bespoke systems.

Figure 2 Triggering system for El Niño impacts across Peru



Note: the system uses observed information in addition to actual forecasts, specifically real-time sea surface temperatures, for which there is a danger level threshold, but no probability threshold. For example, high-probability actions for long lead preparedness may be triggered from an IRI seasonal forecast of (i) rainfall in the highest 10% of past events (the danger level) with (ii) a probability of 40% (i.e. 4x the normal likelihood). Source: from Implementing forecast-based financing mechanism in Peru to enable preparedness for El Niño impacts, *reproduced with permission from the Red Cross Red Crescent Climate Centre.*

explicitly take forecast skill into account include the IASC, which evaluated forecast skill while developing its Standard Operating Procedures for El Niño and La Niña, and WFP and IRI, which have built a series of tools for evaluating forecast skill in their trigger design process. Overall, there seems to be widespread awareness of the relationship between increasing lead times and the increasing uncertainty of forecasts, and the inherent trade-off in wanting to have a long lead time (which gives a greater range of action options) and the risk of acting in vain (because the forecasting skill is weaker for longer lead times). Identifying 'low regrets' actions is a common approach to dealing with this trade-off. Other options include using observational data alongside forecasts, to reduce uncertainty about the risk, and adding a mechanism that can stop implementation before large costs are incurred, if subsequent forecasts indicate that risk is below the threshold.

2.2 Impact-based forecasting

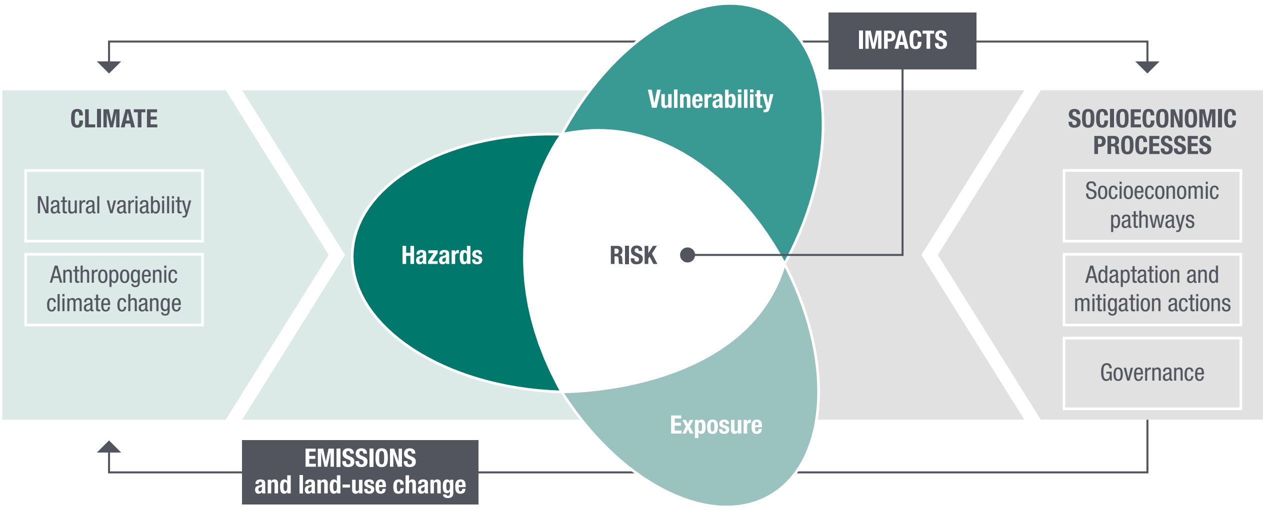
FbA is most relevant for humanitarian actors if the hazard being forecast is likely to have a negative impact on a vulnerable population, so where the hazard, vulnerability and exposure interact (see Figure 3). Understanding at what point an action is relevant, where that action should be focused and for whom requires linking the forecast hazard to anticipated impacts. In order to prepare for and plan responses to forecast hazards, a clear understanding of the potential scale, severity and timing of impacts is needed.

Many agencies have implemented or are in the process of developing methods to integrate vulnerability and exposure information with hazard forecasts to assess likely impact. Four major methods are currently being used: the threshold method, the qualitative combination method, the impact modelling method and the climate sensitivity method (see Table 1).

Table 1 Methods for integrating hazard, vulnerability and exposure information to predict impact

	Methodology	Data required	Spatial scale	Development	Examples
Threshold method	Define a forecast threshold at which people or infrastructure in a specific location are expected to be negatively impacted, based on the vulnerability of that location/infrastructure.	At least one historical event, or simulations, to identify the magnitude of the hazard impact.	Defined for a specific location or a specific infrastructure.	Defined in advance.	• Phase 1 of FbF implemented by the Red Cross in Bangladesh, Peru, Uganda and elsewhere • Heat health action plans set temperature thresholds for action based on historical relationships between temperature and mortality/morbidity in a specific city. England's Heatwave Plan has a threshold for action when maximum temperatures are forecast to be 32° in London during the day and 18° at night, with slightly modified thresholds for other regions (Public Health England, 2014). In India, the heatwave plan developed for Ahmedabad has its lowest alert level starting at 41.2° (Knowlton et al., 2014).
Qualitative combination method	Create a composite index that combines relative vulnerability with forecasted hazard magnitude to create a relative priority score, often a qualitative assessment by a group.	Vulnerability rankings of locations or groups within a larger region. No historical data is required.	Large spatial scale with different vulnerability groups.	Can be done in real-time discussions.	• FAO's early drought response in Kenya. • The Start Fund Anticipation Window, whose rapid decision-making process uses inputs from forecasting partners such as IRI and the London School of Economics and Political Science (LSE), a survey of its membership, independent secondary data analysis from the Assessment Capacities Project (ACAPS) and analysis from a technical advisory group called FOREWARN. • The UK Met Office brings together experts to look at a weather forecast and assign colour codes to different regions depending on a combination of probability and impact, as part of impact-based forecasting.
Impact modelling method	Develop a model that combines hazard magnitude with vulnerability and exposure to predict a level of impact.	Historical hazard and impact data as well as data on the relationships between them to improve the model	Depends on the model.	Model developed in advance.	• Dzud FbF, implemented by the Mongolia Red Cross, is part of a second phase of Red Cross projects that will build on the simpler threshold model and allow programmes to scale up based on modelled impacts rather than a specific threshold for a local area. • Damage models are often run by the insurance sector as an extreme event is approaching and immediately after it hits. • ARC runs crop models using satellite-derived rainfall estimates, to estimate crop yields at the end of the agricultural season. This is combined with vulnerability data to trigger insurance pay-outs. • The Index for Risk Management (INFORM) was used to calculate the potential impact of El Niño. Forecasts were mapped onto risks already quantified through INFORM.
Climate-sensitivity method	Using a combination of socio-economic baseline data and climate data, identify areas where vulnerability is most closely correlated with forecastable climate risks.	Baseline socio-economic data, livelihood zones and climatology.	Large-scale, most often national level.	Developed in advance to target FbA and other climate risk management tools.	• WFP and IRI's approaches to food security, which identify areas where food insecurity most closely correlates with climate risk, and then develop and deploy tools based on the assumption that, in these places, efforts would have the greatest potential impact. Studies using this method show that not all food-insecure areas have high correlation with climate risk, contrary to conventional wisdom. This differs from the impact modelling method in that it attempts to uncover the relationship between climate risk and impacts, rather than trying to quantify anticipated impacts.

Figure 3 The interaction of climate-related hazards, vulnerability and exposure of human and natural systems



Source: IPCC (2014).

Many methods for integrating impact-relevant information overlap (for example, statistical modelling is just a more complicated version of the threshold method, and the qualitative method still requires some sort of threshold in order to start a discussion). The method selected is likely to be a function of several factors, including data availability, how well we understand the hazard–impact relationship (and if it is too complicated to model), whether unexpected events can sway the result and the scale of the hazard itself. The lead time of the hazard is also a factor: it might not be possible to use a complex qualitative method for a rapid-onset event like a flash flood. Finally, the characteristics of the infrastructure or the population at risk will also determine the kind of assessment method that can be used: the threshold method might be best for a specific situation, such as whether a particular wind speed will cause a bridge to collapse or a particular water level will cause a dam to burst.

The field is rapidly evolving due to advances in computing power and data availability. While all the methods reviewed here are being used more frequently than in the past, quantitative modelling is growing particularly rapidly. It is important to note, however, that the examples reviewed in this paper are all led or supported by international agencies. Low-income countries face significant cost and capacity limitations in developing impact models.

2.3 Triggers for action

FbA mechanisms are designed to release funds and initiate early actions when pre-established thresholds are met (see Box 2). Key to this is a predefined process for either directly initiating specific activities, or developing action plans in real time after the forecast has been issued. Throughout this process, effective coordination

Box 2 Selecting hazard triggers

Hazard triggers are established and agreed in advance, based on forecasts or measurements. For flood-related disasters, for example, 20mm of rainfall within a specific time period could be a trigger to initiate a set of action(s). The threshold is referred to as the 'danger level' of interest. Often multiple increasing thresholds are selected to trigger different levels of action (e.g. a forecast of 10mm or 20mm or rain will trigger amber or red alerts). However, this simple approach is complicated because forecasts are inherently uncertain, and so are often expressed in a probabilistic form (for example, there is a 30% probability of exceeding the threshold of 20mm of rainfall; see Section 2.1). In these systems, triggering actions requires defining both the danger level threshold (e.g. 20mm of rain) and the probability of an occurrence of that danger level in the forecast (e.g. a 30% probability). Both values have to be carefully selected so that actions are triggered with an acceptable level of frequency.

We can distinguish two types of trigger systems:

1. Deterministic systems involving a single trigger (i.e. the danger level of some parameter), which can be applied to either a deterministic forecast (which provides a single predicted outcome) or, more usually, real-time monitoring of some precursor to disaster combined with biophysical information, e.g. upstream river flow or vegetation condition.
2. Probabilistic forecast systems, which require both a danger level and probability thresholds. For climate extremes, this would be an ensemble forecast system.

and urgency are crucial in order not to miss the opportunity for early action before a crisis escalates. The Start Network's experience with its Crisis Anticipation Window ahead of the arrival of Hurricane Irma in the Caribbean shows how, despite discussion starting a full week before the hurricane made landfall, uncertainty on where the storm would hit delayed action (Start Network, 2017). While some practitioners have argued for and trialled automated triggers in FbA initiatives that require minimal real-time decision-making, several key informants highlighted the importance of human judgement in tracing evolving crises and deciding on adequate responses on the ground.

2.3.1 Automatic versus subjective triggers

A key distinction exists between FbA systems that involve automatic triggers and subjective triggers based on expert judgement (see Box 3). Institutions including the Red Cross and WFP have established automated triggers to release funding to implement early action or contingency plans developed using expert opinion. These approaches front-load the decision-making process and directly link climate forecasts to their potential consequences (see Box 2 for a more detailed description of hazard triggers). For example, the Uganda Red Cross uses GloFAS, jointly developed by the European Commission and the European Centre for Medium-Range Weather Forecasts (ECMWF), to trigger plans developed through consultation with experts on water and sanitation programming, which in this case involves the distribution of flood relief supplies such as water purification tablets and waterproof bags when flood risk reaches a predefined level. Other practitioners including those that form part of the Start Network, as well as FAO and WFP, use a forecast-informed decision-making process to trigger early action (see Box 3). FEWS NET's monthly food assistance forecasts have been used by the USAID Office of Food for Peace (FFP) in its resource allocation and procurement decisions.

The threshold levels for both types of triggering systems are typically defined on the basis of experience of the hazard and impact – for example how much rainfall leads to damage. Some systems use specific event 'return period' values, such as a one in ten-year drought, which provide an immediate and intuitive connection with the frequency with which this might occur in the long term (see for example the START Drought Finance Facility). Such information can be especially useful for planning. Unfortunately, the process and the rationale for trigger value selection are not readily apparent for most systems. In most cases, the danger level and the forecast probability thresholds are defined locally in conjunction with the system 'users', i.e. those who will make decisions. Ideally this should involve an analysis of the forecast skill such that the 'false alarm' and 'miss' rates are understood, but it is not clear that this is done in practice, despite being part of the FbF Manual 'Menu of triggers' process.

Box 3 Levels of automation in decision-making

Red Cross/Red Crescent FbF projects remove as much real-time decision-making as possible through Standard Operating Procedures (SOPs), or Early Action Protocols (EAPs) as they are now known. These are developed well in advance with decisions already made about triggers, actions and targeting. Experts from national hydro-met offices, disaster risk management authorities and international scientific institutions are involved in the definition of the forecast threshold used as a trigger. Upon submission of the EAP/SOP for funding, the trigger is reviewed by expert bodies to establish whether it qualifies for funding. However, once the forecasts indicated in the EAP reach the defined threshold, no more expert judgment is used and the funding decision is taken automatically. The use of pre-agreed automated plans is a substantial change from the disaster-specific decision-making processes that typically characterise humanitarian operations within the Red Cross/Red Crescent movement.

FAO uses a combined approach in its Early Warning–Early Action activities. This means cross-checking forecast triggers with human judgement to validate triggers based on the situation on the ground, to understand what is realistic in a given context and to assess the quality and reliability of the system. The approach includes consultation with national and regional experts and sub-national FAO offices to build a common understanding of the situation before implementing activities linked to a forecast.

At the other end of the scale, the protocols used by the Start Network determine how expert opinion will be used in response to a forecast – there is no automation. The Start Network uses information from international forecasting centres, real-time monitoring by its members, independent secondary data analysis and inputs from a technical advisory group to translate an alert into a funded action plan in less than 72 hours. Based on this information, a context-specific decision is taken about whether to trigger an action, what projects to fund and the amount of funding to disburse.

WFP has tested both automatically triggered and non-automated actions through the forecast-based finance window of FoodSECuRE and its El Niño defensive procurement initiative. FoodSECuRE uses predefined climate forecast triggers to release funding from a central pool to implement contingency plans. During the 2014–2016 El Niños, WFP analysed the impacts of El Niño events on countries where the organisation purchased food and provided assistance, and used this information as part of its forward procurement process to reduce the risks of price increases in the supply chain.

3 Timing and planning actions

At the centre of FbA initiatives are efforts to provide earlier support to at-risk communities. While practitioners agree on the importance of early action, there is a wide interpretation of what this means and when it can occur. Three broad approaches are used:

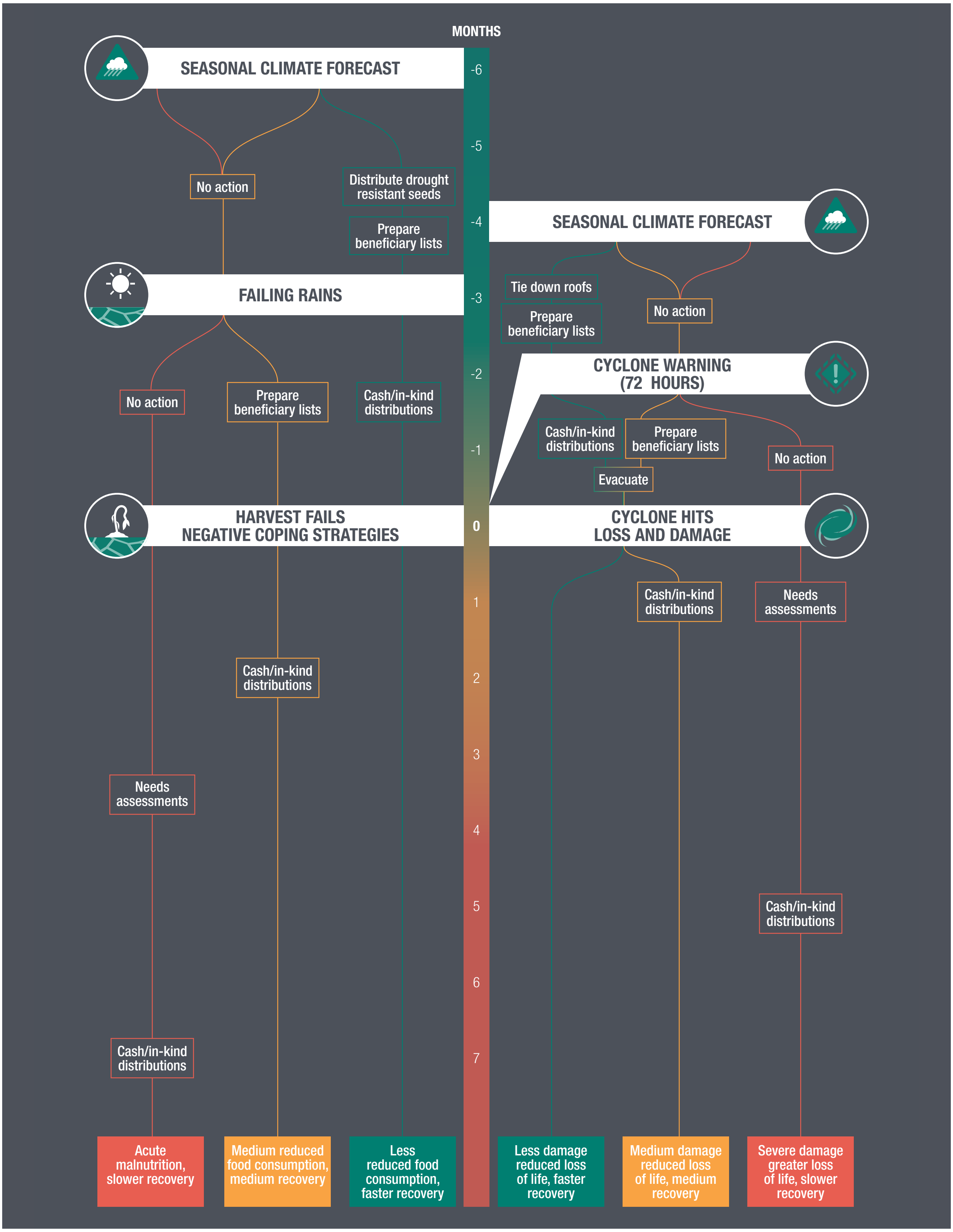
- **Before a hazard occurs.** Practitioners including the Red Cross and WFP use forecasts of climate hazards linked to in-depth analysis of the impacts of these hazards to trigger action before and during the onset of climate or weather hazards. This means that action can be triggered days, weeks or months before the hazard occurs. For example, WFP triggered funding for an anticipatory response in September 2015 based on a forecast of high drought risk due to El Niño conditions during the main October to February agricultural season in Zimbabwe. The main humanitarian impacts of this drought were felt from mid-2016 to early 2017.
- **During and immediately following a climate hazard.** An increasing number of mechanisms use seasonal monitoring of climate and agro-climatic information to detect a shock. This analysis is linked to a forecast of likely impacts, and used to create a trigger to release finance for early action and early response. The action may be triggered and implemented after shocks such as rainfall deficits or changes in temperature have already occurred, but before they have unfolded into fully fledged disasters. This approach entails often unclear overlaps between early action and early response, especially in the case of slow-onset events such as droughts, where windows for both are longer. Mechanisms such as ARC's drought risk pooling facility and the HSNP are examples of this.
- **Across multiple time-scales** (and for non-climate hazard-related shocks). Some practitioners use multiple sources of early warning information, including climate, market and conflict-related information, to forecast the impact of a shock or series of shocks. This approach blends data and uses impact forecasts before impacts emerge or become acute.

All three approaches link hazards or shocks to impacts, but the emphasis is slightly different. The first approach is most often linked to automated trigger mechanisms that generate action before the hazard occurs, in order to reduce its impact (see Figure 4). The second approach typically triggers funding and action right after and sometimes during a climate hazard, for example after rains have failed but at the end of the agricultural season when harvests fall short, or before the worst impacts of that crop failure have unfolded months later. The third approach is most often used in complex environments where multiple factors drive humanitarian crises, and where FbA mechanisms need to prevent the humanitarian consequences of multiple evolving shocks. Figure 4 provides an illustration of the timelines for FbA for cyclones and droughts, illustrating these different approaches.

Increasingly, early action is seen as a series of actions taken at different times, from an early point where there is less certainty in a forecast to the point where a disaster is about to happen. Especially early on there is a preference for 'low regrets' actions, which provide benefits no matter if a disaster actually happens or the forecast turns out to have been a false alarm. In WFP's FbA initiatives, for example, low-cost low-regret actions, such as checking and servicing weather gauges or updating and communicating emergency plans, are initiated when uncertainty is high; as the weather deteriorates, high-cost actions such as evacuation become more acceptable to governments and affected communities. The window for early action is much longer for slower-onset events such as droughts, which allows for more activities to be sequenced in the run-up to an event. As part of its forecast-based early action initiatives in East Africa, FAO organises training and awareness-raising activities, scales up existing disaster risk reduction projects and provides livestock fodder and supplements to protect pastoralist livelihoods. However, longer lead times can also produce greater uncertainty around the correct timing of interventions before a drought.

Some preventative or mitigative forecast-based early actions, such as food distribution, fodder provision or cash transfers, can resemble emergency response activities or shock-responsive social safety nets, but are delivered earlier, with the aim of allowing the population to take measures to protect themselves and their belongings, reducing the need for people to use damaging coping strategies, and to support health, education, food and other expenditures, sustain household food security and protect livelihood assets such as breeding livestock throughout a crisis. In its FoodSECuRE programme, WFP is considering triggering supplementary nutrition

Figure 4 FbA, early response and late response in the case of droughts and cyclones



Note: the actions above represent a simplified chain of events in disaster preparedness and response, and are not meant to encompass all the actions that may be necessary to reduce the impact of a drought or cyclone. The authors would also like to caution that, although forecast-based early action and early response can somewhat mitigate the effects of a disaster, they will not eliminate the need for further response and longer-term risk reduction.

programming 3–4 months prior to a drought for children in high-risk areas. Other preventative measures are geared towards scaling up risk reduction activities or adjusting livelihood practices in the run-up to droughts, floods or other extreme weather conditions. Examples include mapping flood risk areas and repairing dams and irrigation channels. In Kenya, livestock vaccinations are among a set of preventative activities under the National Drought Management Authority (NDMA)'s Drought Contingency Fund (droughts are often accompanied by animal disease outbreaks). Finally, WFP's defensive procurement is intended to increase the efficiency and reduce the costs of post-shock response through the prepositioning of foodstuffs in the supply chain, ready for distribution in case additional food and nutrition support is required after a drought has developed.

Some development and risk reduction programmes overlap with FbA initiatives, raising the question whether early action activities would happen anyway if no FbA system was in place. But as one key respondent explained, although ideally many preventative and mitigative actions should happen anyway, FbA can help with decisions about how to best allocate limited resources, focusing on interventions that are risk-informed and in advance of an imminent impact. FbA can help reduce the impact in those areas, where longer-term preventative and mitigative measures have not yet been carried out. It can also support better management of the 'residual risks' that remain despite DRR efforts, or when DRR is not the most cost-effective option. The aim is not for FbA to replace longer-term DRR programmes but rather complement them and fill gaps as needed.

4 Financing FbA

All forecast-based early action mechanisms recognise the importance of being able to deploy funding and other resources in a predictable and reliable way. FbA programmes have applied a variety of financing tools, including dedicated funds, specific windows in emergency response funds, insurance or contingent finance and direct links to regular resource allocation processes.

Acting on the basis of forecasts does not necessarily require new funding, but it certainly calls for the more rational use of existing funds. In middle-income countries funding is usually available for preparedness, but is often not allocated consistently or quickly enough to reduce disaster losses. Although many FbA initiatives do set aside resources to finance pre-determined actions, infrastructure needs to be in place to deliver support, whether cash transfers or other types of assistance.

In terms of where the funding comes from, there appears to be growing interest in combining different sources, triggered at different times and used to fund different kinds of measures, from communicating information early on, when uncertainty is high, through to higher-cost activities as uncertainty is reduced. All of this requires significant planning, clarification of responsibilities, coordination and costing of anticipatory actions. As initiatives are scaled up, it will become clearer to what extent FbA can help streamline, co-benefit and increase the effectiveness of disaster risk management by donors, governments and humanitarian and development organisations.

4.1 Dedicated FbA funds and funding windows

Dedicated forecast-based and contingency funds have been established under some initiatives. These can be stand-alone funds or part of emergency funds set aside specifically for FbA. The German Federal Foreign Office has established a fund that can be accessed by its partners using a standard operating procedure that includes a forecast-based finance trigger. WFP's FoodSECuRE programme includes a pilot fund with forecast-based triggers linked to contingency plans. The risk financing mechanism of Ethiopia's Productive Safety Net Programme allows the programme to be scaled up based on early warning information evaluated by a national committee.

Windows in existing wider funds have been established that can be triggered by forecast-based triggers and processes. One example is the Start Fund's Anticipation Window, which functions with higher levels of uncertainty than the parent fund but based on a robust decision-making process. Scaling up social protection based on an early warning has been trialled with the Kenya Hunger Safety Net Programme. This involves accessing a separate funding source, rather than funds allocated for emergencies. The pilot was funded by the UK Department for International Development (DFID), with the expectation that, in the long term, the Kenyan government will contribute financial support. The concept is gaining in popularity, and similar mechanisms are being established across Africa and elsewhere to quickly scale up public social protection systems based on forecasts or early warnings. The Mongolian government has recently set aside 1.5% of all national government budgets to reducing disaster risk. Some of this will go to early action, for instance through the prepositioning of emergency hay reserves for herders, triggered by a seasonal climate forecast. The International Federation of Red Cross and Red Crescent Societies has established a Forecast-based Financing Window as part of the Disaster Relief Emergency Fund (DREF), to be used for forecast-based action, and FAO has created an Early Action window within its SFERA emergency fund to support trigger-based mitigation and prevention activities.

4.2 Insurance and contingent finance

Another option for FbA involves market-based mechanisms (i.e. not public funds) such as insurance or contingent finance. These could pay out before disaster impacts have resulted in losses for individual policy-holders or businesses, or have led to credit defaults for cooperatives, enterprises, banks or microfinance institutions (MFIs). There is as yet limited experience with integrating hazard forecast-based triggers into such risk financing and transfer mechanisms. One exception was an El Niño insurance product tested in Peru between 2012 and 2014, which released funds to MFIs and cooperatives based on forecasts, encouraging them to take anticipatory action and to increase lending before, during and after a disaster, when people were in need of additional resources to prepare and respond.

Other insurance and contingent finance initiatives that are already using triggers to support early post-disaster response could be expanded to include more preventative and mitigative actions in the future. The African and Asian Resilience in Disaster Insurance Scheme (ARDIS), launched in 2018 by VisionFund International, Global Parametrics and the InsuResilience Investment fund, will


Scaling up social protection based on an early warning has been trialled with the Kenya Hunger Safety Net Programme. © Marisol Grandon/Department for International Development

be implemented in Cambodia, Kenya, Malawi, Mali, Myanmar and Zambia in its first year. It will support post-disaster recovery lending by providing microfinance institutions with access to credit and insurance-type payouts. Both financing instruments are linked to either a drought or a windstorm index that differs between countries. Disaster risk financing initiatives targeted at governments and NGOs, such as ARC's sovereign drought insurance and ARC Replica drought coverage, might represent a further opportunity to expand into even earlier action.

4.3 Standard resource allocation processes

Forecast-informed decision-making processes are often also resource allocation processes. For instance, WFP's El Niño Defensive Procurement exercise linked forecasts of El Niño impacts on WFP's supply chain to procurement actions designed to limit those impacts. In another example, local governments in the Philippines are increasingly using a specific allocation for disaster risk reduction, the Local Disaster Risk Reduction and Management Fund, before a disaster strikes. Funding is at least 10% of the internal revenue allocation of each local government unit, with 70% for DRR and 30% for rapid response. Local governments are also using parts of this allocation for early action, and policy-level advocacy is ongoing to enable this shift.

5 Mechanisms for delivering FbA

Forecast-based initiatives are being developed at many levels, and are being linked to a range of delivery mechanisms. Expanding the use of FbA will require continued technical innovation and financing, but perhaps no other factor is as important as the channels through which forecast-based action is delivered. Initiatives that use forecasts to trigger and deliver early action have either provided support directly to communities (often in coordination with local governments), or have worked with national governments and partners to strengthen the development and delivery of FbA through state institutions. Whether or not actions triggered by forecasts are part of government early warning and action systems or peripheral to them will depend on the capacity and coordination of government actors, on the country context and on the mandates of agencies promoting FbA. Actions taken on the basis of forecasts can be carried out through existing delivery channels, such as public social protection and safety net programmes, or via stand-alone FbA mechanisms (Costella et al., 2017).

5.1 FbA linked to community development programmes

Forecast-based systems have been integrated into community-based disaster risk reduction and development programmes, as well as linked with country-wide contingency planning and response by humanitarian agencies. For example, forecast-based financing has been used by the Togolese Red Cross to preposition and then distribute relief supplies as the risk of flooding increases. World Vision builds on its longer-term community-development programmes, which facilitate bottom-up generation of early warning information and early action. Similarly, Christian Aid partners, for example through the BRACED project, tend to use a participatory vulnerability and capacity assessment approach. In combination with improved access to climate information services, this aims to increase coping capacity through community resilience planning and motivate early action when a shock is forecast.

FbA initiatives have occurred primarily through the integration of finance and planning processes. Many organisations have their own financial mechanisms and dedicated funds to spend on early action, and deliver directly to high-risk communities in specific countries (as described in Section 4). These financial mechanisms are linked to planning tools known variously as Early Action Protocols (EAPs), Standard Operating Procedures (SOPs), early action plans and contingency plans. In the case of the Red Cross societies, EAPs define 'who takes what action when, where, and with what funds' (Cruz Roja Peruana, German Red Cross and Red Cross Red Crescent Climate Centre, 2016). These EAPs, which are separate from government emergency plans, build on existing Red Cross operational and programmatic capacities. Despite using separate delivery channels, FbA initiatives are often implemented in close collaboration with national governments. Cash transfers using country-wide public or private delivery systems are also growing in popularity, although there is a recognition that cash is not always appropriate. For instance, if markets are unable to meet rising demand for goods before an event, in-kind distributions may be more suitable. The Bangladesh Red Crescent has distributed cash transfers based on a flood forecast; triggered by Dzud forecasting, the Mongolia Red Cross has organised cash deliveries to beneficiaries through local bank branches, and the START Network has disbursed cash based on food insecurity forecasts in Somalia.

5.2 FbA with governments and through social protection and safety nets

Several countries have developed nationally led or government-implemented FbA mechanisms. WFP is supporting government agencies to develop SOPs with pre-agreed triggers and actions in five countries: Bangladesh, the Dominican Republic, Haiti, Nepal and the Philippines. In Zimbabwe, the Ministry of Agriculture and WFP helped farmers switch to drought-tolerant crops when the risk of drought was high. At the national level, forecast-based action has been integrated into safety net programmes in Ethiopia, Kenya and Uganda, among others.

Social protection systems can respond to shocks through vertical or horizontal expansion, piggybacking on pre-established programmes, aligning social protection and humanitarian systems or refocusing existing resources (O'Brien et al., 2018). By linking to established early warning systems, regular cash transfers and other forms of safety net can help reduce the impact of climate extremes on poor families. Additional features entail climate- and disaster-sensitive targeting and planning; central coordination and registries for targeting and verifying disbursements; partnerships between public, private and non-state actors; pooling funds and smoothing expenditures; financing and flexible systems for scaling up when a shock occurs; the provision of timely and predictable benefits; and interventions to support livelihoods, all of which can increase the effectiveness of social protection systems (Castello et al., 2017; O'Brien et al., 2018; Bastagli and Holmes, 2014; World Bank, 2013; Kuriakose et al., 2012). Social protection programmes that already include shock-response systems, such as the HSNP, are more suited to scaling up or integrating FbA.

5.3 International humanitarian response

Finally, FbA has been integrated into international humanitarian response mechanisms. Within the UN system, the IASC has supported the development of global SOPs for El Niño for IASC partners and NGOs in response to the devastating impacts of the 2015–2016 El Niño. The SOPs support the coordination of early action at international, regional and country level, defining roles and responsibilities, taking into account the capacities and resources of the actors involved.

These delivery channels and governance processes do not need to be separate. The Red Cross promotes government leadership in FbF, so that it can coordinate and delegate responsibilities to the Red Cross and other partners. In practice, this could mean the Red Cross carries out portions of government EAPs with government funding, or coordinates with the government to activate Red Cross EAPs using Red Cross funding. Coordination between stakeholders operating at different scales is key to ensuring that the right combination of actions is taken on time to minimise disaster impacts and reduce risks over the longer term. There are challenges with this. Existing FbA initiatives have been co-developed to varying degrees with governments, NGOs, UN agencies and other partners, and in some cases these initiatives have not been coordinated with government contingency plans and early warning systems. Limited capacity or political will, lack of data and weak planning systems and structures into which forecasts are to be integrated were all highlighted as challenges by interviewees and in the literature on FbA. While there is a general recognition that government ownership is desirable to ensure coordination and sustainability, it is less clear when a full handover from humanitarian organisations to governments is possible.

6 The evidence base for forecast-based early action

Investment in FbA is expected to bring about several positive outcomes, and significant attention has been paid to measuring the costs and benefits involved. In particular, studies have looked at outcomes related to:

- an earlier response and reduced response time, so that aid gets to people faster, averting suffering and helping to prevent more severe impacts;
- a decrease in the cost of humanitarian response through greater prepositioning and early procurement; and
- better-quality programme design through pre-planning with more preventative measures, and potential co-benefits in non-crisis times.

These outcomes would suggest that investing early through FbA is more cost-effective than waiting to provide a late response. However, it would be wrong to assume that FbA would be more cost-effective under all circumstances, and there are many possible scenarios where FbA may not be cost-effective. These are described in greater detail below.

Evidence on the costs and benefits of anticipatory action is very limited, and a meta-analysis of evaluations of these initiatives was beyond the scope of this report. Box 4 summarises key studies that have tried to quantify the costs and benefits of an early response. Since empirical evidence around the impact of earlier responses is scarce, most studies have relied on modelling and estimations to assess the impact of alternative approaches. Protocols could usefully build in damage and loss assessment, not only in areas where early action was taken but also where it was not, in order to compare the differential outcomes. However, the benefits of early action can extend well beyond reducing loss and damage. By reducing damaging coping strategies, early action can have long-term effects on malnutrition, education and health that cannot easily be captured in a short timeframe. Furthermore, the impacts of crisis are multi-dimensional, and teasing out attribution of outcomes to specific activities can be difficult. It is therefore critical that any assessments of the costs and benefits of early action through FbA use a mix of qualitative and quantitative approaches to the full range of potential impacts, including less quantifiable effects such as social outcomes, as well as investigating the effectiveness of different activities for different hazards.

The costs and benefits of anticipatory action will differ depending on whether the event is slow- or rapid-onset, and the degree of fragility/conflict. For example, early action for a rapid-onset event can mean the difference between life and death, and therefore in this regard the benefits of early action can be obvious and have a high value. Slow-onset events give ample opportunity to respond months earlier, and hence offer numerous benefits, although these opportunities are often missed due to higher uncertainties associated with the forecasts. The costs and benefits of early action in fragile contexts can be hard to measure, as early action can be hampered by issues outside of a humanitarian agency's control, such as access to affected populations. However, according to the *Global Humanitarian Assistance Report* (Development Initiatives, 2017) the confluence of climate and conflict dominates the majority of crises, and therefore it is critical to understand the relative costs and benefits of early action. The literature is most limited with respect to examining early action in fragile contexts.

6.1 The costs of anticipatory action

6.1.1 The cost of acting in vain

Responding to a crisis before it has fully materialised brings with it the increased risk of acting in vain. The cost can be high. Many interventions that might be considered as part of an SOP will bring benefits regardless of whether the crisis occurs or not. From this perspective, investment is highly likely to be cost-effective regardless of the accuracy of the forecast. Equally, some early action activities can have very high costs, for example evacuation of a large population. It is also important to consider the opportunity cost of any investment, as triggering funding for an extreme event that does not occur will divert funds away from another crisis, and thus limit the scope for early response elsewhere. Nonetheless, it is generally felt that a false early response is more than offset by the cost of a late response. DFID's *Economics of Early Response and Disaster Resilience* study (see Box 4) found that, 'for every early response to a correctly forecast crisis, early responses could be made 2–6 times to crises that do not materialise, before the cost of a single late response is met'.

Figure 5 Illustration of possible outcomes of forecast-based early action

	EXTREME EVENT	NO EXTREME EVENT
ACTION	'Worthy Action' Action cost	'Act in Vain' Action cost + additional costs/benefits
INACTION	'Fail to Act' Response cost	'Worthy Inaction' No cost

Source: adapted from Suarez and Tall (2010).

6.1.2 The cost of supplies

As shown in Box 4, early action can yield significant cost savings through early procurement and prepositioning of humanitarian supplies. These savings will most likely be realised in slow-onset or predictable disaster contexts, where there is a good deal of lead time to be able to respond. Not all items can be procured in advance at a lower price, storing prepositioned supplies can be expensive and certain items will have shelf-lives that may require disposal if a disaster does not occur in the relevant timeframe.

6.1.3 Cost of interventions at scale

Investing in early action and wider resilience-building measures can be expensive. While many measures are 'no/low regret', the types of actions that may mitigate an impending crisis can be costly at scale, for example in contexts with chronic and severe poverty. In many cases, the more expensive investment scenarios may be offset by the avoided cost of humanitarian response, but this is not a given and must be carefully assessed in order to determine the most cost-effective package of interventions in an SOP.

6.2 Other cost–benefit considerations

6.2.1 How early is early?

In Box 4, the USAID and DFID models assume that 'early' means before negative coping strategies are employed. However, in an assessment of the 2015 drought in Somali region, Ethiopia, evidence suggested that people started to be affected a full two years before the crisis was formally recognised. This example raises the question how early is early enough? It also suggests that FbA would be more effective if longer-term development interventions were more explicitly focused on building the resilience of vulnerable populations to address chronic drought risk. There is however little empirical evidence regarding the 'right' timing: assessments of the impact of intervening just before the crisis, as compared to six months beforehand, for example, are non-existent.

6.2.2 Defining triggers

In rapid-onset crises defining the trigger is more straightforward than a slow-onset crisis, where the trigger may be a combination of rainfall forecasts and other weather-related indicators, as well as changes in prices of food and other commodities, politics, etc. How the trigger is defined will affect how accurate the forecast is, the likelihood of acting in vain and therefore the overall cost-effectiveness of the response. Crises often arise as a result of the interplay of changes in rainfall, vegetation and prices, as well as other factors. As a result, the cost-effectiveness of a response can be fundamentally affected by the composition of indicators used to trigger it, and these will vary according to the context and types of livelihoods affected by the disaster.

Box 4 Examples of evidence on the costs and benefits of early action

USAID Economics of Resilience (Cabot Venton, 2018). The study evaluated the economics of early response and resilience across a population of 15 million people in Kenya, Ethiopia and Somalia. The study found that investment in early response and resilience could have saved $4.3 billion over the previous 15 years, or an average of $287 million per year. Every dollar spent on safety net and resilience programming results in net benefits of between $2.30 and $3.30. The US government could have saved $1.6 billion over the last 15 years, or 30%, on its humanitarian aid spend in these three countries. Incorporating the avoided losses to households, the model estimates net savings of $4.2 billion to the US.

DFID Economics of Early Response (Cabot Venton et al., 2013). This study quantified the reduction in costs as a result of procuring goods early in response to humanitarian crises in Kenya, Ethiopia and Niger, and found that the cost of response decreased by between 11% and 45%. The study also modelled the impact of commercial destocking and vet services in Kenya and Ethiopia, and found that these measures had a substantial return on investment (ROI), as well as reducing food deficits by between 9% and 72%.

UNICEF/WFP Return on Investment for Emergency Preparedness (UNICEF/WFP, 2015). This study evaluated the ROI to emergency preparedness, and found that prepositioning of emergency supplies can yield ROIs of 1.6–2.0, and generate significant time savings in response of between 14 and 21 days on average.

Evaluation of WFP Import Parity Approach (WFP, 2011). WFP's import parity approach compares local and international sourcing costs and delivery times for food. An analysis of the price differences between the lowest and next-best quotes from suppliers for more than one-third of all WFP's 2010 food procurement expenditure suggests that the import parity approach led to savings of between 23% and 33% (at least $99 million) in the cost of commodities.

African Risk Capacity Cost Benefit Analysis (Clarke and Vargas Hill, 2013). A cost–benefit analysis of the African Risk Capacity facility looked at the impact of late response as compared to an early response. In this analysis, the main costs to immediate and long-term welfare are assumed to come from reductions in consumption, losses of productive assets (as a result of direct losses or distress sales) and investment opportunities foregone. The study estimates late response losses at $1,294 per household, and early response losses at $49 per household.

Cost Effectiveness of Early Warning (Hallegate, 2012). This study looked at the benefits that would arise from investment in early warning by looking at the benefits of such systems in developed countries and then extrapolating these to developing countries. It estimates returns of between $4 and $36 for every $1 spent on investment in early warning.

7 Taking forecast-based early action to scale

As forecasts continue to improve, the use and geographical coverage of FbA mechanisms is growing. Learning from successes and failures is contributing to the development and institutionalisation of the approach. Organisations and governments running FbA initiatives, as well as donors investing in early action, are attempting to scale up pilots in order to achieve greater impact in preventing and dealing with disasters by covering more people, more hazards and more countries. As these initiatives expand, the community has gained experience and is continually growing the evidence base on effective processes and impacts. This experience and evidence provide guidance for further FbA development. Scaling up may also help early action become more efficient through sharing information and resources and coordinating action. The Red Cross in Peru and Ecuador, for instance, has been covering heavy rains, volcanic ash, Amazon flooding, snowfall and cold waves. Addressing several hazards, rather than just one, has made its presence, and efforts to build and train local teams working on forecast-based financing, more cost-effective. Scaling up FbA through institutionalisation may strengthen coherence between humanitarian and development approaches and between different agencies and governments. Institutional change through FbA is expected to include more robust decision-making and more effective allocation of aid, as well as improved long-term financial planning in government and humanitarian systems.

7.1 Approaches to scaling up

Humanitarian agencies and governments are beginning to scale up their FbA initiatives in a number of ways. Most have started by implementing pilots and gradually expanding the reach and scope of these initial experiences. Scaling involves physical expansion (replicating approaches to new territory and addressing additional hazards), greater social reach (increasing coverage in number or scope of people targeted), extending political engagement and institutional capacity (policy and budget commitments and mainstreaming FbA within institutions by expanding early action to other programmes and institutional processes) and deepening the conceptual framework around FbA (transforming mindsets, administrative structures and power relations) (UNDP, 2013). Scaling can also enable more comprehensive action based on forecasts. The examples in Table 2 show how experiences with scaling up FbA have involved much more than simply covering larger populations.

7.2 Embedding FbA in financing and delivery systems at scale

Somewhat different from the examples in Table 2, the global ENSO SOPs (developed by the IASC) aim to support the coordination of early action at international, regional and country levels. Although tailored to different country contexts, the SOPs are linked to a global analytical cell of climatological, humanitarian and development experts assessing forecasts, vulnerability and coping capacity to identify countries at high risk of being affected by an El Niño/La Niña event. In a first test run in 2016–2017, 19 high-risk countries were alerted and offered support in early action planning and implementation. This indicates the potential for implementing FbA at scale to support coordination and anticipatory action through the international humanitarian system, and in collaboration with national governments.

At country level, operating at scale could mean coordinating FbA initiatives and stakeholders in contexts where government capacity and an enabling environment are in place. Close cooperation between humanitarian and government agencies, as well as collaboration between different sectors and ministries, were highlighted as crucial in the key informant interviews. In Mongolia and Peru, for example, government agencies coordinate forecasting and risk assessments with the Red Cross and FAO so that they can also coordinate interventions, with some actors focusing only on the highest-risk areas of the country, and others including areas that are less likely to be hit by a disaster.

7.3 Challenges for taking FbA to scale

7.3.1 Scaling up pilot initiatives

Scaling up FbA initiatives from existing pilots can present challenges to governments and humanitarian agencies. In some cases, projects have been designed to be pilots or catalytic, which means they are not

Table 2 Examples of scaling up FbA

Dimensions of scaling up	Example
Physical Replication in new geographic locations or for additional hazards	The Togolese Red Cross has distributed non-food items and initiated evacuation plans in several communities downstream of a hydropower dam before water is released that could cause flooding. It will now expand coverage to all potentially affected villages when notified that floodwaters will be released. WFP is covering multiple hazards such as flooding and drought in very vulnerable areas that are likely to need assistance.
Social Increasing coverage in number or scope of people targeted	The FbA system and risk mapping developed by the Mongolia Red Cross cover the entire country, but can only provide supplies to a limited number of people. The system will trigger action to support specifically those forecasted to have the greatest risk of impact, no matter where they are in Mongolia. Rather than expanding action to all areas with heightened risk, this means getting smarter about the households being targeted in relation to their vulnerability.
Political Policy and budget commitments	Increasing the number and scope of its FbF pilots, the International Federation of Red Cross and Red Crescent Societies has established a Forecast-based Financing Window within the Disaster Relief Emergency Fund (DREF), to be used specifically for forecast-based action. The Start Network is adopting a layered approach to managing humanitarian financing for NGOs, with different financial strategies for different scales of risk. For instance, where the Start Fund covers earlier action for small- to medium-scale events, the Drought Financing Facility is designed to respond to drought on a five-year return period.
Conceptual Transforming mindsets, administrative structures and power relations	To anchor early warning/early action approaches more widely within the organisation, FAO is working with operational staff to build capacity around early action. As standard technical and operational procedures, for example for procurement, were not originally designed for early action, processes and mechanisms require adaptation to match FbA and the timeliness required to make it work. An early warning/early action toolkit currently under development is aimed at supporting capacity-building and embedding the concept more widely within and beyond FAO operations.
Comprehensive Expanding range of anticipatory actions taken to support beneficiaries based on forecasts, enabling more comprehensive impact	In Somalia, SomReP is providing unconditional cash transfers, as well as information and advice tailored to the livelihoods of at-risk people. Many organisations are expanding their programmes and developing more comprehensive sets of actions. This includes prepositioning stock, training staff and purchasing supplies, both to support forecast-triggered distributions, and for post-event response where required.

embedded in a larger institutional context, can be too narrow or are focused on a particular hazard context, making them unsuitable for direct replication elsewhere.

The need for longer-term support, joint programming and sufficient and predictable sources of finance is another hurdle. There may also be a lack of clarity around ownership, duty of care and sustainability once operating at scale. This may be linked to current M&E systems and the novelty of FbA approaches, which means that, while there is a general sense and initial evidence that early action pays, we do not yet know how FbA projects are changing attitudes or behaviours, or the extent to which they are actually reducing disaster impacts and helping build resilience in the longer term.

Communication, coordination and timing is also challenging in some cases due to a lack of clarity on timeframes and on the benefits of different early actions, and difficulties in collectively agreeing triggers and actions. As has become clear through the IASC's ENSO SOPs and the Start Fund Anticipation Window, it is essential to have pre-established strategies to deal with the uncertainty inherent in FbA systems, to ensure that decisions on initiating action are taken early enough. Greater clarity is required around who triggers action for the ENSO SOPs, and how this is communicated to relevant stakeholders. An Oxfam review of the Somalia Early–Warning, Early–Action dashboard in the 2016–17 drought has highlighted the importance of building a common understanding around whether a system should facilitate early action, timely response or both. In this instance, lack of clarity and diverging views of the objective complicated implementation, created discontent with the mechanism and may make it more difficult to scale up the system in the future (Oxfam, 2017).

Within governments and humanitarian agencies, the expertise required for effective FbA implementation at scale is often limited or absent, responsibilities for leading within organisations or governments can be unclear and FbA is not a strategic objective for many organisations. In Kenya, for example, the NDMA implements early action for drought, whereas flood preparedness and response sit with the National Disaster Operation Centre (NDOC), which does not integrate FbA. One key informant outlined that, while there is frequent exchange between the NDMA and the NDOC, their delivery systems, expertise and mandates are different, and the complexity and shorter time windows for sudden-onset events such as flash floods further complicate the replicability of FbA mechanisms for these additional types of shocks.

Finally, limited or unclear forecasting skill, gaps in forecasting information and capacity limitations in early warning systems can restrict their use, reduce confidence in FbA and inhibit scaling up. As one interviewee noted, although this is not a 'deal breaker' for FbA – and can be overcome through the use of other sources of forecast information and investment in forecasting capacity – additional funding will be required to support the generation and provision of forecast information.

7.3.2 The political economy of using forecasts at scale

The political economy of using forecasts systematically and at scale to trigger the release of funds and initiate action prior to a disaster is extremely complex. Interviewees in this study pointed to a number of issues, including capacity constraints (to produce and interpret forecasts), lack of funding up-front (though many governments have funds available for disaster response) and, critically, loss of political control over the allocation of resources. Governments and donors are, understandably, not keen on spending budgets on early action based on a forecast when levels of uncertainty are high; even when uncertainty is low it is difficult to commit resources up-front. As one key informant pointed out, the challenge remains that, even in high-income countries like the US and UK, there is insufficient political buy-in or confidence to automatically take decisions based on a trigger: decision-making power remains with technical or political institutions. In other instances there may be a political desire to retain control over the parameters used to declare an emergency, limiting or blocking FbA initiatives from the outset. In Ethiopia, the experimental forecast-based trigger designed for the LEAP programme was not implemented partly because it removed subjectivity in decision-making and the government's control over communication of early warnings. In Kenya, on the other hand, concerns related more to a potentially hostile press and negative media reaction to issuing a false alarm. Investing in FbA may mean foregoing or delaying other programmes and investments. The potential to act in vain based on forecasts and the lack of visibility of the benefits of early action are important political disincentives to fully integrating FbA in international humanitarian financing and national and NGO delivery mechanisms. In addition, promoting inter-ministerial and sectoral collaboration around early action is not straightforward. As one key informant pointed out, information-sharing between ministries and links between emergency plans and centrally managed protocols are not always in place. Internal politics and competition between ministries over funds get in the way.

How forecasts are being used is a key question for FbA initiatives. Interviewees highlighted that the gains from using FbA in a specific context depend on the 'right' interplay of risk profiles and hazards affecting a country and the institutional capacity and political will to forecast hazards or impacts and finance and deliver FbA. Haiti, for instance, is highly vulnerable to a range of natural hazards, but competing priorities and limited capacity in government and meteorological agencies challenge the development of effective FbA. Bangladesh, which is also frequently affected by natural hazards, has seen an influx of funding and proposals for FbA and preparedness projects. This can be overwhelming for national agencies and demands strong coordination at country level. Nepal was mentioned by one key informant as an example where FbA has made easier and quicker advances due to a combination of available resources, capacity improvements and political will. Strengthening forecasting capacities will also require longer-term investments, such as setting up higher education and training programmes.

Overall, there is a strong desire to institutionalise FbA in humanitarian and government risk-financing mechanisms, and the process of developing the protocols with agreed actions and costs will certainly increase confidence in these mechanisms. However, more work needs to be done to identify and understand the incentives and interests of all relevant stakeholders if FbA is to become standard practice.

8 Conclusion

The field of early action is rapidly advancing and its proponents are identifying similar sets of challenges and modifying the mechanisms to deal with many of these. Although limitations persist in the forecasting skill and capacities needed to generate and interpret data, establish triggers and target vulnerable populations, the evidence seems clear that early action can reduce disaster losses and has the potential to reduce the humanitarian burden. More can be done in this regard with existing forecast information and impact data. With the increasing risks of more severe and frequent weather events driven by climate change, FbA offers an important new tool to better manage these risks.

As well as reducing loss and damage associated with known hazards and predictable disasters, FbA has the potential to improve long-term financial planning in the humanitarian sector and clarify responsibilities for early action. It will only do so, however, if the use of forecasts can be integrated into humanitarian and DRR systems, and decision-making protocols are established in advance to identify concrete actions, roles and responsibilities. To have a significant impact, FbA will need to be adopted at scale, building on existing delivery channels and strengthening these, and draw on a range of financing mechanisms.

For these mechanisms to expand and become a core component of humanitarian action and disaster risk management, some fundamental principles are needed. FbA is gaining traction in countries where governments have some forecasting capacity and their own delivery mechanisms for supporting vulnerable households, so engaging with government agencies in the design and modification of these mechanisms will be critical. Care must be taken, however, to ensure that FbA mechanisms are free from political manipulation by donors or national governments and retain their function as a robust, science-based and effective *ex ante* mechanism for resource allocation.

FbA requires a clear articulation of roles and responsibilities, based on comparative advantage, capacity and access to resources. Careful monitoring of how funds are spent and regular evaluations can improve the effectiveness of FbA and enhance accountability. FbA should be seen as a more robust decision-making approach to the allocation of humanitarian or contingency funding resources, and although new funds have been created in some cases to facilitate early action, in the future FbA will have to avoid creating parallel funding systems and planning structures. Existing donor and government funds and other financing mechanisms will need to be expanded to support FbA, linking where possible to existing early warning systems and contingency planning processes.

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Annexes

Annex 1

Table A1 List of FbA initiatives reviewed

FbA system	Countries	Space/timescale	Hazard type
WFP FoodSECuRE	Guatemala, Philippines, Zimbabwe	Country-level project but forecast information provided at district level	Drought, flood, storms
WFP Early Warning Unit	Bangladesh, Dominican Republic, Haiti, Nepal, Philippines	National but trying to focus on populations that are vulnerable and exposed	Flood
Red Cross Red Crescent FbF	Uganda	River basin scale; days	Flood
Red Cross Red Crescent FbF	Togo	River basin scale; days	Flood
Red Cross Red Crescent FbF	Peru	Local scale; days–season	Heavy rain (and associated flood risk); cold waves
Red Cross Red Crescent FbF	Ecuador	Regional – river basin/national (volcanos)	Floods/volcanos (ash fall, wind speed)
Red Cross Red Crescent FbF	Bangladesh	Regional – river basin/coastal zones	Floods, cyclones
Red Cross Red Crescent FbF	Solomon Islands	National	Droughts
Red Cross Red Crescent FbF	Mongolia	National	Dzud
Red Cross Red Crescent FbF	Kenya	Regional – river basin	Floods and drought with new project at national level
Red Cross Red Crescent FbF	Mali	Regional – river basin	Floods
Red Cross Red Crescent FbF	Niger	Regional – river basin	Floods (droughts to be explored)
Red Cross Red Crescent FbF	Zambia	Regional – river basin	Floods
Red Cross Red Crescent FbF	Malawi	Regional – river basin	Floods
Red Cross Red Crescent FbF	Tanzania	Local – city level	Floods – urban
Red Cross Red Crescent FbF	Ethiopia	Regional – river basin	Floods (drought to be defined)
Red Cross Red Crescent FbF	Philippines	National – river basin	Typhoons/floods
Red Cross Red Crescent FbF	Vietnam	City level	Heatwaves (city)
Red Cross Red Crescent FbF	Indonesia	River basin	Floods (new project at national level – not yet started)
IFRC FbF window DREF	Global (190 National Societies)		
Start Network – Collective Crisis Modifier	Zimbabwe	Country level; seasonal	Various
WFP El Niño Defensive Procurement	Global		Drought, floods, storms
LEAP – EUPORIAS pilot	Ethiopia	National system – woreda information	Drought
Kenya HSNP and livestock asset protection policy	Kenya	Sub-county level	Drought

FbA system	Countries	Space/timescale	Hazard type
Kenya drought EWS and DCF	Kenya	County level	Drought
Kenya FSSG	Kenya	County	Drought and food security
FAO EW/EA pilots	Kenya, Madagascar, Pacific Islands, Paraguay, Sudan; with Guatemala, Philippines planned for late 2017	Country level	Various
Somalia Resilience Program (SomReP)	Somalia	Community-based, piloted in 3 regions of Somalia where SomReP partners are operating	Drought, floods, conflict, climate change
GlobalAgRisk Extreme El Niño Insurance Products (EENIP)	Peru	District	El Niño-related hazards
Darfur Rain Timeline	Sudan		Precipitation affecting logistics
Start Fund Crisis Anticipation Window	Global	Country level	All hazards
Start Network Drought Financing Facility	Pakistan, Zimbabwe	Country level	Drought
Welthungerhilfe (WHH) Drought Forecast-based Financing	Madagascar		Drought
Inter-Agency Standing Committee (IASC) ENSO Standard Operating Procedures	Global	Global–country	Multiple: all ENSO-related hazards
African Risk Capacity (ARC)	Africa	Insurance	Drought
ARC Replica Coverage (Start Network and WFP)	Mali, Mauritania, Senegal	Insurance	Drought
FEWS Food Assistance Outlook Briefing and monthly procurement cycle	Central America, Central Asia, Sub-Saharan Africa, Haiti, Yemen	Multiple	Food security
Improved Early Warning Early Action (ACCRA and Oxfam)	Ethiopia	Woreda level	Multi-hazard
Urban Early Action Early Warning	Kenya	City (Nairobi)	Multi-hazard
Start Fund Bangladesh	Bangladesh	Multi-scale sub-national, time depending on hazard	Multi-hazard
IIED/Christian Aid	Kenya	County level	Drought, food security
Christian Aid/RWAN	Philippines	Municipality	Cyclones, ENSO/drought
Christian Aid BRACED	Burkina Faso, Ethiopia	District/woreda	Drought, food security
Christian Aid/partners	Malawi	District	Drought, flood, food security
Christian Aid/Centro Humboldt	Nicaragua	National	Drought and long-term climate scenarios
Christian Aid/GEAG	India	State	Drought, flood, food security

Annex 2

Table A2 Selected FbA pilots

	Somalia	Bangladesh	Kenya	Peru	Tajikistan	Zimbabwe
Initiative	SomReP	Red Crescent FbF (Phase I)	FAO Early Warning Early Action	Red Cross FbF (Phase I)	Start Network Anticipation Window	WFP FoodSECuRE
Hazard(s)	Drought, floods, conflict, climate change	Floods, cyclones	Drought	El Niño, floods, snowfall, cold waves	Multi-hazard	Drought
Fund	Donor pooled EW/ EA fund	German Federal Foreign Office FbF fund	Early Action window in the Special Fund for Emergency and Rehabilitation (SFERA)	German Federal Foreign Office FbF fund	Start Fund Anticipation Window	Multilateral contribution from Norway
Information used in forecast/early warning	Community-based early warning indicators Data on food security and livelihoods, health and nutrition and conflict FSNAU/FEWS NET	Weather forecasts of the Bangladesh Meteorological department and the Bangladesh Water Development Board	Kenyan government drought information early warning system (short-range weather forecasts, hydrological data, market and trade information, socio-economic indicators, livestock movement indicators); IRI seasonal rainfall forecasts; Global Agriculture Stress Index; FAO's Predictive Livestock Early Warning System (forage coverage forecast); Kenyan government Long and Short rain assessments (crop production, livestock prices, food security)	Risk analysis (DesInventar, national statistical and sectoral agencies, meteorological offices) and climatological/ meteorological forecasts (meteorological offices, geophysical institutes, NOAA, IRI, European Centre, etc.) for a range of seasonal to daily forecasts	World Bank Climate Investment Fund, Tajikistan country information, district-level meteorology stations within Tajikistan, Weather Online, for analysis of number of days experiencing precipitation in 2016–17 winter, verbal reports from district-level staff and community on emergency situation	WFP's forecast analysis based on climate models (climatology/ precipitation), Zimbabwe Meteorological department and the Southern Africa Regional Climate Outlook Forecast (SARCOF), long-term trends in food insecurity and vulnerability through the Zimbabwe Integrated Context Analysis, Zimbabwe Vulnerability Assessment Committee (ZimVAC), WRSI
Type of trigger	Phased approach based on combination of information: normal, alert, alarm and emergency, with each deterioration triggering a range of early actions using qualitative information method	Short-term hydro-meteorological forecast using threshold method providing a lead time of 48 hours for cyclones and 7–10 days for floods	Phased approach based on a combination of indicators (normal, alert, alarm), each corresponding to a different set of early actions. Combination of quantitative (rainfall, hydrological thresholds) as well as qualitative (expert analysis of where the drought is likely to hit hardest)	Seasonal and short term climatological and meteorological forecasts using threshold method (El Niño: 3-month, 1-month, 7-day; floods: 1-month, 9-day, 2-day; snowfall and cold waves: 5-day)	Combination of forecasting information and expert analysis of risk that a crisis occurs (qualitative information method)	Combination of forecasting information and expert analysis of risk that a crisis occurs (qualitative information method)
Implementing agency/ies	ACF, ADRA, CARE, COOPI, Danish Refugee Council, Oxfam, World Vision	Bangladesh Red Crescent Society (BRCS) Technical support from German Red Cross and Red Cross Red Crescent Climate Centre	FAO	Peruvian Red Cross Technical support from German Red Cross and Red Cross Red Crescent Climate Centre	Start Network members (Welthungerhilfe, Mercy Corps and ACTED involved in previous activation)	WFP

	Somalia	Bangladesh	Kenya	Peru	Tajikistan	Zimbabwe
Funding released to date	$777,791 funding gap approved	Approximate funds spent in direct cash payments: Flood 2016: €92,000 Flood 2017: €54,000 Cyclone 2017: €124,000	$400,000	Approximate funds for relief goods and services activated: El Niño 2015–16 rains: €240,000 Cold wave 2016: €60,000	£145,704 spent	$100,000

Sources: Start Network (2017); Action Against Hunger, ADRA, CARE, COOPI, DRC, Oxfam and World Vision (2014); Red Cross Red Crescent Climate Centre (2016); FAO (2018); Machenda (2015); World Food Programme (2016); World Food Programme (2017); World Food Programme (2018); Giuffrida (2017); Cruz Roja Peruana, German Red Cross and Red Cross Red Crescent Climate Centre (2016); Ibrahim and Kruczkiewicz (2016).

Annex 3

Table A3 List of key informants

Name	Affiliation
Davaajargal Batdorj	Mongolian Red Cross
Lorenzo Bosi	WFP
Mathieu Destrooper	German Red Cross
Dunja Dujanovic	FAO
Brenden Jongman	WB GFDRR
Georgina Jordan	World Vision
Michael Kühn	Welthungerhilfe
Romain Lare	Togolese Red Cross
Jesse Mason	WFP
Emily Montier	Start Network
Sunya Orre	Kenyan National Drought Management Authority
Greg Puley	OCHA
Sanna Salmela-Eckstein	IFRC
Jerry Skees	Global Parametrics

Annex 4

Table A4 Glossary of FbA concepts

Forecast-based financing	Forecast-based Financing (FbF) is a mechanism first developed by the Red Cross to release humanitarian funding based on forecast information for planned activities which reduce risks, enhance preparedness and response and make disaster risk management overall more effective. The Red Cross, meteorological services and communities at risk agree on selected actions to be taken once a forecast reaches a certain threshold of probability. Each action is then allocated a budget to be activated when a forecast is received (Red Cross Red Crescent Climate Centre, n.d.).
Forecast-based early action	Action taken in the short term after the issuance of a science-based early warning, but before a potential disaster materialises (Coughlan de Perez et al., 2015). In this study we found multiple interpretations of the word 'forecast'; some organisations focused on forecasting climate hazards based on an analysis of their possible impacts, while others focused on forecasting the impacts themselves, with differing levels of complexity. As a result, there is little consensus on what counts as forecast-based action and when it is taken. Some adopt a broad interpretation including actions to reduce vulnerability, training and prepositioning relief (Coughlan de Perez et al., 2015). Others include early response after a climate hazard has already had an impact, or before multiple shocks and stressors have worsened an existing humanitarian crisis.
Early response	There is often confusion over whether early action refers to action taken ahead of an impending shock to reduce its impact, based on forecasts/predicted needs – or simply a faster, more timely humanitarian response (Oxfam, 2017). For clarity, we use early response to refer to the latter.
Late response	Late response most often refers to a humanitarian response implemented when severe impacts of a hazard have already begun to occur. In the case of drought this may be as much as six months after a failed agricultural season. In cost–benefit studies this is often formalised as a humanitarian response that arrives after negative coping strategies have been employed and after prices of food and other items have begun to destabilise (e.g. Cabot Venton, 2018).
Impact (humanitarian and disaster)	Disaster impact is the total effect, including negative effects (e.g. economic losses) and positive effects (e.g. economic gains), of a hazardous event or disaster. The term includes economic, human and environmental impacts, and may include death, injuries, disease and other negative effects on human physical, mental and social wellbeing (UNISDR, 2017).
Impact-based forecasting	Forecasting the impact of a hazard, or multi-hazards, on individuals or communities at risk. Examples include forecasting the possible impact of rainfall on road users during rush hour, or the impact on passengers of closing an airport due to strong winds. These could be done in a subjective way working alongside transport customers, or in an objective way through developing an impact model using vulnerability and exposure datasets as well as meteorological information (World Meteorological Organization, 2015).
Vulnerability	The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards (UNISDR, 2017).
Exposure	The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas (UNISDR, 2017).
Risk	Risk is defined as the probability and magnitude of harm attendant on human beings and their livelihoods and assets because of their exposure and vulnerability to a hazard. The magnitude of harm may change due to response actions to either reduce exposure during the course of the event or reduce vulnerability to relevant hazard types in general (World Meteorological Organization, 2015).
Disaster risk reduction	Disaster risk reduction is the concept and practice of reducing disaster risks through systematic efforts to analyse and reduce the causal factors of disasters. Reducing exposure to hazards, lessening the vulnerability of people and property, wise management of land and the environment and improving preparedness and early warning for adverse events are all examples of disaster risk reduction (UNISDR, 2017).
Disaster risk management	Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses (UNISDR, 2017). DRM systems therefore include early action based on hazard forecasts.
Early warning system	An integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities, systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events (UNISDR, 2017). FbA systems are in many ways a subset of early warning systems focused on better translation of forecasts into anticipatory action. They also allow for action to be taken based on probabilistic information, and therefore for responses to be triggered that may not be followed by a disaster event.

Contingency (emergency) planning	A management process that analyses disaster risks and establishes arrangements in advance to enable timely, effective and appropriate responses. Contingency planning results in organised and coordinated courses of action with clearly identified institutional roles and resources, information processes and operational arrangements for specific actors at times of need. Based on scenarios of possible emergency conditions or hazardous events, contingency planning allows key actors to envision, anticipate and solve problems that can arise during disasters. Contingency planning is an important part of overall preparedness. Contingency plans need to be regularly updated and exercised (UNISDR, 2017). FbA systems all link to some kind of contingency planning, SOP, EAP or decision-making process.
Forecast	A forecast is a prediction or estimate of future events, especially coming weather or a financial trend. In this study, most initiatives focused on climate and weather forecasts. Weather forecasts provide information about the expected state of the weather up to 10–14 days in advance, while climate forecasts and outlooks provide information about the expected state of regional climate beyond the timeframe of long-range weather forecasts (~10–14 days) (Western Water Assessment, 2018).
Forecast skill	A statistical evaluation of the accuracy of forecasts or the effectiveness of detection techniques. Forecast skill is determined by comparison of the disseminated forecast with a reference forecast, such as persistence, climatology or objective guidance; it shows what 'value' the forecast adds to simple schemes (American Meteorological Society, 2012). Forecast accuracy is determined by comparison of the disseminated forecast with actual observations (World Meteorological Organization, 2017).

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