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Information systems in a changing climate: Early warnings and drought risk management

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ABSTRACT

Drought is among the most damaging, and least understood, of all "natural" hazards. Although some droughts last a single season and affect only small areas, the instrumental and paleoclimate records show that droughts have sometimes continued for decades and have impacted millions of square kilometers in North America, West Africa, and East Asia. To cross the spectrum of potential drivers and impacts, drought information systems have multiple sub-systems which include an integrated risk assessment, communication and decision support system of which early warning is a central component and output. An early warning system is much more than a forecast – it is a linked risk information (including people's perception of risk) and communication system that actively engages communities involved in preparedness. There are numerous drought systems warning systems being implemented at different scales of governance. We draw on the lessons of over 21 drought early warning systems around the world, in both developing and developed countries and at regional, national and community levels. The successes illustrate that effective early warning depends upon a multi-sectoral and interdisciplinary collaboration among all concerned actors at each stage in the warning process from monitoring to response and evaluation. However, the links between the community-based approach and the national and global EWSs are relatively weak. Using the rich experience of information systems across the globe, this paper identifies pathways for knowledge management and action at the relevant scales for decision-making in response to a changing climate.

1. Introduction

Drought has long been recognized as falling into the category of incremental but long-term and cumulative environmental changes, and is also termed as a slow-onset or creeping event. Similar slow onset but rapid transition issues include: soil degradation and desertification processes, ecosystem changes and habitat fragmentation, nitrogen overloading, and coastal erosion, among others. Such creeping changes are often left unattended in their early stages. Eventually, neglected creeping changes can become urgent crises that are more costly to deal with since critical thresholds for reversibility have been exceeded (Glantz, 2004). Early warning systems (EWS) in such contexts are needed, not only for event onset at which a threshold is exceeded but also for intensification and duration ranging temporally from a season to decades and spatially from a few hundred km^2 to hundreds of thousands of km^2.

All dimensions of food, water and natural capital security are affected by climate extremes and variability and are likely to be affected by climate change (IPCC, 2007). While climate change is commonly presented as a gradual shift in climatic trends, its impacts will be most strongly felt by resource insecure populations through changes in the distribution, nature and magnitude of extreme events as these affect crops, disease outbreaks and soil and water quality (IPCC, 2012).

The United Nations International Strategy for Disaster Reduction (UNISDR, 2006) notes that early warning information systems must be people- and location-centered, integrating four elements – (i) knowledge of the risks faced; (ii) technical monitoring and warning service; (iii) dissemination of meaningful warnings to those at risk; and (iv) public awareness and preparedness to act. The authors of the survey go on to argue that failure in any one of these elements can mean failure of the whole early warning system. Although recent drought-related disasters have contributed to a sense of urgency, drought has not received commensurate attention within natural hazards research as have the direct and immediately visible impacts of hurricanes and floods. Most countries, regions and communities, currently manage drought risk through reactive, crisis-driven approaches (WMO, 2006; UNISDR, 2011).

The International Symposium on Integrated Drought Information Systems (ISIDIS) held in Casablanca, Morocco in November,

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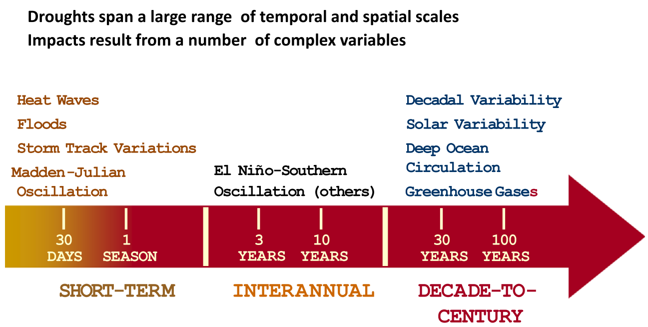

Fig. 1. Drivers of drought: a weather-climate continuum across climate timescale.

2011 brought together the experiences of over 19 early warning systems across the world (http://www.wmo.int/pages/prog/wcp/agm/meetings/isidis11).

This symposium was followed by several activities, which are ongoing, to assess and improve impacts assessment and information systems for responding to climate related risks under the Declaration of the High Level Meeting on National Drought Policy held in Geneva in March 2013 (Sivakumar et al., 2014) and in support of the Global Framework for Climate Services (GFCS) being implemented by the World Meteorological Organization (WMO). These risks span the weather to climate continuum with drivers crossing seasonal to decadal and longer timescales (Fig. 1). In this paper, we analyze these experiences using the framework of monitoring and forecasts, risks assessment and scenario generation, communication, and the extent to which information is embedded in responses and adaptation practices. In the following discussion, a drought information system represents an integrated risk assessment, communication and decision support system of which early warning is a central component and output. In turn, an early warning information system involves much more than development and dissemination of a forecast (i.e. an early “signal”); it is the systematic collection and analysis of relevant information about and coming from areas of impending risk that (a) informs the development of strategic responses to anticipate crises and crisis evolution; (b) provides capabilities for generating problem-specific risk assessments and scenarios and (c) effectively communicates options to critical actors for the purposes of decision-making, preparedness, and mitigation. One of the principal challenges for famine EWS is pinpointing when the crucial “tipping point” from livelihood crisis into emergency is likely to occur (Bailey, 2013).

2. Drought monitoring, prediction and indicators

Drought is among the most damaging and least understood of all “natural” hazards. Although some droughts last a single season and affect only small areas, the instrumental and paleoclimate records show that droughts have sometimes continued for decades and have impacted millions of km^2 in North America, West Africa, and East Asia. So memorable were the impacts of major drought events in regions such as the Great Plains of USA, Sub-Saharan Africa and the Northeast in Brazil that they are embedded in literature and cultural memory. In 1991–1992, parts of Africa suffered the worst dry-spell of the twentieth century when drought covered a region of 6.7 million km^2 and affected 24 million people. The combination of the above factors results in warning systems for drought being more complex than those for other hydro-meteorological hazards and are, consequently, relatively less developed globally.

Drought remains a hidden risk. Drought risk is not well-represented in multi-hazard risk mapping since it is difficult to calculate the drought risk in the same way as risks associated with other hazards (UNISDR, 2011). NOAA's National Weather Service (NWS) defines a drought as “a period of abnormally dry weather sufficiently prolonged for the lack of water to cause serious hydrologic imbalance in the affected area”. Although all types of droughts (meteorological, hydrological, agricultural, socio-economic) are initiated by an extended precipitation deficiency, it is insufficient solely to monitor precipitation to assess severity and resultant impacts. Effective drought monitoring systems integrate precipitation frequency and intensity and other climatic parameters with water information such as streamflow, snow pack, groundwater levels, reservoir and lake levels, water demands at different stages of crop growth, and soil moisture into a comprehensive assessment of current and future drought and water supply conditions (Svoboda et al., 2002).

There have been significant scientific advances in the last two decades in climate prediction from one to six months in advance to help decision-makers reduce risks associated with climate variability (Schubert et al., 2014). General Circulation Models (GCMs) and associated statistical ensemble methods are being routinely used to provide predictions of impending climate anomalies and offer promise for increasingly useful forecasts of the onset, severity and duration of drought for large geographic regions on monthly and seasonal timescales (Dai, 2010). Region-specific aridity has increased substantially in drought-prone areas, since the 1970s as evidenced by recent drying over Africa, southern Europe, East and South Asia, and eastern Australia. Although El Niño -Southern Oscillation (ENSO), tropical Atlantic SSTs, and Asian monsoons have played a large role in the recent drying, recent warming has increased atmospheric moisture demand.

An emerging need is a better understanding of the links between temperature and land surface feedbacks on drought intensification and how these affect components of the water budgets that influence soil moisture estimates (for agricultural drought monitoring), snowmelt runoff and discharge and groundwater-surface water interaction (for hydrological drought monitoring), and precipitation anomalies (for meteorological drought monitoring). These indicators are used to produce composite products based on other climate indices, numerical models and input of regional and local expert judgment. The classification schemes used for each indicator, and their relative limits and strengths are available from numerous sources (Heim, 2002; Dai, 2010). A comprehensive list of such indicators, such as the Standard Precipitation Index and Palmer Drought Severity Index, is available on the web sites of the National Oceanic and Atmospheric Administration (NOAA) (www.drought.gov) and the National Drought Mitigation Center (NDMC) (http://drought.unl.edu/). Additional indicators include the Palmer Crop Moisture Index, Keetch–Byram Drought Index, Fire Danger Index, and evaporation-related indicators such as relative humidity, temperature departures from normal, reservoir and lake levels, groundwater levels, surface soil moisture observations and snowpack. Some indicators are calculated at point locations and others at regional or climate divisions, drainage/hydrological basins, or other geographical units.

Change detection is critical in natural resources management (Ludwig et al., 1993). Since 1972, Landsat satellite data have been extensively used for environmental changes providing multiple, synoptic, global coverage of high-resolution having multi-spectral imagery allowing for change detection over time. Drought monitoring thus requires a comprehensive and integrated approach to determine the drought extent and impacts. Central to detection are the characterization, monitoring and understanding of land cover and land use change, since these have major impacts on sustainable land use, as well as land-atmosphere interactions affecting regional climate change (IGOS-P, 2011).We now turn to a summary assessment of existing drought information systems in which the above indicators are used. The list is not meant to be comprehensive but illustrative of major ongoing activities assessed during ISIDIS in Casablanca and subsequent workshops. These included the European Drought Observatory, the AGRHYMET (CILSS Regional Center for Agricultural Meteorology and Hydrology in Niamey, Niger) System and the Crisis Prevention Network which link Famine Early Warning Systems Network (FEWS Net), the UN System, and the US National Integrated Drought Information System (NIDIS).

3. International and national drought early warning systems: a brief survey

Risk assessment for early warning and risk management requires indicators that are internationally agreed and locally referenced. WMO provides global meteorological information, such as precipitation levels, cloudiness, and weather forecasts. The FAO's Global Information and Early Warning System on Food and Agriculture (GIEWS) and Humanitarian Early Warning Service (HEWS) by the World Food Programme (WFP) provide information on major droughts occurring globally. The FAO-GIEWS provides information on countries facing food insecurity through monthly briefing reports on crop and food prospects, including drought information, together with an interactive map of countries in crisis. Reports are not specifically focused on drought conditions and are released monthly or less frequently. The HEWS collects drought status information from several sources including FAO-GIEWS, WFP, and FEWS Net, and synthesizes this information into maps and supporting notes (from FAO-GIEWS) which is then provided, on a monthly basis, through the HEWS website (UNEP, 2006).

Drought early warning triggers multiple other warnings systems (such as for water resources, wildfire etc.) in a cascade of "early warnings" (Glantz, 2004). Regional and national experience and lessons are drawn from the 19 cases discussed at ISIDIS in Casablanca (2011) and elsewhere since then (Fig. 2). On a regional scale, the FEWS Net for Eastern Africa, Afghanistan, and Central America reports on current famine conditions, including droughts, by providing monthly bulletins that are accessible on the FEWS Net webpage. New efforts include the proposed development of a Global Drought Information System (Pozzi et al., 2013) that will produce global maps of monthly precipitation deficits.

The Southeast Asia Drought Monitor developed by the International Water Management Institute (IWMI), covers western India, Afghanistan and Pakistan. There is in general heavy reliance on remote sensing data and as such there are long-standing needs to improve in situ information such as meteorological and agricultural data.

The European Commission Joint Research Center (EC-JRC) provides publicly available drought-relevant information through the following real-time online maps: daily soil moisture maps of Europe; daily soil moisture anomaly maps of Europe; and daily maps of the forecasted top soil moisture development in Europe (seven-day trend).

Fig. 2. Case studies on assessing Drought Early Warning Systems in different parts of the world presented at the ISIDIS, Casablanca, Morocco, November 2011. Symbol courtesy: ian.umces.edu.

The WMO Regional Climate Outlook Fora (WMO RCOFS) which bring together national, regional and international experts review conditions and develop climate outlooks (http://www.wmo.int/pages/prog/wcp/wcasp/clips/outlooks/climate_forecasts.html) primarily based on ENSO forecasts and teleconnections. These fora are now central to implementing the GFCS. As ENSO conditions develop in a particular year, the WMO coordinates the development of a global scientific consensus, involving a collaborative process to review best available evidences and predictions. The outcome is the El Niño Update, a unified global statement on the expected evolution of ENSO for months ahead, which is issued to NMHSs and to the world at large (www.wmo.int/pages/prog/wcp/wcasp/enso_update_latest.html).

Many countries have developed drought early warning systems capable of integrating information from various sources and providing warnings of the imminent onset of drought in-country and across a region (Stone, 2011; Susnik, 2011; Galu, 2011). Efforts focused on drought early warnings continue in countries such as Brazil, China, Hungary, India, Nigeria, South Africa, and the United States. Regional drought monitoring activities exist or are also being developed in the Pacific Region, Southeastern Europe, Eastern and Southern Africa, West Asia and North Africa. In Africa, regional centers such as the IGAD Climate Prediction and Applications Centre (ICPAC) in Nairobi and the SADC Drought Monitoring Centre (DMC) in Gaborone, supported by WMO and regional Economic Commissions and the Sahara and Sahelian Observatory (OSS) provide current data, develop climate outlooks and issue warnings to NMHSs.

At the national level, there are several examples. In China, the Beijing Climate Center (BCC) of the China Meteorological Administration (CMA) monitors drought development. Based on precipitation and soil moisture monitoring from an agricultural meteorological station network and remote-sensing-based monitoring from CMA's National Satellite Meteorological Center, a drought report and a map on current drought conditions are produced daily and made available on their website. In Vietnam, drought forecasting and early warning is the responsibility of the "Short-term and Long-term Drought Forecasting Department", within the National Institute of Hydrometeorology. At the state level in India, the drought management system follows a uniform approach throughout the country, though a few exceptions exist (Prabhakar and Shaw, 2007). The states have established a drought early warning system, under the Weather Watch Group. The Karnataka state has established a special Drought Monitoring Center. The center monitors rainfall, water-reservoir levels and other relevant parameters on daily basis in the rainy season improving the capacity of the state in terms of analyzing the weather information (Prabhakar and Shaw, 2007).

In the USA, the Federal Government's National Integrated Drought Information System (NIDIS) and the University of Nebraska-based National Drought Mitigation Center (NDMC) jointly support or conduct impacts assessment, forecast improvements, indicators and management triggers and the development of watershed scale information portals (web-based). In partnership with other agencies, tribes and states, the NIDIS teams coordinate and develop capacity to prototype and then implement regional drought early warning information systems using the information portals and other sources of local drought knowledge. The U.S. Drought Monitor, an innovative partnership among academia and Federal agencies (Svoboda et al., 2002), provides information on the current conditions of drought at the national and state level through an interactive map available on the website accompanied by a narrative on current drought impacts and a brief description of forecasts for the following week. It has a unique approach that integrates multiple drought indicators with field information and expert input, and provides information through a single easy-to-read map of current drought conditions and notes on drought forecast conditions across the nation. The US Drought Monitor and its offshoot, the North American Drought Monitor (Svoboda et al., 2002), are central to NIDIS.

Some innovative approaches to creating integrated indicators from available climate and socio-economic datasets are being undertaken. These include for example, delineation of global patterns and impacts of droughts through the mapping of several drought-related characteristics – either at a country level or at regular grid scales. These maps are produced by integrating a number of publicly available global datasets (Eriyagam et al., 2009). Other relevant mapping projects are carried out primarily by a few international organizations/projects, although they are not normally focusing on droughts per se. UNEP's World Atlas of Desertification shows the global extent and severity of desertification (Middleton, 1997; UNEP, 1992).

Major parts of the world which face recurring severe droughts, still do not have comprehensive information and early warning systems in place (such as in western and southern Africa, parts of India, and South America, the Mediterranean Basin, among others). Some of the most promising investment opportunities lie in empowering vulnerable communities with EWI and the capacity to act. This is particularly urgent in national contexts of low government capacity or where communities are politically marginalized. Beyond capacity building, governments can create enabling environments for community-based early action by ensuring that public policies support the response strategies of vulnerable groups, and work with early warnings providers and agencies to increase community access to official EWI in an appropriate form.

One example is a community-based drought EWS operated in the Garba Tulla district of northern Kenya by the Garba Tulla. In some areas, farmers have identified local language radio programs as credible and accessible mechanisms to deliver forecasts if they occur together with follow up meetings with extension agents or other intermediaries (Pulwarty, 2007). This latter point of following-up is important. In northern Uganda, through the Rapid SMS Community Vulnerability Surveillance Project initiated by UNICEF and ACTED, communities at risk have been provided with mobile phones with which they can relay data to a monitoring centre (Bailey, 2013). Traditional forecasting remains an important source of climate information in many rural communities. There is growing appreciation that traditional observations and outlook methods may have scientific validity and increased interest in harmonizing traditional and modern scientific methods of climate prediction. Studies have been initiated in some countries, such as Zimbabwe and Kenya, to gain further understanding of traditional forecasting.

4. Value of early warning systems

Hallegatte (2012) estimates that potential benefits from upgrading the hydro-meteorological information production and early warning capacity in all developing countries to developed-country standards would result in (a) avoidable asset losses of between USD 300 million and 2 billion per year due to natural hazards, (b) saving lives on an average of 23,000 per year, which is valued between USD 700 million and 3.5 billion per year using the Copenhagen Consensus guidelines; and (3) additional economic benefits of between USD 3 billion and 30 billion per year. The total benefits would reach between USD 4 billion and 36 billion per year with benefit-cost ratios between 4 and 35 with co-benefits. However, even these significant economic benefits are not commensurate with actions or even provided the impetus for securing sustained action.

The examples from the ISIDIS in Casablanca and elsewhere illustrate that effective early warning depends upon a multi-sectoral and interdisciplinary collaboration among all concerned actors at each stage in the warning process from monitoring to response (Glantz, 2004; Pulwarty and Verdin, 2013).

These cases have demonstrated that social protection and early warning information interventions can provide disaster risk reduction while helping to meet the goals of adaptation to changes in extreme events (Stone, 2011; Pulwarty, 2011; Bailey, 2013). Due to the complex nature of droughts, a comprehensive and integrated approach that would consider numerous drought indicators is required for drought monitoring and early warning (Hayes et al., 2005). Location-specific environmental changes (i.e. ecosystems changes, loss of biodiversity and habitats, land cover/land changes, coastal erosion, urban growth etc) become critical. Adaptive actions are adjustments in assets, livelihoods, behaviors, technologies and polices that address ongoing and future climates variability and change (IPCC, 2012). Drought information systems are an important tool in a governments and community's portfolio to achieve adaptation as an output of sustainable practices.

In most locations early warning is still treated as a linear process. There are multiple factors that limit current drought EWS capabilities and the application of data in drought preparedness, mitigation, and response globally (Wilhite et al., 2000). These include: inadequate density and data quality of meteorological and hydrological data and the lack of data networks on all major climate and water supply parameters; inadequate data sharing between government agencies and the high cost of data; and inadequate indices for detecting the early onset and end of drought, although the Standardized Precipitation Index (SPI) has been cited as an important monitoring tool. Other issues of concern include the lack of specificity of information provided by forecasts, especially during non-ENSO years which limit the use of this information by farmers and others, and the fact that early warning system data and information products are often not user accessible and users are often not trained in the application of this information for decision making (Pulwarty, 2007).

The links between the community-based approach and the national and global EWSs are relatively weak (Birkmann et al., 2011; Pulwarty and Verdin, 2013). Monnik (2000) noted, some years ago, that the central constraints on implementation include:

- Lack of a national and regional drought policy framework;
- lack of coordination between institutions that provide different types of drought early warnings;
- lack of social indicators to form part of a comprehensive early warning system; and
- lack of efforts in strengthening, testing and evaluating EWS across spatial and temporal scales.

Within operational environments critical limiting factors include:

- Quality/pedigree of information available to decision-makers at all levels;
- factors that influence whether or not information will be used;
- factors which determine whether risk communications can be trusted; and
- limited governance structures that facilitate better decision-making practice including adapting the decision-support systems to the different levels of decision makers.

Reasons for this situation include the complexity of decision making processes; the diversity of responses across regions; monitoring gaps and uncertainty about climate changes at local scales; time lags in implementation; and economic, institutional and cultural barriers to change. In turn, these agencies must understand the concerns of industry, user groups, state and local governments, and the public at large.

5. From forecasts to information systems: reframing early warning in support of adaptation

The experience of NIDIS, FEWSNet and other information systems discussed in the ISIDIS in Casablanca illustrate that early warning represents a proactive political process whereby networks of organizations conduct collaborative analyses. In this context, indicators help to identify when and where policy interventions are most needed and historical and institutional analyses help to identify the processes and entry points that need to be understood if vulnerability is to be reduced. Taking local knowledge and practices into account promotes mutual trust, acceptability, common understanding, and the community's sense of ownership and self-confidence.

The key, integrated recommendations coming out of the ISIDIS and the HMNDP, include the following.

5.1. Assessing and communicating the multi-sectoral and diverse nature of drought impacts

Given a changing climate and the climate variations across months, to seasons to decades, it is critical to acknowledge the importance of cross-scale nature of climate, early warning information and adaptation response, and the corresponding monitoring and research needs. Decadal prediction lies between initialized weather or ENSO forecasts and future climate change projections – not just “extremes” or “trends”.

Much more work is needed to show the value of existing observations to improve impact assessments and warnings. The lack of specificity of reliable information provided by forecasts, especially during non-ENSO years and projections limit the use of this information by farmers and others (accuracy vs. precision). There is an ongoing need to include associated/additional information of direct relevance to users such as soil moisture levels, relationships with fire danger levels, hydrological impacts, etc. as may have been identified. There is a need to include information on important production impacts where appropriate e.g. include crop/pasture simulation outputs, dam levels (important for irrigation), information from experts “in the field” such as cattle stocking numbers, etc. To this end a formal information pedigree should be developed that is relevant, authoritative, accessible, and user compatible/usable. This would include:

- Definition of the core set of data characteristics and information technologies needed to maintain the minimum acceptable level of stewardship;
- placing multiple indicators within a statistically consistent triggering framework and scenario planning to address problem-definition and characterize multiple uncertainties, both technical and institutional capacity;
- inventory and map available local resource capabilities (infrastructure, personnel, and government/donor/NGO-supported services) to complement food, water and other program operations;
- developing risk and vulnerability profiles of drought-prone regions and locales including the impacts of the benefits of early warning; and
- understanding and communicating the economic value and societal benefits of early warning information.

5.2. Governance and knowledge management: improving policy coherence and adaptive management at each scale

It has long been noted that national governments, providers of early warnings and agencies should develop or improve present approaches to increase community access to official early warning information and tailor it to their specific needs, and to identify policies and practices that impede or enable the flow of information among information system components (Birkmann et al., 2011).

As important as indicators are to such systems, essentially it is the governance context in which EWSs are embedded which determines the effectiveness of practices and whether it is viable to make preparedness a mandatory part of any longer term programme. For people-centered strategies at the so-called last mile, a mixed portfolio of centralized and decentralized activities is required.

The UNISDR Global Assessment Report (UNISDR, 2011) highlighted two key dimensions of Climate Risk Management (CRM) governance:

- Accountability: CRM needs to be located in a ministry or department, preferably with planning oversight and some fiscal responsibility to provide political authority and policy coherence across sectors. Emergency management organizations can rarely play that role.
- Efficiency: only occurs when CRM is carried out locally in partnership with at-risk households and communities and organizations that represent them. Benefits are cost-effectiveness, sustainability, citizenship and social cohesion.

More recently it has become necessary to frame the goals and objectives of international and country and local-level program intervention strategies in terms of “securities” of water, food, energy. In specific cases, agencies optimize preparedness by maintaining levels of operational redundancy. For example, the World Food Programme's Forward Purchase Facility allowed it to pre-position a supply line to the Sahel 6 months before the peak of the 2012 crisis. Appropriate redundancy measures also include ongoing operational presence and greater staff continuity in areas at risk. However redundancy is viewed as “slack” in the system, which many countries and individuals view as sustaining inefficiencies. Levine et al. (2011) note that agencies should develop “early action platforms”, building short-term emergency capacities into long-term development and social protection programmes which can adapt and scale up in response to early warning signals. Agencies with separate development and adaptation divisions should develop plans to more closely integrate the two.

Leadership is required, and in many cases exists or arises out of crisis but these “policy entrepreneurs” need to be recognized and supported at several levels. Specifically, leadership is needed to bring about systemic reforms and to ensure operational direction for early action at each level (Bailey, 2013). This is especially so where inaction can be a rational strategy for governments if at-risk populations are politically unimportant or uncertainty is used as dodge to avoid difficult or contentious problems. A critical component of leadership is to ensure that lessons are not just identified but are indeed “learnt”. This includes authorizing and undertaking regular and credible preparedness audits to maintain optimal alertness (White, 1986; Healy and Ascher, 1995; Levine et al., 2011) and answering questions such as “Given better data and information coordination, would responses have been improved for past events?”

5.3. Windows of opportunity and doors of perception: overcoming constraints on using EWS to inform long-term risk reduction

Central to the deliberations in ISIDIS was to understand how the systems discussed operated prior to, and during, actual contingencies. Significant events, such as US Drought of 2011 (and 2012) or Horn of Africa Drought, that attract the attention of the public and leadership, have been identified as offering "windows of opportunity" for including long term risk reduction plans, such as for climate change adaptation. A policy window opens when the opportunity arises to change policy direction and is thus an important part of agenda setting (Kingdon, 1995). The assumptions behind the utility of policy windows are that (1) new awareness of risks after a disaster leads to broad consensus, (2) development and humanitarian agencies are "reminded" of disaster risks, and (3) enhanced political will and resources become available. However, during the post-recovery phase, reconstruction or rehabilitation require weighing, prioritizing and sequencing of policy programming. Multiple mainstreaming agendas can be too many for most decision-makers and operational actors to digest, with attendant lobbying for resources for various actions, and there is the pressure to quickly return to conditions prior to the event rather than incorporate longer term development policies (Christoplos, 2006). In addition, while institutions clearly matter, they are often simply not there in the aftermath (or even before occurrence) of a disaster. As shown in diverse contexts such as ENSO-related impacts in Latin America, induced development below dams or levees in the USA, and flooding in the UK, the end result is that short-term risk reduction can actually produce greater vulnerability to future events (Pulwarty et al., 2003; Berube and Katz, 2005; Penning-Rowsell et al., 2006). The idea that cumulative reduction of smaller scale risks, through emergency response based on short-term early warning or only low thresholds of exceedences, increases vulnerability to large events has been referred to as the "lessening hypothesis" (Bowden et al., 1981).

Evaluations of food crisis responses in the Horn of Africa have shown that agencies respond late for the most part, e.g., delivering fodder when pastures were recovering or distributing seeds after rains have passed (Ververs, 2012). The international system faced similar challenges in the lead-up to the 2011 Somalian famine (Galu, 2011; Fig. 3). In this case, there was a strong and clear signal from early warnings providers about the deteriorating situation and the likelihood of famine; however, donors and agencies were not responsive. Both the appeal response and its financial support were not increased until famine was declared. Despite the early warnings, many humanitarian actors doubted that the situation would be significantly worse than a normal "dry" year (Ververs, 2012). The primary explanation for this delay was the simple failure among agencies to design their responses according to when particular interventions are appropriate and whether they can be delivered in time especially when key household, community and national decisions are being made.

5.4. Mapping the last mile: linking early warning with early response means linking the crisis calendar to the decision calendar

Despite the huge investment that has been made to improve early warning, too often humanitarian assistance continues to arrive late in pastoral areas or is responding to the wrong signal. Aid has been able to prevent humanitarian crises, but it is difficult to find examples where a large-scale use of humanitarian aid based on early warnings has prevented a livelihood crisis, e.g. leaving pastoralists with their assets intact (Levine et al., 2011).

Developing response plans based on crisis calendars is tied to decision calendars (Pulwarty and Melis, 2001), which identify when during the timeline of a crisis particular interventions in the context of monthly and seasonal decisions are appropriate and whether they can be delivered in time. This approach sets out the expected timeline of a crisis by plotting the seasonal calendar together with the livelihood and coping strategies people usually undertake, and the alternatives available given present and forecast climate conditions. Specifically, the strategy of linking the crisis calendar to the decision calendar will identify windows of opportunity concerning the level of both preparedness and reserves, and the potential confounding factors such as when particular interventions are needed or when barriers may occur in the efforts to protect livelihoods and avoid destructive coping strategies (Levine et al., 2011; Pulwarty and Melis, 2001). Levine et al. (2011) found that lead times for interventions for agencies operating in the Horn of Africa could potentially be shortened from periods of three to five months to a few days or weeks, simply by analyzing the tasks involved in starting up a response and identifying those that could be done in advance (Bailey, 2013).

Overcoming impediments to information flow has been characterized by the Consultative Group on International Agricultural Research (Hall et al., 2001), NIDIS (2007) and others as addressing or making explicit existing barriers to cross-agency collaboration, allowing innovations and new information to be introduced and tested, and clarifying, for all partners, the benefits of participation in design, implementation and maintenance.

NIDIS has approached these dimensions by creating an enabling environment (for national and local governments), sustaining a collaborative framework among research, monitoring and management and promoting community-based early action through policies and regulations which support the response strategies of vulnerable groups. The NIDIS "touch" is to:

- Identify appropriate partners and representatives;
- set goals and priorities – problem definitions with it's partners on the ground and at local and national government levels;
- use professionals from relevant agencies/communities etc. to build common ground;
- produce collectively authored gaps assessments for monitoring, forecasting and impacts-agreement on the way forward;
- build longer term collaborative partnerships that allow queries on information of provided; and
- determine trade-offs and characterization: decision quality based on precise technological information versus decision acceptability based on the procedural needs for effective participation.

Broad societal processes that create dynamic pressures and unsafe conditions are not easy to change, yet are fundamental to human vulnerability. Adaptation involves not only using facilities to cope with the immediate problems but also leaving slack or reserve for coping with conjunctive risks and/or future problems (IPCC, 2012). Levine et al. (2011) and others note, for instance, that it is much cheaper to use support to the market to help people to buy food compared to feeding them. Traditional assumptions are that effective functioning of early warning systems requires: first, prior knowledge of risks faced by communities and other users of the early warning information; second, a technical monitoring and warning service for these risks; third, an effective strategy for dissemination of understandable warnings to those at risk; and finally, knowledge and preparedness to act (Traore and Rogers, 2006; Dekens, 2007).

In the context of a changing environment, meeting the most critical emergent needs require that:

- Disasters should be seen as risks to investments in "capitals" including human capital. Faster rates of change of both the climate, including heat stress and evaporative demand, and the development systems may drive surprises and rapid transitions in which early warnings of emerging thresholds will be increasingly critical;
- impact assessment and scenario development must approach climate model output far more critically than at present. There

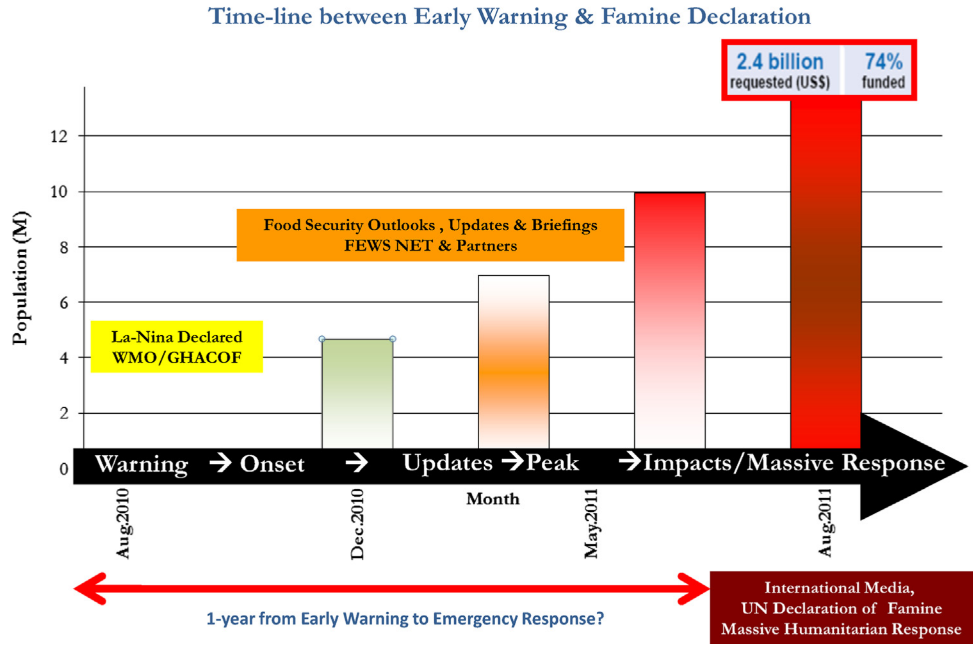

Fig. 3. Genesis of Horn of Africa Drought Crisis 2010/2011 (Galu, 2011).

is no substitute for local monitoring and local communities must be supported in data and surveillance gathering;

- there is the ongoing need to take on the institutional aspects of “capacity” and “coordination” at national and local levels much more directly than is being done. This gap exposes itself vividly when the needed sustained collaborative framework among research, monitoring and decision-making/management to take advantage of windows of opportunity do not exist; and
- central to the above factors is the development, support, and training of a cadre of professionals and policy entrepreneurs who view the role of linking science, policy and practices as a core goal and the systems that support their activities over the long term.

Comparing the window(s) of opportunity for a particular intervention with its lead time allows identification of whether an intervention can be delivered on time and whether the consequences of interventions can be prefigured (Levine et al., 2011; Galu, 2011). All interventions have appropriate windows of opportunity which are determined by the “crisis calendar” (stages of drought) and effective response. Realizing the benefits of warnings requires investments in community-based capacity, international monitoring, prediction and mapping and moving these capabilities to seasonal and long-term decision calendar for communities, businesses and people.

6. Conclusions

Drought is recognized as a slow-onset or creeping event. Although recent drought-related disasters have contributed to a sense of urgency, drought has not received commensurate attention within natural hazards research like those events such as hurricanes and floods which have the direct and immediately visible impacts. Most countries, regions and communities, currently manage drought risk through reactive, crisis-driven approaches. In a pro-active approach, early warning systems are important as they are central to integrated risk assessment, communication and decision support system of the drought information systems. A brief survey of the international and national drought early warning systems presented in this paper shows that effective early warning depends upon a multi-sectoral and interdisciplinary collaboration among all concerned actors at each stage in the warning process from monitoring to response and evaluation. However, the links between the community-based approach and the national and global EWSs are relatively weak. This paper identified pathways for knowledge management and action at the relevant scales for decision-making in response to a changing climate.

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