Science for Humanitarian Emergencies and Resilience (SHEAR) scoping study:

Annex 2 - The current status of early warning systems and risk assessments in Africa, the Caribbean and South Asia – A literature review

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Report Summary

The report forms part of the Science for Humanitarian Emergencies and Resilience (SHEAR) scoping study, which aims to provide the UK Government's Department for International Development (DFID) with evidence-based recommendations on future research priorities for risk assessments and early warning systems. The focus is on weather-related hazards (i.e. cyclones, floods, droughts and landslides) ***for humanitarian and development purposes*** in low-income countries across Africa, South Asia and the Caribbean.

Overall 190 papers, reports and online resources were reviewed with a fairly even coverage across each region and on early warning systems, risk assessments and analytical tools, and on how information is used to inform decision making. International data sets show that the total numbers of people affected by weather related emergencies and disasters are greatest in South Asia but the Caribbean islands stand out as having particularly high 'risks to people' and economic damage from hurricanes and flooding per capita. Floods and droughts are important in Africa and although landslide risks affect fewer people they are locally important in Nepal, India and in some Caribbean islands (CRED, 2013).

Early warning systems require several components, i.e. risk knowledge, monitoring and warning systems, dissemination and communication and response capacity. A weakness or breakdown in any one part of an early warning system can result in its failure (UNISDR, 2006; Kundzewicz, 2013). The report's findings suggest a very mixed picture with good examples and continued progress on early warning systems in parts of South Asia and the Caribbean but far less progress on national risk assessments and a lack of integration between warning systems and risk assessment tools. For example:

- There are successful operational country-wide cyclone early warning systems in the Caribbean, Bangladesh and India. The success of these systems can be backed up with evidence showing a reduction in serious harm and loss of life.
- There are reasonably good flood early warning systems in South Asia, including India, Pakistan and Bangladesh but these could be improved.
- Progress on early warning systems is highly variable in African countries but some regional systems have been reasonably successful. Notable examples include FEWS-NET and the Food and Security Nutrition Working Group (FSNWG), which both provided timely information on the food insecurity crisis in East Africa in 2010 and 2011 (Ververs, 2012).
- There are some good examples of community-based early warning systems for floods in Asia but there can be difficulties scaling these up to larger areas.

The main findings on risk assessments are more limited because, with few exceptions, there was a lack of good examples of detailed, quantitative risk assessments ***for humanitarian purposes*** in Africa, the Caribbean and South Asia.

The review highlights specific opportunities to improve both early warning systems and risk assessments in each region, particularly with regards to (i) flood forecasting and the communication of drought forecasts in Africa (ii) drought and flood forecasting in the Caribbean and (iii) early warning systems for landslides in Nepal, an important hazard in terms of fatalities. These findings will be considered alongside other evidence from surveys and end-user and expert workshops to inform the SHEAR programme.

SECTION 1

Introduction

Background

This objective of the Science for Humanitarian Emergencies and Resilience (SHEAR) scoping study is to provide the UK Government's Department for International Development (DFID) with evidence-based recommendations on future research priorities for risk assessments and early warning systems for weather-related hazards (i.e. cyclones, floods, droughts and landslides) for humanitarian and development purposes in low-income countries across Africa, South Asia and the Caribbean.

Objective and structure of this report

The objective of this report is to provide a summary of the status of early warning systems, as well as risk assessments and related modelling activities currently in place for weather-related hazards in Africa, the Caribbean and South Asia.

Information was collected by reviewing grey and peer-reviewed literature and relevant websites. Overall 190 papers, reports and online resources were reviewed with a fairly even coverage across each region and on early warning systems, risk assessments and analytical tools and on how information is used to inform decision making.

The peer reviewed literature is extensive particularly if searches extend to 'natural hazards' or 'vulnerability assessment.' Existing reviews, which focused on disaster risk reduction and humanitarian aid, were particularly useful, for example UNDPs 2012 review of drought risk management in Africa and Asia (UNDP, 2012). The review has also focused on risk assessments and early warning systems that are in use for humanitarian purposes in order to understand the situation on the ground in countries of interest.

The findings from this literature review will be combined with other evidence collected from surveys and four workshops and brought together in a final report.
The report has been structured as follows:

- Section 1 describes the objectives of the report and gives an overview of the impacts of weather-related hazards in the three regions
- Section 2 provides an overview of the current status of early warning systems
- Section 3 gives a summary of risk assessments for humanitarian and development purposes
- Section 4 provides some preliminary conclusions related to good practice examples of early warning systems and the areas where substantial improvements could be made
- Section 5 gives details of the references used to compile this report

The impacts of weather-related hazards in the three regions

The natural hazards considered in this literature review are a result of extreme weather events and climate variability that occur in all parts of the world. A changing climate may lead to changes in the frequency and intensity of extreme weather and climate events. The Inter-governmental Panel on Climate Change (IPCC) highlighted the increased risks of flooding and erosion in coastal areas and a *likely* increase in tropical cyclone maximum wind-speeds, a particular issue for small island states (IPCC, 2012). Natural hazards become natural disasters when people's lives and livelihoods are destroyed. The losses caused by natural disasters are a major obstacle to sustainable development.

In terms of their consequences, the four main weather-related natural hazards that affect Africa, the Caribbean and South Asia are:

- **Floods** – Floods generally come about as the result of excess rainfall resulting in high river discharges and/or surface water inundation, as well as coastal surges causing extreme sea levels and inundation of coasts and estuaries.
- **Drought** – These are caused by a deficiency of rainfall, soil moisture, river flows and groundwater recharge and generally develop slowly over periods of months to years.
- **Cyclones** – Cyclones are areas of very low atmospheric pressure over tropical and sub-tropical waters that build up into a large, circulating mass of wind and thunderstorms up to hundreds of kilometres across that cause loss and damage owing to coastal flooding, heavy rainfall and high winds.
- **Mudslides and landslides** – These are generally local events that occur after periods of intense rainfall, prolonged saturation or undercutting on steep slopes with unstable soil or rock conditions

Table 1 provides data from the Centre for Research on the Epidemiology of Disasters (CRED) that maintains an Emergency Events Database (EM-DAT). Table 1 and Figure 1 provide summaries of the impacts of the four major weather related hazards in the three regions between 1990 and 2013, based on the CRED EM-DAT database.

These data show that the total numbers of people affected are greatest in South Asia but if the numbers of people killed or injured are normalised by total population[1] the Caribbean islands stand out as having particularly high 'risks to people' and economic damage from hurricanes and flooding.

Region	Number of people killed	Number of people injured	Number of homeless people (millions)	Total number of people affected (millions)	Economic damage (US$ billion)
Floods					
Africa	17,978	26,446	3.976	53.814	5.857
The Caribbean	3,994	358	0.127	2.070	0.648
South Asia	57,783	15,749	15.039	745.741	58.794
Droughts					
Africa	1,339	0	0	262.232	2.244
The Caribbean	0	0	0	1.855	0.191
South Asia	200	0	0	363.188	2.430
Cyclones					
Africa	2,937	11,916	1.517	9.684	1.663
The Caribbean	6,057	4,153	0.547	15.805	30.446
South Asia	169,717	288,187	4.274	80.762	15.799
Mudslides and landslides					

[1] Assuming populations of about 1.6 billion, 1.0 billion and 7 million for South Asia, Africa and the Caribbean respectively based on Word Bank figures.

Region	Number of people killed	Number of people injured	Number of homeless people (millions)	Total number of people affected (millions)	Economic damage (US$ billion)
Africa	888	201	0.024	0.042	0
The Caribbean	2	0	0.001	0.001	0
South Asia	4,750	1,150	1.200	2.092	0.725

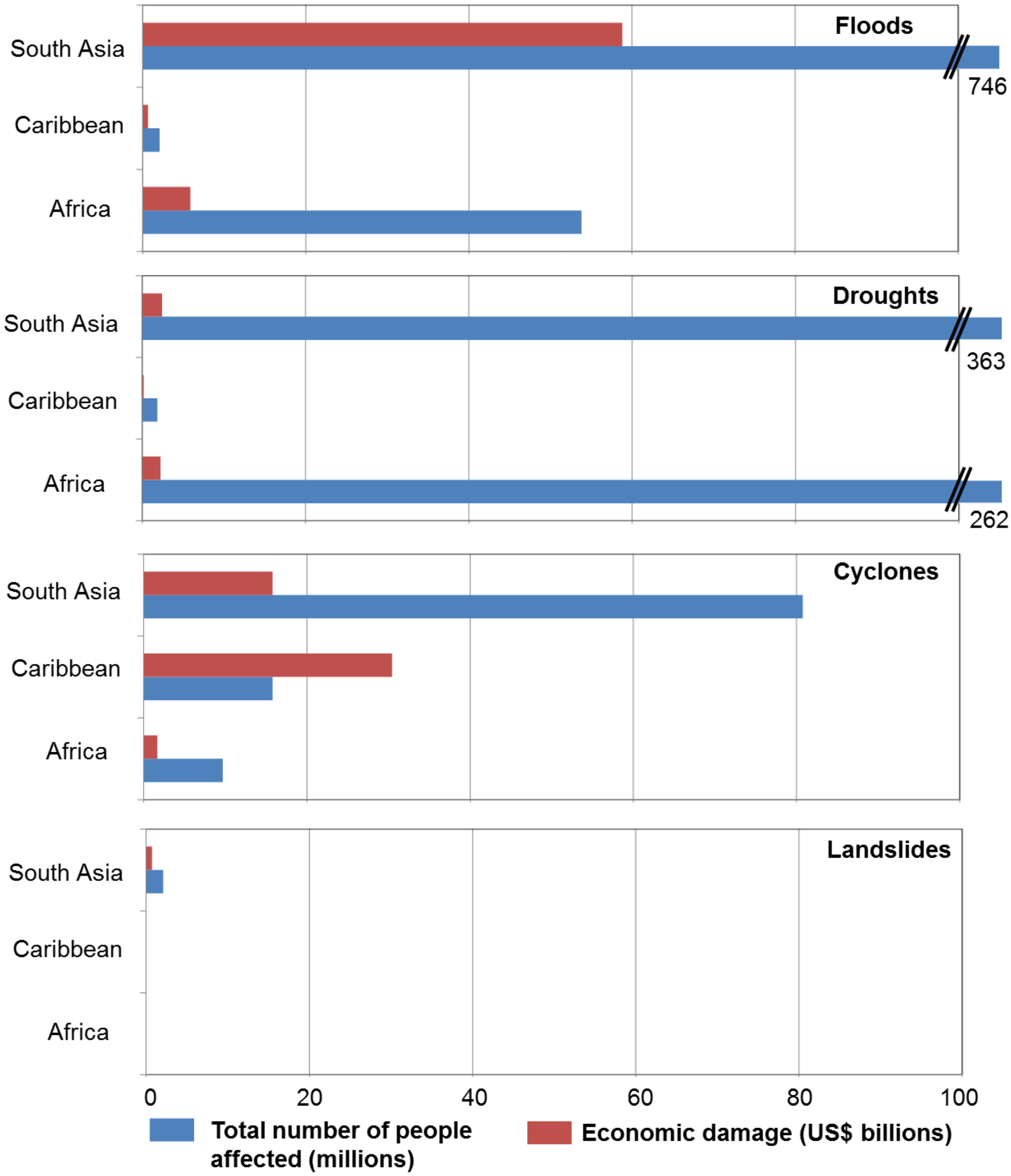
Notes: The total number of people affected is the number of people requiring immediate assistance during a period of emergency, i.e. requiring basic survival needs such as food, water, shelter, sanitation and immediate medical assistance. The total number of people also includes the number of people injured and killed as a result of the disaster.

The economic damage consists of the direct (e.g. damage to infrastructure, crops, housing) and indirect (e.g. loss of revenues, unemployment, market destabilisation) consequences on the local economy.

(Source: CRED, 2013)

Table 1 Summary of the impacts of weather-related hazards in Africa, the Caribbean and South Asia between 1990 and 2013

Figure 1 Total number of people affected and economic damage in US$ for weather-related hazards in Africa, the Caribbean and South Asia between 1990 and 2013



(Source: CRED, 2013 EM-DAT: The OFDA/CRED International Disaster Database, www.emdat.be, niversité Catholique de Louvain, Brussels, Belgium.)

SECTION 2

Early warning systems

Introduction

A global survey of early warning systems carried out by the United Nations International Strategy for Disaster Reduction, (UNISDR, 2006), resulting from the assessment of progress towards the Millennium Development Goals, concluded that to be effective, early warning systems must be people-centred and must integrate the following:

- Risk knowledge
- Monitoring and warning systems
- Dissemination and communication
- Response capacity

A weakness or breakdown in any one part of an early warning system can result in its failure (UNISDR, 2006; Kundzewicz, 2013).

Early warning systems for floods

This section provides an overview of the status of early warning systems for floods in the three regions. The implementation of a comprehensive flood early warning system comprises several components (WMO, 2010) including:

- Real-time observation of hydro-meteorological information
- Real-time data communication
- Forecasting
- Warning
- Response

Africa

In 2003 the World Meteorological Organisation (WMO) indicated that the main weaknesses with regards to flood forecasting systems for the Southern African Development Community (SADC) were as follows:

- Absence of flood forecasting systems in most countries
- Weak data transmission networks
- Weakness in utilisation of data collection networks
- Lack of quantitative rainfall forecasts
- Lack of adequate real-time data collection
- Shortage of qualified personnel

(WMO, 2003a; Moges, 2007)

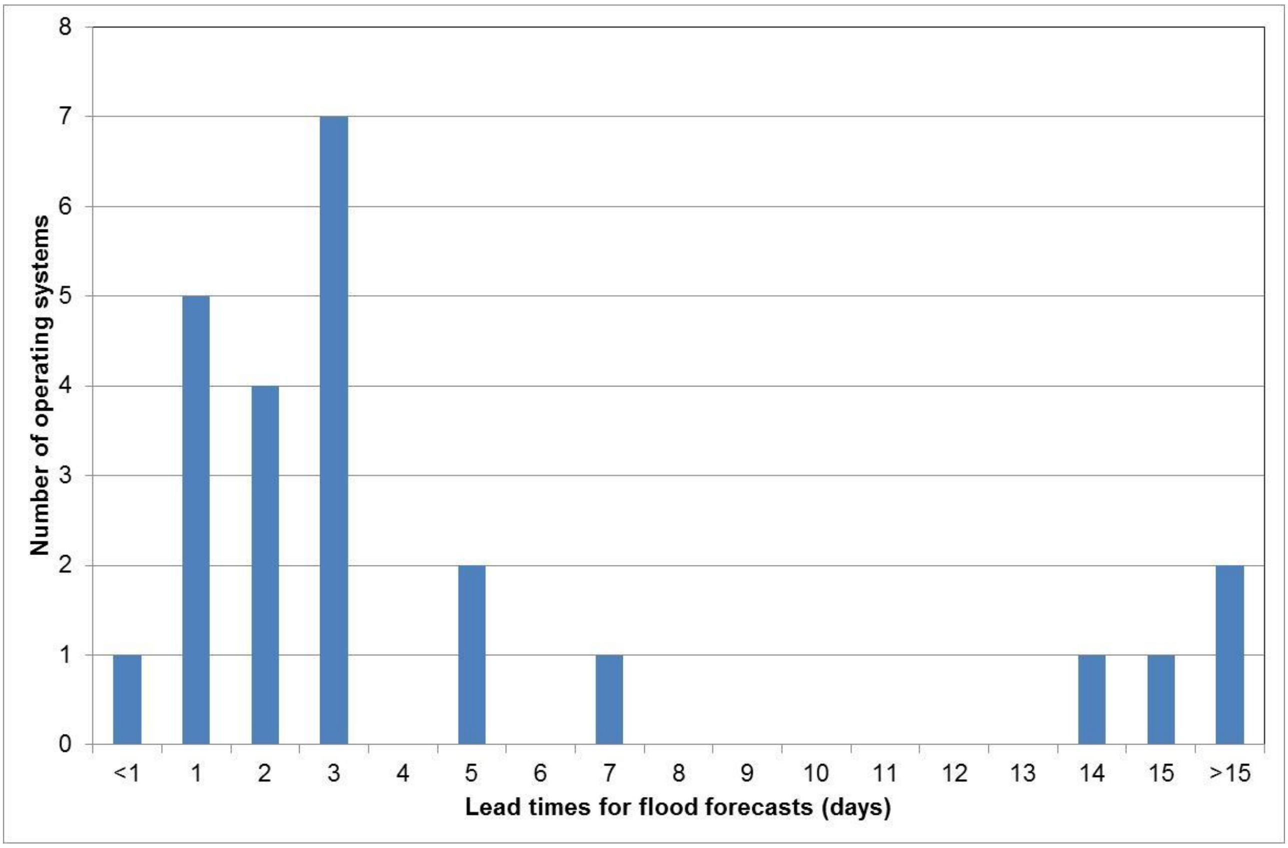
Over the past decade, there has been a significant increase in the number of institutions and research dedicated to dealing with flood management, including flood forecasting in Africa

(Thiemig et al., 2011); however, detailed information on them is not always easily accessible (Burek et al, 2011). There is the potential to significantly improve flood management in the region; however, the increase in the number of different institutions makes the coordination of research more complicated. A clear understanding of the early warning systems in place and the research that is currently being undertaken is important for the efficient coordination of future efforts.

In 2011 Thiemig et al. carried out a study that reviewed the published literature on flood forecasting systems in Africa. This information was supplemented by data collected from a questionnaire sent to hydrological and meteorological institutions responsible for flood management issues in Africa. Compared to other continents the amount of web-based information available addressing ongoing transnational flood forecasting and early warning initiatives is still relatively limited (Thiemig et al., 2011).

An important parameter for early warning systems is the amount of lead time that they provide. The lead time is the time between the issuing of a message containing a forecast and the time when the forecast flood peak is reached. Of the 29 institutions in Africa that currently run a flood forecasting system in an operational mode, 24 specified their lead times (Thiemig et al., 2011). The lead times reported are shown in Figure 2. This indicates an emphasis on short-range forecasts with lead times of up to three days, as well as long-range forecasts with lead times of 14 days or more. Figure 2 also indicates that there are almost no medium-range forecasts with lead times between five and 11 days.

Figure 2 Reported lead times for flood warning systems in Africa



(Source: Thiemig et al., 2011)

There do not appear to be any operational pan-African flood forecasting and warning system. The European Commission's Joint Research Centre (JRC) is investigating the potential of using the European Flood Alert System (EFAS) to establish an African Flood Alert System to provide early warnings across the continent. The applicability of EFAS methodologies to African basins is being tested in the Juba-Shabelle River basin, which is shared between Ethiopia and Somalia (EC, 2013; Thiemig, and de Roo, 2010). This has included the piloting of probabilistic forecasts (Thiemig et al., 2010). The EFAS is also being tested in the Zambezi catchment in southern Africa and the Volta catchment in western Africa. There are also plans to pilot the EFAS in the Limpopo catchment. EFAS methodologies have shown a potential to provide medium-ranged flood forecasts for African basins (Burek et al., 2011).

There has also been work in the Nzoia catchment near Lake Victoria to look at the use of satellite rainfall data in flood forecasting (Yong Hong et al., 2009). The NASA Applied Science Programme has partnered with USAID and the Regional Centre for Mapping of Resources for Development in Nairobi to set up the SERVIR-Africa hub. This integrates satellite observations and predictive models with other geographic information to monitor and forecast ecological changes and respond to natural disasters in 18 states in east and southern Africa (SERVIR-Africa, 2013; Irwin, 2011). SERVIR-Africa has the potential to be used as implement an operational water-hazard warning system (Yong Hong at al., 2009; Irwin, 2011); however, information available from SERVIR-Africa indicates that it does not currently appear to be used for operational flood forecasting.

There have been some community-level flood warning initiatives in Africa or example on the Buzi River in Mozambique, as well as west and central Africa (IntoAction, 2007; IFRC, 2009). However, the general lack of operational community-level early warning and information-sharing systems means that warning information often does not reach the communities that most need it (Tall et al., 2012). For example, in southern Africa, available forecast information does not specifically target vulnerable groups, and thus the information either does not reach the community level at all or fails to reach the more marginalised groups (Archer at al., 2007; O'Brian et al, 2000; O'Brien and Vogel, 2003; Ziervogel and Calder, 2003; West et al., 2008).

With respect to early warning systems for floods in Africa the issues can be summarized as follows:

- There are many ongoing flood forecasting initiatives in Africa; however, information on these is often not easily accessible especially to the most vulnerable groups in society
- There is a need for a complementary flood forecasting and early warning system for medium-ranged forecasts (i.e. lead times between five and 15 days)
- There is a requirement for increased technical capacity within the institutions responsible for flood forecasting and warning
- Dissemination of existing flood forecasts and warnings to end-users and the public could be improved
- There is a need to improve the collaboration between the provider and the end-user of flood forecast information
- There is a need for clear, concise and unambiguous visualisation and decision support products to support both forecasts and warnings
- There is a need for real-time flood forecasting showing maps of forecast extent for large river catchments in Africa

South Asia

Flooding in South Asia is the natural hazard that has the highest humanitarian impact. There has been a considerable amount of research done that has assisted in implementing operational flood forecasting systems over the past 35 years.

Bangladesh

A flood forecasting and warning system was established by the Bangladesh Water Development Board (BWDB) almost 35 years ago. Over a decade ago, Bangladesh incorporated hydraulic models into its flood forecasting system. Daily deterministic forecasts are made throughout Bangladesh using river discharge data collected at the India–Bangladesh border by Bangladeshi authorities (Webster et al., 2012).

The system forecasts water levels and uses measurements of water level together with rainfall and satellite information. During the monsoon season the forecasting model simulates the water level conditions during the previous seven days (hind-cast simulations) and then provides forecasts of water levels for up to three days in advance.

The European Centre for Medium-Range Weather Forecasts (ECMWF) together with the Bangladeshi Government have developed a flood forecasting system with a one to 15-day lead time. They created the Climate Forecast Applications Network (CFAN) to distribute it. This system was first used experimentally in 2004 and became operational in 2007 (Webster, 2013). The CFAN produces probabilistic daily forecasts of the Brahmaputra and Ganges River flows sending them to the Bangladesh Flood Forecast and Warning Centre. If the probability of flooding exceeds 80%, warnings are issued to government offices across Bangladesh (Webster, 2013).

In 2009, to boost regional capacity-building, the CFAN handed over its flood-forecast modules to the Bangladesh Flood Forecasting and Warning Centre. When the large volume of data proved too difficult for the centre to handle, the responsibility shifted to an international non-government entity, the Regional Integrated and Multi-Hazard Early Warning System (RIMES) (Webster, 2013). The RIMES framework is innovative but suffers from funding pressures that affect forecasting groups in low-income countries. Limited funding also means that the necessary cadre of scientists to tackle specific problems cannot easily be maintained (Curry, 2013).

Various authors (see Islam et al., 2000; Mirza et al., 2003; Haque et al., 2011; Habib et al., 2012 and many others) have indicate that the improvements in flood forecasting have reduce the number of fatalities from this hazard in Bangladesh.

India

The Central Water Commission (CWC) in India has developed a website to facilitate the process of making information about hydrological and hydro-meteorological data available to the public. CWC started flood-forecasting services in 1958 using information from upstream water level gauges. The flood forecasting services of CWC collect hydro-meteorological data from 878 sites (CWC, 2010). There is currently a network of 175 flood forecasting stations including 28 inflow forecasts, in nine major river catchments and 71 sub-catchments. The WISDOM website provides a flood warning service to non-registered users. Registered users can access and request the available data in their preferred format (Jha, 2012).

Following recent floods in India it has been reported that CWC will invest in satellite-linked sensors to improve flood forecasting and that spending on flood forecasting could increase five-fold over the next few years (Chaudhary, 2013). There has been some recent criticism of CWC's failure to provide warnings for floods in Uttarakhand in June 2013 that led to several hundred people being killed (DNA, 2013).

Nepal

There is a web-based, real-time data acquisition system for flood early warning with a telemetry system for real-time data acquisition installed on 44 stations in major river catchments in Nepal (Gautam, 2011). Real-time water levels for these gauges are available on the Department of Hydrology and Meteorology's web page. A performance evaluation has been made of the weather research and forecast model covering Nepal. It was found that for the first day the forecast is highly reliable. In day 2 the results are "random" and in day 3 of the forecast it overestimates the rainfall in all cases (Regmi et al., 2011).

There have been a number of community-based flood early warning system set up by the Department of Hydrology and Meteorology, Practical Action, local government, and Non-Governmental Organisations. Community level disaster management committees have been formed in seven villages in the West Rapti River basin (Gautam and Phaiju, 2013). Work by Practical Action in Nepal found that for flood warnings to be successfully disseminated, warning systems reliant on power were simply not viable for various technical and financial reasons (e.g. there is limited, intermittent or absent mains electricity supply) and that:

- Genuinely representative committees and volunteer groups had to be created, trained and their capacity built
- Local media, especially, the local FM station should play a major role in disseminating information widely

(Gautam and Phaiju, 2013)

Practical Action also concluded that:

- Investment in early warning systems in Nepal is a cost effective use of limited resources where risk can be anticipated and measured
- High tech and high cost systems are not only inappropriate but unsustainable
- Information provided by early warning systems should be intelligible and user friendly are fundamental to any system.

(Practical Action, 2009)

Pakistan

The National Flood Forecasting Centre was established in Lahore in 1992. Flood forecasting and warning activities are carried out during the flood season from mid-June to mid-October every year. There has been some criticism of the failure of the Pakistan government to make use of European Centre for Medium-Range Weather Forecasts, as has been the case in Bangladesh (see Webster, 2013). There has been research recently undertaken on using probabilistic flood forecasts in Pakistan (Shrestha and Webster, 2013).

In 2010 Pakistan was hit by floods that affected up to 20 million people (Singapore Red Cross, 2010). In 2011 Burton carried out a review of the response to these floods for the International Federation of the Red Cross and Red Crescent Societies. Burton observed shortcomings in both national and community level early warning systems (Burton, 2011), these issues are also echoed by Amhad, 2011. One of the main issues in 2010 was not the forecasting of the flood, but that warnings were not taken sufficiently seriously by regional authorities, media, and residents (Fair, 2011). Webster states this may be related to the methods used to communicate the warnings to different stakeholders (Webster, 2013).

Following the 2010 floods, UNESCO launched a major project in cooperation with the Government of Japan to upgrade the flood forecasting and early warning systems of Pakistan, and to conduct a flood mapping exercise of the Indus River. An Integrated Flood Analysis System (IFAS) that comprises a flood forecasting system using global satellite rainfall was developed (Aziz and Tanaka, 2012). The new flood forecasting models that have been developed cover the Indus; however, they need to be extended to the Jhelum, Chenab, Ravi and Sutlej Rivers (Hanif, 2012).

Sri Lanka

Mathematical models have been used by researchers since at least the mid-1990s to forecast floods in Sri Lanka (see Dharmasena, 1997) and there has also been research into the use of artificial neural networks for flood forecasting (see Sugeeswara and Jayawardena, 2011). However, in 2011 following serious floods Herath Manthrithilake, head of the Colombo-based International Water Management Institute's said that "*Sri Lanka does not have a proper [flood] forecasting system. This is an area to look into, probably, as part of preparedness*" (Gamage, 2011).

Apart from Sri Lanka and Afghanistan, operational flood forecasting systems in South Asia appear to be reasonably well developed. However, there are issues with the lack of co-operation between South Asian countries preventing more timely flood warnings and also the method of communication of the warnings in some countries. Floods that have occurred in the past three years in transboundary river catchments between Pakistan and Afghanistan; India and Nepal; and Nepal and Bangladesh have highlighted that there is a lack of regional cooperation for a variety of reasons (e.g. insufficient staffing levels, water resources disputes). Rajendra Sharma, head of Nepal's flood forecasting division recently said: "*For genuine regional flood forecasting, all countries including India and China will have to actively participate in the exchange of hydrological and meteorological data.*" (BBC, 2013). In the near future more accurate remote sensing data on water levels in major transboundary rivers could help to improve this situation.

The Caribbean

The picture concerning flood forecasting and warning in the Caribbean is variable. Many islands do not have the capacity or the resources to provide a flood warning service. Jamaica where the first flood forecasting systems were set up in 1992, has warning systems for six of its larger catchments together with some community-based schemes (Haiduk, 2005); however, there is room for these to be improved. There have also been pilot flood forecasting systems implement in some catchments in Barbados and Guyana (Boyce and Whitehall, 2013).

The Caribbean Institute for Meteorology and Hydrology (CIMH) provides outreach support to national meteorological and disaster management agencies, the latter in partnership with the Caribbean Disaster and Emergency Management Agency. Functions of CIMH include the provision of advice to governments; the collection, analysis and publication of hydrological and meteorological data; research and consultancy; and the provision of facilities for training. CIMH provides a 4 km x 4 km resolution numerical weather prediction rainfall accumulation over Haiti. The rainfall forecasts are superimposed onto a map of watershed delineations. The outputs are produced daily and posted online for public viewing (CIMH, 2013).

There are radars covering most of the Caribbean; however, apart from on a few pilot sites, they do not appear to be used for flood forecasting, possibly owing to the relatively small size of the catchments and the accuracy of the rainfall radar predictions. It is a goal of the CIMH to have a comprehensive weather and climate related early warning system (Trotman, 2010). CIMH is currently finalising a web-based operational system for both flood drought and drought forecasting.

Early warning systems for tropical cyclones

Tropical cyclones, also popularly known as hurricanes or typhoons, are globally monitored and forecast on a daily basis through the World Meteorological Office's (WMO) Global Tropical Cyclone Warning System (UNISDR, 2006). A number of private sector organisations have also developed models for the re-insurance industry to assess the risk posed by tropical cyclones; however, these models are often "black-boxed" and their results are not generally available.

Africa

In Africa it is primarily Madagascar, Mozambique and to a lesser degree South Africa that are affected by cyclones. The Tropical Cyclone Regional Specialised Meteorological Centre with WMO forecasting have responsibility for the south-west Indian Ocean is La Réunion run by Météo France. La Réunion uses an integrated software system that allows the forecaster to build a conceptual model of the real and future state of the atmosphere by overlaying all available observations, radar and satellite imagery, objective analyses and Numerical Weather Products (NWP) products. Mauritius uses NWP products obtained from the UK. Meteorological Office and Météo France, as well as persistence, climatology, and sea surface temperature observations.

Although each southern African country has its own meteorological service, it is only the South African Weather Service that runs a regional NWP model (Reason and Keibel, 2004). Weather forecasting elsewhere in southern Africa tends to rely on European Centre for Medium-Range Forecasts or UK Meteorological Office products combined with manual analyses based on any available local station data (Reason and Keibel, 2004).

In Mozambique successful early warning systems have been developed, but many rural communities tend to rely on indigenous based warning systems (Gall, 2004). In the past ten years a colour coded warning system has been developed (i.e. blue, yellow and red) to represent how long it is before high winds can be expected and what action to take. Flags are flown at approved locations to match the colour of the alert. A distinctive siren signal is played on public radio stations immediately before the broadcast of a cyclone advice message during the yellow and red phases (Benessene, 2005).

There is some limited evidence (see Cosgrave et al., 2007) that the warnings related to the floods and cyclone that hit Mozambique in 2007 were relatively successful; however, this was a "*relatively small emergency*" (Cosgrave et al., 2007).

South Asia

India

In India the forecasts of cyclone tracks are prepared with the help of forecasting models of different types, including numerical techniques. Currently, the Indian Meteorological Department uses a limited run of the quasi-lagrangian dynamic model for cyclone track prediction along with other synoptic, climatological and empirical techniques. The forecast advisories received from different international agencies are also considered while finalising the forecast. The current accuracy of track forecast is about ±140 km for a 24 hour forecast and ±250 km for a 48 hour forecast. This translates into warnings covering very large areas if issued more than 24 hours ahead. This limits the lead time of the warning to 24 hours (NDMA, 2008).

The forecasting of the super Cyclone 'Phailin' by the Indian Meteorological Department that made landfall in October 2013 was deemed to be a success by India's National Disaster Management Agency (Shankar, 2013), the United Nations (UNEP, 2013a) and the World Bank. A total of 21 lives were lost as a result of the Phailin and an additional 23 lives due to flash flooding in its aftermath. A comparable cyclone in India in 1999 led to over 10,000 fatalities (World Bank, 2013a).

Bangladesh

Bangladesh has a cyclone early warning and evacuation system, and more than 2,400 emergency shelters to protect coastal inhabitants from tidal waves and storm surges caused by cyclones. The Bangladesh Meteorological Department issues warnings for any impending cyclone and storm surge via newspapers, television channels and radio stations, as well as the local government administration and the local Cyclone Preparedness Programme (CPP) volunteers run by the Red Crescent Society (Dasgupta et al., 2010). The CPP has around 160 full-time staff and 43,000 trained volunteers (Habib et al., 2012).

Although the overall quality of forecasting cyclones and storm surges has improved over the years, the general consensus is that there is scope for further improvement. At present, the forecast of an area likely to experience a storm surge as the result of a cyclone is usually over-estimated and delineated over a large section of the coastal zone, which can lead to unnecessary repetitive evacuations and loss of trust in the early warning system (Dasgupta et al., 2010).

The Bangladesh Meteorological Department has stated the need for more accurate forecasting of cyclone landfall location and flood inundation depths. Warning messages in Bangladesh have become progressively more people-centred and include the potential impacts of cyclones (Habib et al., 2012). Officials of the Red Crescent Society, CPP volunteers and residents of past cyclone affected areas have emphasised the need for raising awareness to promote proper and timely evacuation.

Numerous organisations and authors (see Islam et al., 2000; Mirza et al., 2003; Haque et al., 2011; Habib et al., 2012, WMO, 2012 and many others) have stated that Bangladesh's cyclone warning system has assisted in significantly reducing fatalities, despite the number of people exposed to cyclones increasing in the past 40 years. There are others (e.g. Paul, 2009) who argue that despite considerable progress, much more needs to be done to further reduce the vulnerability of cyclone impacts for coastal residents of Bangladesh (Paul, 2009).

Sri Lanka

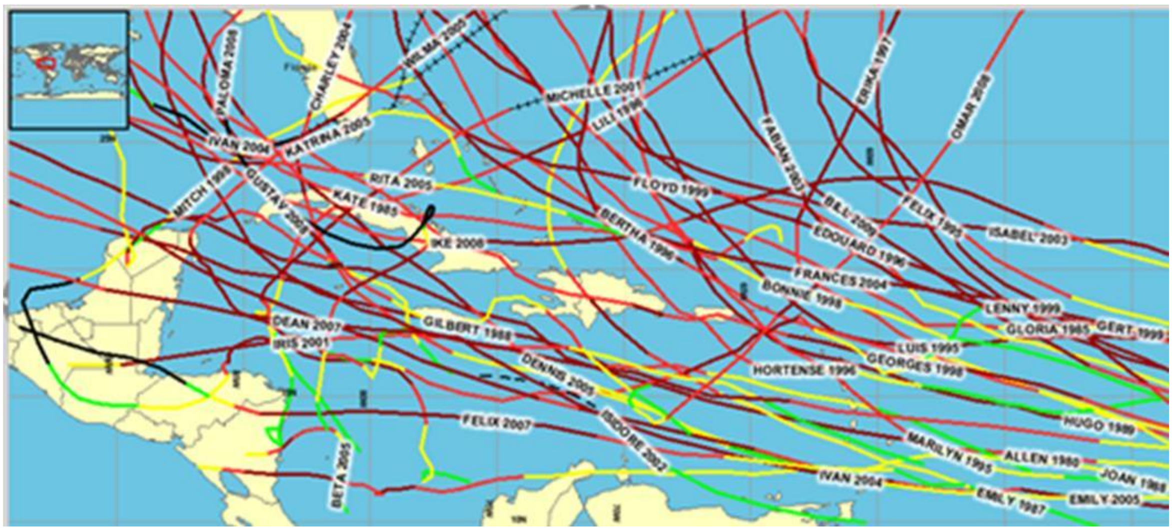
For long term forecasting of tropical cyclones Sri Lanka is reliant on other services such as the Indian Meteorological Department and the America Joint Typhoon Warning Center that issues cyclone warnings in the North West Pacific Ocean, South Pacific Ocean and Indian Ocean.

The Sri Lankan Meteorological Department started operating a new Doppler radar system in late August 2013, allowing it to detect changing weather patterns at least three hours earlier. However, it has been reported that the Meteorological Department still lacks the necessary manpower and technological know-how to meet the many of the forecasting and warning challenges posed by tropical cyclones (IRIN, 2013a).

Caribbean

Figure 3 shows a map of the Category 3, 4 and 5 hurricanes over the Caribbean between 1980 and 2009. Generally the Caribbean is well covered by cyclone early warnings systems. Recently new radars have been installed in Barbados, Belize, Guyana, and Trinidad and Tobago. Météo-France Martinique is creating a mosaic of the four new radars, together with the five that are already installed in French Guiana, Martinique, Guadeloupe, the Dominican Republic and Jamaica (WMO, 2011).

Figure 3 Category 3, 4 and 5 cyclone tracks over the Caribbean between 1980 and 2009



(Source: WMO, 2010c)

Between 1998 and 2008, Cuba was struck by more than 20 tropical storms, of which 14 became hurricanes. During this period, 11 million people were evacuated. Damage to infrastructure was considerable, with more than one million houses affected and estimated economic losses of US$18 billion, yet only 35 lives were lost (UNDP, 2011). The Cuban tropical cyclone early warning system has been cited by the WMO as an exemplar of good practice (WMO, 2010c). The UNDP together with the relevant Cuban stakeholders is in the process of assisting some other Caribbean states apply the lessons learnt relating to the dissemination and responsiveness to cyclone warnings in Cuba, taking into account the different socio-political circumstances that exist elsewhere in the Caribbean.

In the Caribbean all hurricane forecasts and warnings are available on public web sites (except for Turks and Caicos). Some are internally managed, others are hosted in other countries/territories (WMO, 2010c). However, it has been reported that there is a need to strengthen the access capacities (e.g. bandwidth) and possibly set up “mirror sites” to allow accessibility at any time during an event (WMO, 2010c). In the Caribbean real-time media (e.g. TV and radio) are considered to be the highest priority to disseminate warning information directly to the public. In some countries (e.g. Bahamas, Cuba), a meteorologist directly appears on TV or broadcasts live on radio in case of severe weather to deliver the important and credible information. Cuba has a system that allows the meteorological service to broadcast directly to the national TV channel (WMO, 2010c).

The Caribbean Catastrophe Risk Insurance Facility (CCRIF) is a parametric (index-based)[2] insurance scheme covering hurricane and earthquake risk. CCRIF is a risk pooling facility, for Caribbean governments. It is designed to limit the financial impact of catastrophic hurricanes and earthquakes by quickly providing short term liquidity when a policy is triggered (CCRIF, 2013). CCRIF offers members access to a Real Time Hazard and Impact Forecasting System (RTFS), which is a storm impact forecast tool, built on the core TAOS ('The Arbiter of Storms') modelling technology (see Watson, 1995). The RTFS provides countries with access to hazard and impact maps in Google Earth which show wind speed over terrain, wave height in open water, storm surge height and inundation along the coast, cumulative rainfall over the duration of the storm, and wind effects on vegetation, structures and electrical power (CCRIF, 2013). Through this platform, information is provided on expected impacts of storms/hurricanes on populations, land area, ports and airports.

Early warning systems for droughts

There are three general types of drought: meteorological; agricultural; and hydrological. A meteorological drought refers to a precipitation deficit over a period of time. An agricultural drought occurs when soil moisture is insufficient to support crops or livestock. A hydrological drought occurs when below-average water levels in reservoirs, rivers and groundwater, affect non-agricultural activities (e.g. water supply, energy production) (Wilhite and Buchanan-Smith, 2005; UNISDR, 2009). Early warning systems play an important role in drought risk management, and seasonal forecasts and climate models can inform decisions that reduce the humanitarian impacts.

In 2012 the UNDP carried out a consultation exercise with more than 400 people, (with 3,000 years of relevant collective experience), working in drought-related fields in Africa and Asia. In both regions there were found to be very few examples of systems for drought risk assessment and the dissemination of early warning being well established and highly regarded (UNDP, 2012). The UNDP found that it was institutions who were responsible for early warning systems who expressed "*most of the few positive views*" (UNDP, 2012). The UNDP states that the "*divergence between the producers and users of the monitoring information raises a question about the feasibility and practicality of the existing drought assessment and early warning systems and processes*" (UNDP, 2012).

Regional Climate Outlook Forums, that are active in several parts of the world, routinely provide real-time regional climate outlook products (WMO, 2013). The RCOFs are a key mechanism for developing and disseminating consensus in regional seasonal forecasts including droughts. They have been endorsed as a key activity in the WMO developing Global Framework for Climate Services (Graham et al., 2012). With regards to the SHEAR Programme the relevant RCOFs are:

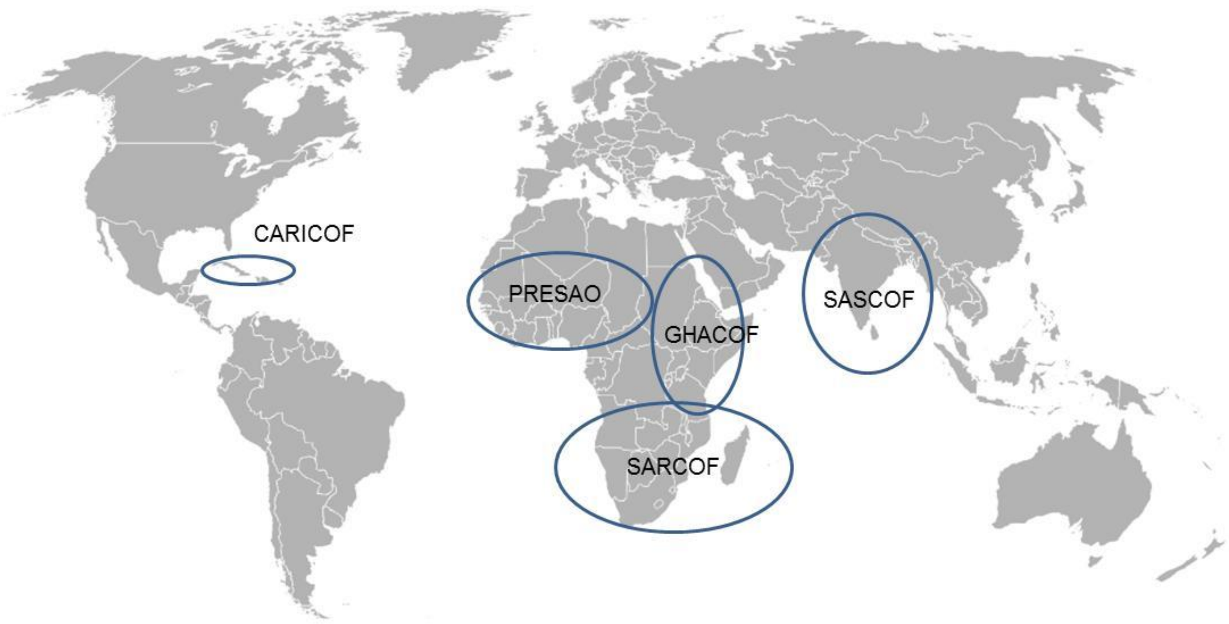
- **Greater Horn of Africa Climate Outlook Forum (GHACOF)** that covers Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Somalia, Tanzania and Uganda and is coordinated by the Inter-Governmental Authority on Development Climate Prediction and Application Centre, Nairobi, Kenya
- **Southern African Regional Climate Outlook Forum (SARCOF)** which covers the 14 countries comprising the Southern African Development Community (SADC) and is coordinated by the SADC Drought Monitoring Centre, Gaborone, Botswana
- **Climate Outlook Forum for West Africa (PRESAO: PRÉvisions Saisonnières en Afrique de l'Ouest)** which is coordinated by the African Centre of Meteorological Application for Development (ACMAD), Niamey, Niger

[2] Parametric or index-based insurance does not indemnify the actual loss, but makes a payment upon the occurrence of a triggering event (e.g. a drought or cyclone).

- **South Asian Climate Outlook Forum (SASCOF)** that includes Afghanistan, Bangladesh, Bhutan, India, Maldives, Myanmar, Nepal, Pakistan and Sri Lanka
- **Caribbean Climate Outlook Forum (CARICOF)** which is coordinated by the Caribbean Institute for Meteorology and Hydrology (CIMH) and covers Antigua, Bahamas, Barbados, Belize, Cayman Islands, Cuba, Dominica, Dominican Republic, Grenada, Guyana, Haiti, Jamaica, Montserrat, Panama, St. Vincent & Grenadines, St. Lucia, St. Kitts, Suriname and Trinidad & Tobago.

The coverage of the RCOFs is shown in Figure 4.

Figure 4 Regional Climate Outlook Forums (RCOFs) relevant to the SHEAR programme



There has been considerable progress made in measuring drought and the development of food insecurity early warning systems, particularly those that look a few weeks or months ahead, based on a more nuanced understanding of drought and better regional climatology (Shepherd, 2013). Initiatives such as the Famine Early Warning System Network (FEWSNET) have developed sophisticated indicator and alert approaches on a regional basis that link drought, food availability and food access. FEWSNET covers the following regions relevant to SHEAR:

- East Africa
- Southern Africa
- West Africa
- South Asia – Afghanistan
- The Caribbean – Haiti

(FEWSNET, 2013)

Africa

Nyabeze et al. (2011) carried out a gap analysis of drought monitoring and forecasting systems in Africa. They found that in southern Africa meteorological bulletins with average seasonal temperatures, accumulated precipitations for the season, Standardised

Precipitation Indices (SPIs), rainfall, moisture index, land use and elevation are produced. However, Nyabeze et al. (2012) found that drought early warning systems produce a limited number of indices at inappropriate scales, which means that there is a narrow range of possible users. For example, in South Africa, the SPI is produced; however, the spatial scale is too coarse for most users. There has been research carried looking at the suitability of continental scale hydrological models for drought forecasting (Trambauer et al., 2013).

Graham recently reported that monitoring systems in African countries are inadequate considering the variability of precipitation and river flows, sizes of catchments/aquifers and variability of geophysical conditions (Graham, 2012). Historical data are not readily available to users. There has also been a decline in the number of meteorological stations in Africa owing to high maintenance costs (Graham, 2012). The main challenges to monitoring of drought in Africa are as follows:

- Meteorological and hydrological data networks are often inadequate in terms of the density of stations for all major climate and water supply parameters. Data quality is also problematic because of missing data or a short length of record
- Data sharing is inadequate between government agencies and research institutions
- High costs limit the application of data in drought monitoring, preparedness, mitigation and response. Rainfall, temperature data and the derived parameters are costly, because the national meteorology agencies, which are public institutions, often charge high fees even if the data are required by education and research institutions

Various authors (e.g. Nyabeze, 2011, Nyabeze et al., 2011; Graham, 2010; Graham et al., 2012; Iglesias and Garrote, 2012, UNESCO-IHE, 2011; UNDP, 2012) have discussed the gaps in drought early warning systems for Africa. These can be summarised as:

- There is a need to improve the understanding and modelling of the African climate to provide more reliable seasonal early warning systems
- There is a need for predictions of the temporal distribution of seasonal rainfall: onset, cessation, in-season dry spells
- There are strong indications from stakeholders that the development of the ability to predict temporal distributions of rainfall (e.g. season onset, duration, and dry spell frequency) is the highest priority need for the agricultural sector
- Drought forecasts and warnings often do not penetrate to the most vulnerable and poorest members of society as illustrated by Box 1. Issues raised by the UNDP with regards to the dissemination of drought warnings include:
    - Lack of outreach to key stakeholders at the national and subnational levels
    - Poor interpretation and communication of forecasts
    - Forecasts that in their current form are not relevant enough to the needs and decision making timelines of stakeholders
    - Lack of trust in seasonal forecasts (UNDP, 2012)

It is also important to note that decision makers are often not comfortable with uncertainty and forecasts and require hard data before initiating a response (Save The Children and Oxfam, 2012).

Box 1 Drought forecasting in Ethiopia

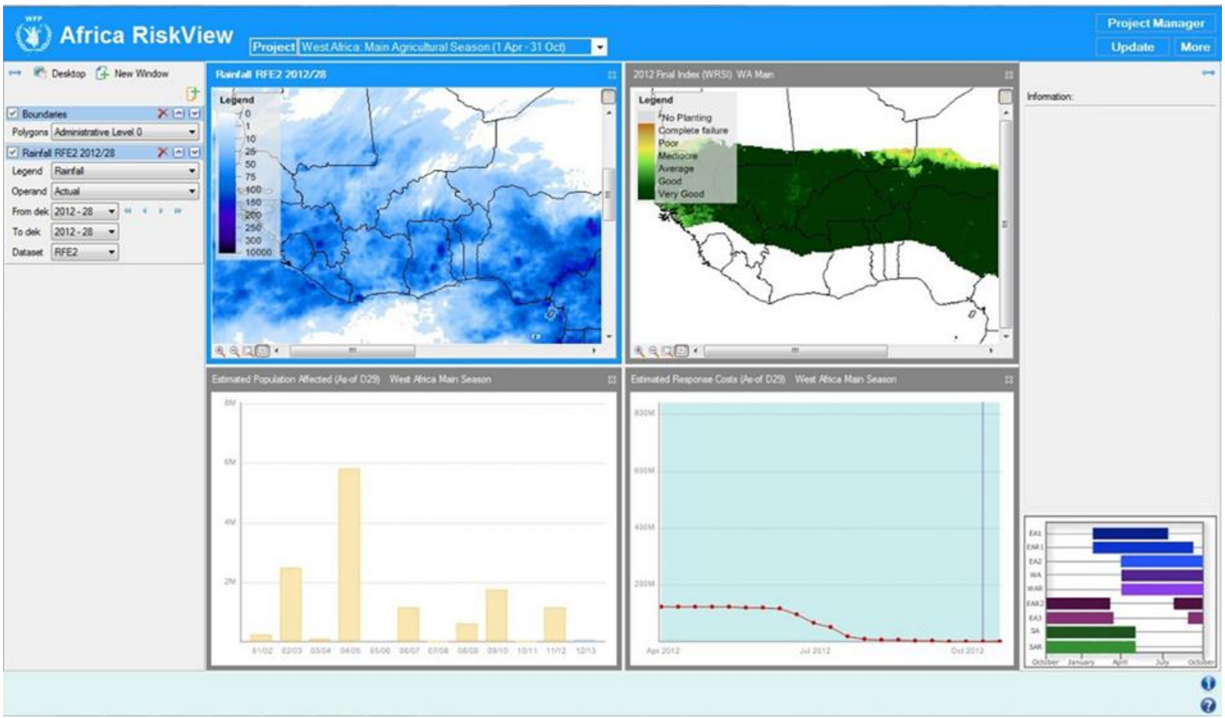
In Ethiopia it looks like there is a good, dependable early warning system and timely response; an efficient and comprehensive multi-million dollar risk transfer financing mechanism; a co-ordinated disaster risk management structure extending to local levels. However, inadequate focus on particular parts of the country where chronic drought and insecurity have presented significant challenges to effective disaster risk management. Assessments also suggest that there is a lack of focus on sustainable post-disaster recovery.

(Shepherd et al., 2013)

The African Risk Capacity (ARC) is a treaty-based organisation, recently established as a Specialised Agency of the African Union (AU). The ARC is designed to improve current responses to drought food security emergencies and to build capacity within AU member states to manage these risks. ARC is a specialised agency of the African Union to assist member states recover from natural disasters. Currently it is focused on droughts through an index based weather-related insurance mechanism that operates at a sovereign state level (ARC, 2013).

ARC has developed Africa RiskView, which is a software package that uses satellite-based rainfall data sets to quantify the impact of a severe drought and to trigger pay-outs to participating countries. Africa RiskView provides decision-makers with expected and probable maximum costs of drought-related responses before an agricultural season begins, and as the season progresses, at a nation-state level for every country in sub-Saharan Africa (ARC, 2013). An example of the outputs from the Africa RiskView system is shown in Figure 5. Africa RiskView provides one of the few examples in low-income countries of where the forecast of an event is linked to the risk i.e. an integrated approach between the forecast and the risk.

Figure 5 Example of an output from the Africa RiskView



(Source: ARC, 2012)

There are some examples of successful community-based warning systems. ACTED has been working in Karamoja, Uganda since 2009 on drought warning systems comprising indicators collected on a monthly basis by the community (ACTED, 2009). ACTED and the district authorities are currently building a systems of text and radio messages for wider dissemination of warning messages.

South Asia

Bangladesh

Drought forecasting is not as well developed as flood forecasting, despite the country experiencing 20 major droughts in the past 55 years (Monirul Qader Mirza, 2010). The Bangladesh Meteorological Department is responsible for drought forecasting; however, it does not have its own models. There has been some limited research on the “diagnosis” of drought in Bangladesh using the Standarised Precipitation Index (SPI) calculated at 27 locations over Bangladesh using historical rainfall data recorded between 1961 to 1990 (Rafiuddin et al., 2011). However, to forecast droughts traditional methods of weather forecasting, together with data from satellites such as National Oceanic and Atmospheric Administration (NOAA) are used (Hossain, 2004).

India

The India Meteorological Department generates the short (i.e. one to two days) and long range (monthly and seasonal scale) forecasts. The National Centre for Medium Range Weather Forecasting is responsible for the medium range predictions. The short and medium range forecasts are for weather (i.e. temperature, rainfall) over meteorological subdivisions of India. Long range forecasts are made for two or three sub-regions of the country based on a 16-parameter statistical model (Hossain, 2004). In 2012 it was announced that India was launching a US$75 million research project to forecast the onset of the south-west monsoon and droughts more accurately (BBC, 2012).

Nepal

Although western Nepal is vulnerable to droughts, there is no operational drought forecasting system for the country (Monirul Qader Mirza, 2010).

Pakistan

There are several organisations involved in monitoring drought related hydro-meteorological parameters in Pakistan including: the Pakistan Meteorological Department (PMD); the Water and Power Development Authority; the Provincial Drainage and Irrigation Authorities; and district governments. The PMD maintains a network of some 200 meteorological stations. In 2004 the PMD was planning to install another 350 meteorological stations to strengthen existing drought monitoring system (Ahmad et al., 2004). The PMD took an initiative to establish a National Drought/Environment monitoring and Early Warning Centre (NDMC) in 2004-05 after the drought of 1999 to 2001 in Pakistan. Its main objective is to monitor the drought situation in the country and issue advisories. Its national centre is in Islamabad.

Caribbean

Chen et al. (2005) noted that monitoring (agricultural) drought in the Caribbean was seen as a case of comparing monthly and annual rainfall totals to their respective averages and monitoring biological indicators in the field. In recent years, the Caribbean Institute for Meteorology and Hydrology (CIMH), with the assistance of a subset of the National Meteorological and Hydrological Services in the Caribbean, has been engaged in a comprehensive effort to establish a more structured, proactive and coordinated approach to monitoring and predicting drought across the Caribbean (Farrell et al., 2010).

The CIMH produces seasonal rainfall and temperature forecasts (Trotman, 2010). This is part of the Caribbean Drought and Precipitation Monitoring Network which helps to improve the prediction of droughts in the Caribbean. This initiative currently utilises two widely used meteorological drought indices: the Standardised Precipitation Index (SPI) (McKee et al., 1993) and Deciles (Gibbs and Maher, 1967). CIMH generates SPI and Deciles information over one, two, six and 12 month time scales (Farrell et al., 2010).

Farrell et al. (2010) state that the 2009-2010 drought in the Caribbean "*exposed yet another deficiency in the region, where national meteorological services, even though the information is available, lacks the capacity to, in some cases digest or other cases to divulge or adequately communicate information provided. It is critical that the region develops good forecasting capability as an important component of our region's adaptation strategy*" (Farrell et al., 2010). The Food and Agriculture Organization (FAO) has also reported that the impacts of drought on agriculture is generally not taken into account in disaster risk management plans in the Caribbean (FAO, 2013). CIMH provides drought notifications for most countries in the Caribbean and is currently finalising a system via which end users can receive drought forecasts via the internet and a mobile phone application.

Early warning systems for landslides

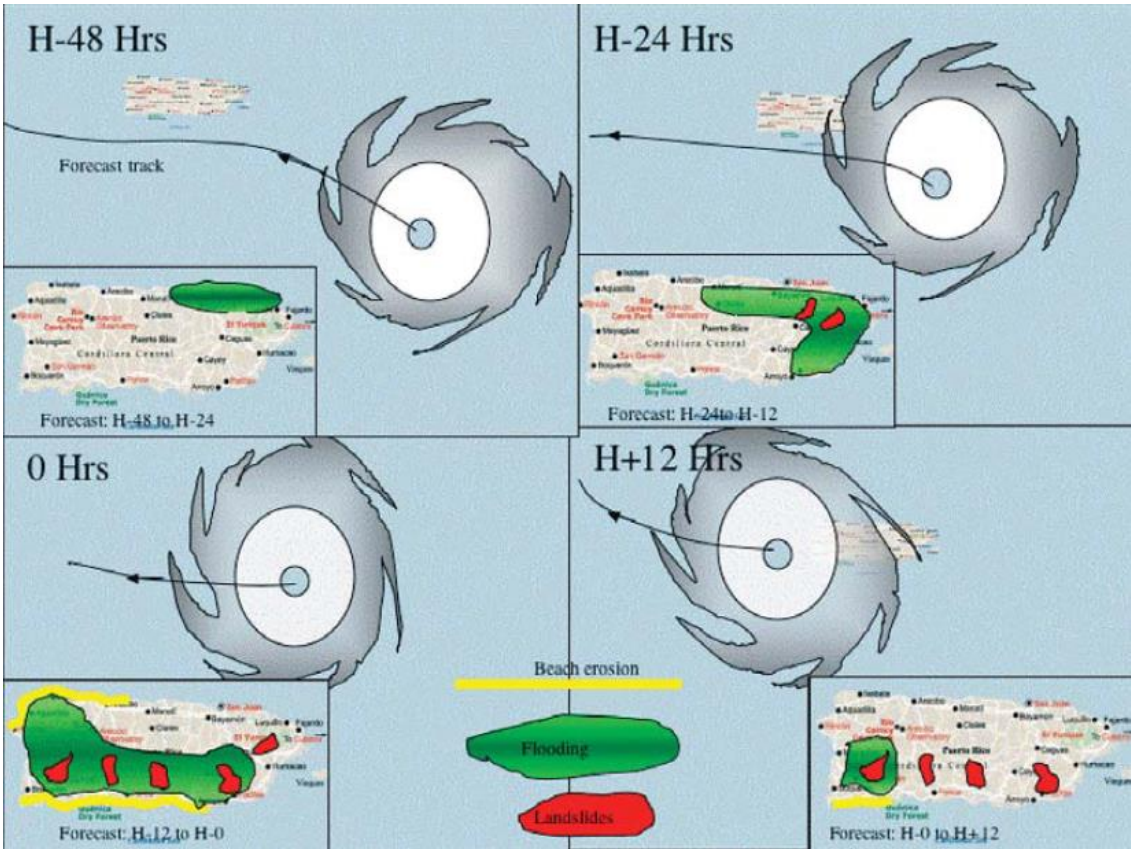
In order to forecast landslides and debris flows the following are required:

- Observations, generally from satellites or radar, to track and nowcast "dangerous" levels of precipitation
- Hydrological models to 'nowcast' hillslope runoff and changes in discharge in watercourses
- Landslide models to warn when and where landslides and debris flows are likely to occur, which require elevation, soils and geological data

Compared to cyclones, droughts and floods the amount of research that has been carried out for landslide early warning systems would appear to be relatively limited. Casagli et al. summarised 60 research projects around the world that have been carried out as part of the "International programme on landslides" (Casagli et al., 2008). Few of these research projects have been focused on early warning systems for landslides.

In the Caribbean some work has been carried out looking at the feasibility of developing and implementing a prototype warning system, specifically for the islands of Puerto Rico and Hispaniola (Negri et al., 2005). Figure 6 shows the overview of a conceptual diagram of this system. This system has been implemented in North Carolina in the USA (see Gourley, 2013); however, it is unclear how much progress has been made implementing this system in the Caribbean.

Figure 6 A conceptual diagram of a potential forecast-guidance product for flooding, landslides, and beach erosion, from 48 hours before to 12 hours after the event.



(Source: Negri et al, 2005)

In South-East Asia research is being carried out using satellite data and landslide susceptibility maps to forecast the initiation of landslides, based on meteorological forecasts and landslide monitoring measures (Kassa, 2010), but this remains at prototype stage.

Although, in the past decade, in Nepal landslides have resulted in the highest number of deaths of any natural hazard, there is no early warning system in place for them (IRIN, 2013b). A senior Nepali official has recently stated that landslides have a low priority because there is no government department with a clear mandate for them (IRIN, 2013b).

In Pakistan there have been some limited community-based landslide early warning systems implemented, but there are no systems at a regional scale. There would appear to be a need for a landslide forecasting system (see Nasser Mughal, 2011).

In India there has been research carried out recently to build an early warning systems for landslides. Research has been carried out using wireless monitoring systems for a site in Arunachal Pradesh (see Chandra, 2011). In parts of Tamil Nadu research into landslide early warning techniques using data mining techniques have been carried out (see Venkatesan et al., 2013); however, this system would appear to be at best at a prototype stage. Work carried out on landslide early warnings has been carried out at a local scale. There is need to have an early warning system that extends across the areas susceptible to landslides (ie NW Himalayas, E Himalayas and the NE states) (Geol. Survey of India, 2013).

There does not appear to be an operational early warning system for landslides anywhere in Africa.

SECTION 3

Risk assessments

Introduction

In the context of this document, risk has been defined as the combination of the probability of a natural hazard occurring and its potential adverse consequences for people. Hence, to assess the humanitarian risk posed by weather-related hazards it is necessary to have information about the probability and characteristics of the hazard, together with the vulnerability and exposure of the people affected. The terms “hazard” and “risk” are often, incorrectly, used synonymously.

One of the main drivers of risk in low-income countries is increasing exposure. In sub-Saharan Africa the loss of life from floods has increased consistently since 1980 because the rapid rise in exposure has not been accompanied by a commensurate decrease in vulnerability. Farmers and informal small and micro-enterprises occupy the bulk of the labour force in many parts of Asia and Africa (UNSDR, 2013). The people working in these sectors are often very vulnerable to weather-related hazards particularly in low-income countries. Wisner et al. also emphasise that the poor communities bear the brunt of the risk because of their exposure, or their inability to recover and that there is a need to encourage disaster responses that are community-based and development-oriented rather than relying on a ‘top-down’ approach (Wisner et al., 2005).

There have been success stories. For, example it has been estimated that the mortality risk associated with tropical cyclones in East Asia and the Pacific fell by 50% between 1980 and 2010 (UNISDR, 2011), despite the exposure increasing by 160% (UNISDR, 2013).

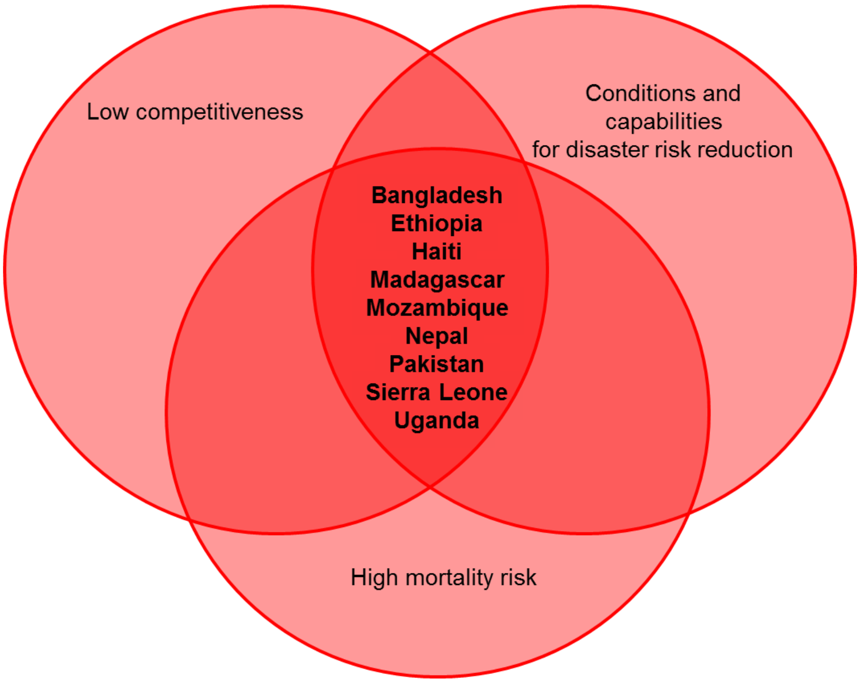
The recent UNISDR Global Assessment Report on Disaster Reduction reported that in terms of the risks posed by weather related hazards that:

- Direct losses are at least 50% higher than internationally reported figures.
- A new wave of urbanization is unfolding in hazard-exposed countries. In India the urban population is expected to grow from 379 million in 2010 to 606 million in 2030 and 875 million in 2050
- Six of the ten countries with the greatest assets at risk to cyclone wind damage are small island states
- Investors have often paid insufficient attention to growing hazard exposure and its threat to business resilience. Countries and cities competing to attract investment have often downplayed the risk posed by natural hazards

(UNISDR, 2013)

Figure 7 compares indices of mortality risk; competitiveness, and conditions and capabilities for disaster reduction. Figure 7 shows the countries in the regions covered by the SHEAR Programme that have not been successful in attracting investment, have low capacities to manage disaster risks and have high mortalities. The social cost of extensive risk are not accounted for by either governments or businesses and are largely absorbed by either governments or business and are largely absorbed by low-income communities, undermining their potential for development and eroding their resilience (UNISDR, 2013) .

Figure 7 Countries with high mortality risk, low competiveness and weak conditions and capabilities for risk reduction

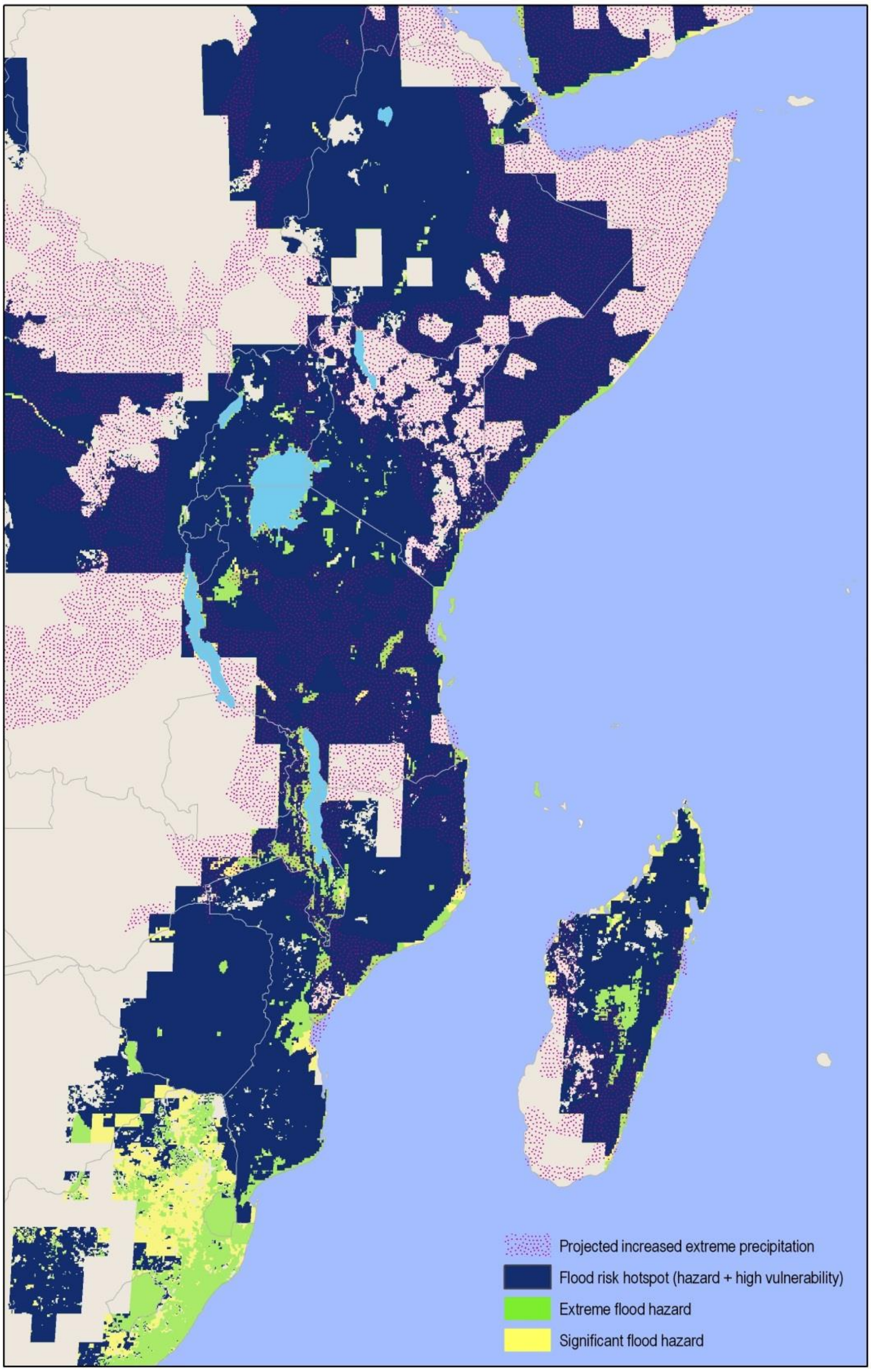


(Source: UNISDR, 2013)

There are have been a number of initiatives involved in mapping emerging trends and "risk" hotspots in low-income countries (see Care, 2013, Morjani et al., 2006). Care has carried out a study to identify the most likely humanitarian implications of climate change for the next 20 to 30 year period. Specific hazards associated with climate change, specifically floods, cyclones and droughts were mapped and placed in relation to factors influencing vulnerability. The results identified hotspots of high humanitarian "risk" under changing climatic conditions (Care, 2013). An example of a flood "risk" map for East Africa is shown in Figure 8. The results are these maps are provided via Care's web site; however, as Figure 8 illustrates the spatial scale at which the flood hazard is shown is coarse, as is the level at which the impacts of floods on people are assessed.

The availability, quality and maintenance of digital data are a major issue in low-income countries. The scale and quality at which input data are available defines the maximum scale of the output data and thus the scale at which hazard and risk information can be produced. This is the reason that the few pieces of risk modelling carried out for low-income countries are often carried out at a relatively coarse scale (e.g. regional or national levels).

Figure 8 Flood "risk" map of east Africa



(Source: Care, 2013; "Humanitarian Implications of Climate Change: Mapping Emerging Trends and Risk Hotspots" Copyright © 2009 CARE International. Used by permission.)

Flood risk assessments

Africa

In Africa risk identification is not effective owing to poor database management skills and lack of mapping skills (UNISDR, 2013b). In South Africa flood hazard maps have existed for most urban areas for the past two decades. However, few flood hazard maps exist for rural areas of South Africa mainly because adequate data are often unavailable (Els and van Niekerk, 2013). Even though South Africa is Africa's largest economy, Els and van Niekerk concluded that flood hazard modelling is challenging owing to limited topographic and hydrological data, meaning the mapping should only be considered for the prediction of the flood hazard parameters for "large scale purposes" (Els and van Niekerk, 2013). Satellite-derived flood hazard maps are often used by Non-Governmental Organisations and international agencies as flooding take place to provide an idea of the both the flood hazard and flood risk (for examples see OCHA, 2013a; 2013b). There are some examples (e.g. Mozambique) where national flood risk maps showing the number of people and schools affected by flooding have been produced (see GRIP, 2010) but they are based on limited data.

Hazard mapping is sometimes carried out following a disaster. For example, MapAction is a Non-Governmental Organisation that deploys fully trained volunteers to carry out humanitarian mapping for disasters. This creates a "shared operational picture" to help organisations make informed decisions and to deliver aid to the right place (MapAction, 2013). MapAction maintains a catalogue of maps of natural disasters that they have produced over the past 10 years.

In the next two years Africa Risk Capacity intends to produce flood hazard maps for different probabilities of flood events in sub-Saharan Africa; however, it is currently not clear as to whether these maps will be based on historical flood events (i.e. flood extents available from remote sensing), or based on the outputs of some form of modelling exercise that would be probably be reliant on existing inaccurate and coarse data sets.

There have been some community-based flood hazard mapping initiatives in Africa (for examples see Red Cross, 2004; Kienberger, 2007; Benjamin, 2011; EPA, 2012; Fabiyi et al., 2012). However, these rarely appear to be integrated with flood hazard mapping initiatives taking place at a regional or national scale.

To conclude flood hazard mapping for Africa would appear to be piece meal and flood risk mapping, where the exposure and vulnerability of people to flooding is taken into account has not been widely undertaken, and where it has it has been based on limited data.

The Caribbean

Flood hazard mapping in the Caribbean is highly variable. National flood hazard mapping has been carried out for Grenada; Guyana; Jamaica; Montserrat; St Lucia; St Vincent; Trinidad and Tobago (Cooper and Opadeyi, 2006; Lumbroso et al., 2011; Lyew-Ayee and Ahmad, 2010). However, the accuracy of the data available to produce these maps was often limited (e.g. maps are based on inaccurate topographic data). There have been other flood hazard mapping exercises carried out in, for example, Barbados (see Thomas, 2004). However, there would not appear to be any flood risk maps (i.e. maps that show economic damage or loss of life). There are some documents such as the Jamaica Risk Atlas (Lyew-Ayee and Ahmad, 2010) that provide information on exposures of people to a number of natural hazards including: fluvial and coastal floods; hurricanes; and landslides. Figure 9 shows national flood hazard mapping that has recently been completed for Montserrat.

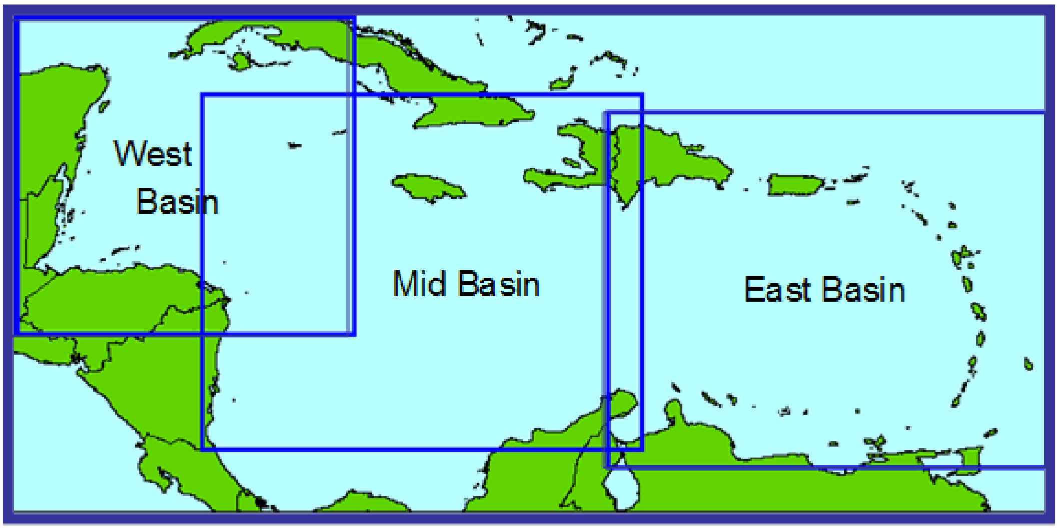
The World Bank has funded a Caribbean Risk Atlas that consisted of the following: Development of a hazard and risk assessment information platform; asset vulnerability identification and assessment; and education and awareness on results of risk assessment and risk reduction. The project covered floods, cyclones and earthquakes. However, the project has yielded case studies that only cover specific “risk hotspots” in Jamaica, Grenada, and Barbados. The project utilised GeoNode, which is an open source web-based platform for sharing geospatial data and maps funded by the World Bank (Geonode, 2013). However, the maps available on the GeoNode platform for the Caribbean currently appear to be very limited (see http://cariska.mona.uwi.edu/ for further details).

With respect to coastal flooding, as part of this Caribbean Disaster Mitigation Project, an atlas of probable storm effects in the Caribbean Sea was produced. This atlas provides estimates of storm surge levels for the 10, 25, 50 and 100 return period for a number of areas of the Caribbean (Caribbean Disaster Mitigation Project, 2000). The areas covered by this project are shown in Figure 10. However, again this study only covered the hazard not the risk posed by coastal flooding. The results of the project also do not appear to be widely available (Farrell, 2009).

Figure 9 National flood hazard map of Montserrat

(Source: Lumbroso et al, 2011)

Figure 10 Map showing the areas for which surge modelling has been carried out in the Caribbean



(Source: Caribbean Disaster Mitigation Project, 2000)

Recently the Caribbean Catastrophe Risk Insurance Facility (CCRIF) and Swiss Re have developed an excess rainfall index-based insurance product for the Caribbean, similar to its product for cyclones. The CCRIF establishes a member state's excess rainfall policy as follows:

- Applying historical rainfall data to an exposure database and using a vulnerability function, that maps loss percentage to rainfall amounts, to generate a historical risk profile (both event-specific and annual aggregate)
- The risk profile provides the necessary information for CCRIF/Swiss Re to price coverage
- Coverage characteristics, within limits, are selected by each country separately (CCRIF, 2012b)

The excess rainfall product is triggered independently of the current hurricane product (CCRIF, 2012b).

South Asia

A vulnerability atlas has been produced for India containing cyclone, flood and earthquake hazard maps for the country as a whole, and depicting the vulnerability of states to these hazards on a macro scale (Building Materials and Technology Promotion Council, 2006). It also includes a database based on the housing stock in India in 2001.

In Nepal there has been a comprehensive risk assessment carried out for all the natural hazards affecting the country. The project included the development of a synthesis report on Nepal's major hazard risks. This was carried out by reviewing the existing vulnerability and hazard reports, studies, analyses and assessments at the national and sub-national levels in conjunction with a detailed economic analysis using the loss probability modelling of Nepal's risks in conjunction with projected economic losses from forecasted hazards; and the mapping of high risk geographic regions (ADCP et al., 2012a, 2012b).

In Pakistan there has been flood hazard mapping carried out for most major rivers. For example Amarnath details recent exercises to map recent floods that have occurred in

Pakistan (e.g. the 2010 flood) using remote sensing data (Amarnath, 2013). There have also been exercises showing the areas of agricultural land inundated during historical floods. However, the appears to have been very limited risk modelling or assessment done for the country.

In Sri Lanka there has been some research using Synthetic Aperture Radar to produce flood hazard maps (see Kudahetty, 2012); however, the underlying topographic data are coarse and the maps produced do not appear to be used by the relevant authorities.

Cyclone risk assessments

Cyclone-risk hotspots include Mozambique and Madagascar, the Caribbean, Bangladesh, several parts of India and Sri Lanka. In order to estimate the cyclone risk the wind direction and speed together with the frequency and intensity of wind storms is required, as well as details of the vulnerability of the people and property likely to be affected.

Africa

Mozambique is one of the countries in Africa most severely affected by cyclones. There has been some work undertaken by government organisations to produce a risk map for cyclones at a national scale. Work on estimating the risk from cyclones in the rest of Africa would appear to be relatively limited.

The Caribbean

Data are essential to inform decisions aimed at reducing disaster risk. Unfortunately, geospatial data in Caribbean countries is not readily available, as it is stored by different ministries and agencies that separately manage and collect data in various forms. In the Caribbean:

- Meteorological Services are often not involved in the national risk assessment process
- Users' needs with regards to hazard analysis are not well known
- There is a need for strengthening the relationship among Meteorological Services, disaster risk reduction agencies and stakeholders through training and workshops on hazard analysis and risk assessment
- There is also a requirement for training on methods for hazard analysis including the identification of different danger thresholds which serve as basic criteria for 'watch' and warnings (WMO, 2010c)

The Caribbean Catastrophe Risk Insurance Facility (CCRIF) has been described in Section 2 of this report. The CCRIF offers parametric (index-based) insurance which disburses funds based on the occurrence of a pre-defined level of hazard and impact without having to wait for an on-site loss assessment. Payments are made on the basis of exceeding a pre-established trigger event loss (CCRIF, 2012c). This is estimated in a model in which hazard inputs (in this case wind speeds) are generated from independently-provided input data (e.g. a tropical cyclone track). The hazard levels are then applied to the pre-defined government exposure to produce a loss estimate (CCRIF, 2012c).

South Asia

AIR World Wide has recently developed a cyclone risk model for India (AIR World Wide, 2013). The model combines a cyclone hazard model with a high-resolution industry exposure database for India. This contains counts of all insurable commercial, residential, and industrial properties and their respective replacement values, along with information about occupancy and the physical characteristics of the structures, such as construction type and height classifications (AIR World Wide, 2012).

Separate wind and flood damage functions have been developed for a wide range of building types including complex industrial facilities. The model, which accounts for policy conditions specific to India, has been extensively validated against historical hazard and loss data and has undergone peer review (AIR World Wide, 2012).

Drought risk assessments

Drought-risk hotspots are mainly located in sub-Saharan Africa; South Asia, particularly Afghanistan, Pakistan and parts of India.

Africa

Kaiser et al. carried out a drought hazard assessment at a continental scale in Africa to identify and predict drought through the analysis of long-term trend in vegetation patterns and its relation with the El Niño/Southern Oscillation (Kaiser et al., 2003).

Rapid risk assessments are often carried in relation to droughts in relation to food security out. One example is the Tanzania Food Security Information Team that carried out a rapid vulnerability assessment in 2006/2007 with respect to food security in parts of (Nyabeze, 2011).

As discussed in Section 2 Africa Risk Capacity (ARC) has developed Africa RiskView (ARV) which provides a transparent method to model drought-related crop losses at nation-state level and the impact on populations' food security from droughts for sub-Saharan African. It translates the impact into equivalent financial terms to provide an estimate of financial drought risk and therefore to determine the appropriate amount of risk to transfer to the ARC risk pool. It also provides the means to manage an index-based insurance pool that can access the international risk markets and trigger early disbursements to countries (Nyirenda, and Goodman, 2013).

The Caribbean

There does not currently appear to be a credible drought risk model for the Caribbean i.e. that provides a measure of the impact on agricultural production or people's livelihoods.

South Asia

There has been some work done in South Asia modelling drought risk. The long-term agricultural and macro-economic impacts of droughts in Andhra Pradesh, India have been modelled with a range of drought risk management strategies. By analysing meteorological and agricultural data over 30 years, the effect of mild, moderate and severe droughts was measured on five different crops in the eight most drought-prone districts of Andhra Pradesh, including average annual and probable maximum losses (see Lvovsky et al., 2006). The frequency and severity of meteorological drought at different locations was modelled using historical data and a stochastic weather generator simulating 500 years of weather. Average yield and average annual losses for each crop for the 500 year time series were then computed, and the effect of drought intensity and duration on each crop converted to monetary losses based on market prices (Lvovsky et al., 2006).

Landslide risk assessments

Of the three regions covered by SHEAR the Caribbean is the one most affected by landslides. The geology and climate of the Caribbean contribute to the prevalence of landslides in the region. Increasing population density are among the major causes of landslides in the region due to changing land cover and disturbance of hill-slopes. Recent landslides in August 2012 claimed the lives of two people in Trinidad and Tobago (Gonzales 2012). Landslides in December 2012 and April 2013 caused extensive damage to roads and homes (Williams 2012; Williams 2013). The World Bank estimates that 40% of global economic losses due to landslides are experienced in the Caribbean, and Central and South America (Dilley et al. 2005).

Similar to flood maps, landslide hazard has been mapped in a piecemeal fashion for the Caribbean. Islands such as St Lucia, Jamaica have landslide hazard maps. There have been some community-based hazard assessment of landslides (see Box 2); however, there does not appear to have been any risk modelling of landslides where both the probability of the hazard and the impacts of people (either in terms of loss of life or impacts on their livelihoods) have been modelled.

In India a rapid assessments of the damage caused by landslides to buildings and agricultural land have been undertaken using high resolution images from Indian launched satellites (Martha and Vinod Kumar, 2013). In Nepal the risk of landslides has been assessed in a country wide assessment of natural hazards and their resulting risk (see ACDP, 2012a and 2012b for further details). A hazard map of landslides in Nepal is shown in Figure 11. In Pakistan there has been some limited mapping undertaken for landslides and some hazard mapping produced for some susceptible regions, but there does not appear to have been any modelling of landslide risk.

Box 2 Management of slope stability in communities (MoSSaiC) in Saint Lucia

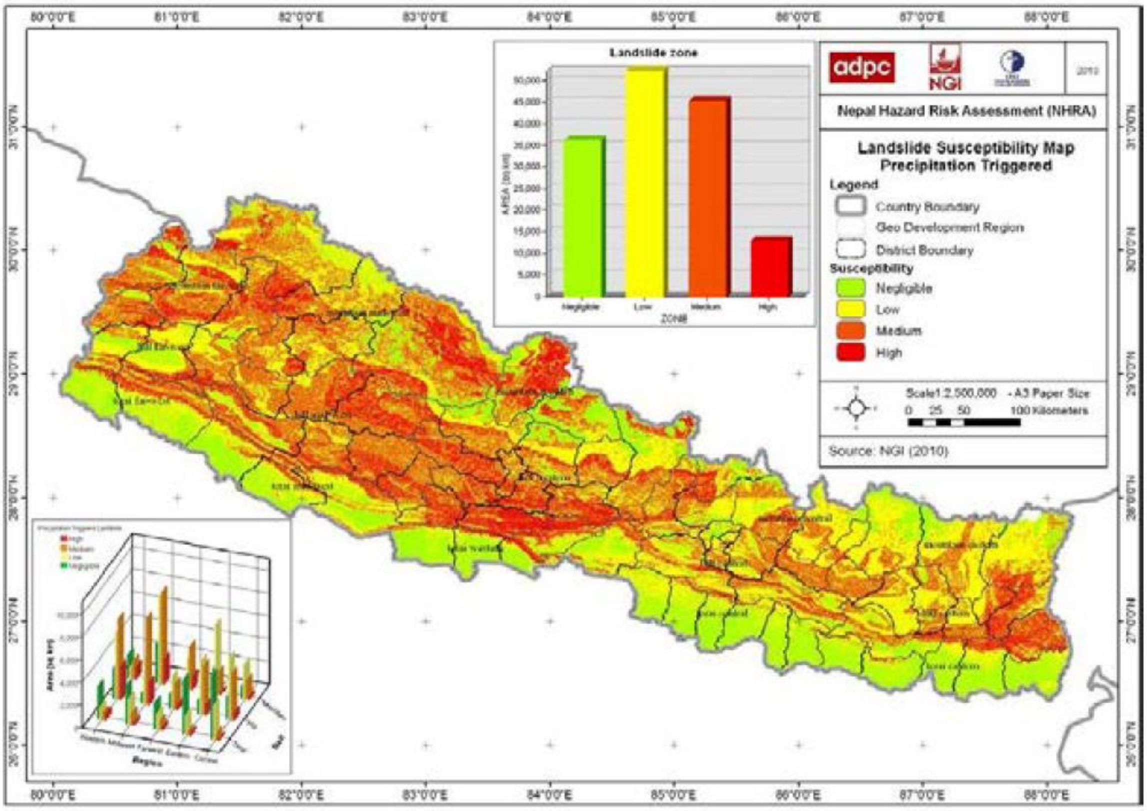
MoSSaiC is community-based project in which community residents are engaged in identifying landslide risk causes and solutions including:

- Identifying localized physical causes (often poor drainage) of landslide hazard
- Helping to assess appropriate mitigation measures that are designed to address the causes of landslides

Scientific methods are used to justify solutions.

(Source: World Bank, 2012)

Figure 11 Precipitation triggered landslide susceptibility map of Nepal



(Source: ADPC et al, 2012a)

SECTION 4

Conclusions

This report has provided an overview of available information on early warning systems and risk assessments for weather related risks in Africa, the Caribbean and South Asia. The findings suggest a very mixed picture with good examples and continued progress on early warning systems in parts of South Asia and the Caribbean but far less progress on national risk assessments and a lack of integration between warning systems and risk assessment tools.

The main findings on early warning systems based on the literature review were as follows:

- There are successful operational country-wide cyclone early warning systems in the Caribbean, Bangladesh and India. The success of these systems can be backed up with evidence showing a reduction in serious harm and loss of life. Cuba arguably has the best cyclone warning system in the Caribbean in terms of reducing loss of life, although it is also one of the countries with most disasters (based on CRED data for 1990-2013).
- There are reasonably good flood early warning systems in South Asia, including India, Pakistan and Bangladesh but these could be improved. It was recently reported that India's Central Water Commission funding for flood forecasting could increase five-fold over the next few years (Chaudhary, 2013).
- Progress on early warning systems is highly variable in African countries but some regional systems have been implemented. Examples include FEWS-NET and the Food and Security Nutrition Working Group (FSNWG), which both provided timely information on the food insecurity crisis in East Africa in 2010 and 2011, although there have been some criticism as to how warnings were disseminated (Ververs, 2012).
- There are some good examples of community-based early warning systems for floods and droughts in Africa and Asia but there can be difficulties scaling these up to larger areas. For example, Mozambique has a reasonably good flood warning system, Uganda has a good drought early warning system that covers the Karamoja sub-region and Nepal has a flood early warning system that covers five river basins (East Rapti, Narayani, West Rapti, Babai and Karnali).

The main findings on quantitative risk assessments for humanitarian purposes are that with a few exceptions they are rare owing to a lack of detailed data at a suitable scale.

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