INPUT PAPER

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FLOOD EARLY WARNING IN PRACTICE: LESSONS LEARNED FROM A COMPARATIVE ANALYSIS

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1. Introduction

At the edge of the end of the Hyogo Framework for Action (HFA) era, the United Nations Office for Disaster Risk Reduction (UNISDR) has started since 2012 a global consultation to gather inputs to develop the structure and content of the HFA successor (so called HFA +). This background input paper for the Research Area 4 of the 2015 edition of the Global Assessment Report (GAR) on DRR intends to contribute to this consultation process, exploring a main area for reducing disaster risk: Early Warning Systems (EWS) for floods risk.

Modern flood risk management acknowledges that floods cannot be stopped from occurring and places emphasis on how to reduce the vulnerability of risk prone communities. It considers that flood protection infrastructures are needed, but not sufficient to reduce the risk. Residual risk will remain and has to be managed through enhanced preparedness capacity and increased response time to act. A EWS is typically designed to augment the response time during a flood event. When warnings are issued before a flood, additional time (lead time) is created to take action and save lives and properties. The larger the lead time, the more available time to take action, but also the lower probability for a correct forecast. A balance, thus, has to be found between the needed time and the expected accuracy. To use the additional time effectively, the actions to be taken have to be planned in advance (preparedness).

A EWS adds value to strengthen preventive flood risk actions, namely to:

1) increase the response capabilities of the authorities and population for flash floods
2) plan emergency and risk communication procedures
3) strengthen the institutional capacity in order to operate an EWS and communicate the warnings.

Evidence that EWS have had a key role in reducing vulnerability is mounting (Golnaraghi, 2012). The 2011 edition of the GAR showed that since the 1990s the vulnerability to mortality risk due to floods and tropical cyclones has decreased at the global level (in aggregate terms). Countries in Asia-Pacific are driving these positive results (UNISDR, 2011). However, regional differences persist, and exposure to floods and tropical cyclone is increasing in all regions, offsetting the effects of vulnerability reduction appreciated by the GAR.

From an economic perspective, the 2011 GAR and other authors (Teisberg and Weiher, 2009) commented how EWS's have generally proved to be effective investments that outstrip their costs in economic returns. Teisberg and Weiher (2009) concluded that 40 USD was saved for every dollar invested in the regional forecasting and warning system. In Belgium, having substantial flood protection, and thus a lower residual damage, unpublished work has estimated that 5-10 Euro was saved for each Euro invested in managing of residual risk, including an EWS. However, in many cases, a concrete business case for an early warning system and cost-benefit analysis is not yet at hand.

There are several studies that suggest that vulnerability reduction in floods and cyclones mortality risk have been due to improved EWS (Webster, 2013) (Basher, 2013). The enhanced capacity of EWS and forecast in the past three decades have been possible thanks to technological advances in computer calculus power, improvement of risk models and the availability of data. As well social disciplines (especially cognitive psychology and risk perception) have played a role in strenghtening the capacities of the communities, especially in developing countries. This mainly reflected an increase understanding of risks and warnings and adoption of the correct behavours. At the local level, preparedness and response measures have improved, making the use of warnings more effective in saving lives.

EWS end-users, and in particular risk managers, have lately driven a demand for multi-hazards warning systems. This is in line with the evolution of the disaster risk management concept, and in particular DRR, which have pointed out the interconnections of risks (natural-natural, natural-technological, technological-technological) and the need to prevent, mitigate and prepare for disasters caused by different kind of hazards in a holistic fashion.

UN agencies such as the World Meteorological Organization (WMO) and UNISDR have highlighted that effective risk management requires countries to invest in integrated and multi-hazards EWS. The WMO has since 2006 organized a series of symposiums, expert meetings and sessions on the role of EWS in DRR[i]. WMO also compiled a series of good practices that have been instrumental to identify actions needed for EWS to contribute to vulnerability reduction (Golnaraghi, 2012)

It is largely recognized that multi-hazard EWS are needed for sound risk management as each hazard has specific characteristics. In particular, detention timeframes varies significantly. While seismic events and tsunami warnings are a matter of hours, minutes or seconds, droughts can be a matter of weeks and months. Consequently, prevention, risk reduction and preparedness measures need to be planned and implemented differently. A general principle for the accuracy and lead time of an EWS is the following: the larger lead time, the more available time to take action, but also the lower probability for a correct forecast. A balance thus is to be found between the needed time and the expected accuracy. In order to use the additional time effectively, the actions to be taken have to be planned in advance.

This paper discusses the lessons learned from a comparative analysis of EWS for floods in Europe (Belgium) and Africa (Egypt, Mali) . Through a series of EU-funded projects and related published and unpublished material mainly FREEMAN (Schelfaut et al., 2011), FLAFLOM (Cools et al., 2012), WETwin (Cools et al., 2013) and AFROMAISON (Zwarts, 2010).

Though many technical challenges remain in the development and design of an EWS, this paper will focus on the substantial challenges in the effective use of an EWS as a tool to strengthen preparedness and community resilience to floods and droughts. An important element of the assessment is to which extent the HFA (priority 2) has contributed in building more effective EWS nationally and regionally. The paper will finally conclude with recommendations for the post-2015 framework on disaster risk reduction (HFA2).

2. Chain of elements needed for an effective EWS

The UNISDR Platform for the Promotion of Early Warning (PPEW) identified four interactive elements for EWS to be effective[ii]:

- The available risk knowledge of hazards, vulnerabilities and exposure of people and economic assets (at national and local level).
- The monitoring and warning service technical capabilities of the authorities, and their forecasting and issuing warnings capacities
- The dissemination communication outreaching capacities. This includes how understandable is the warning to those communities at risks.
- The response capability in terms of knowledge and capacities of the authorities to take appropriate response measures.

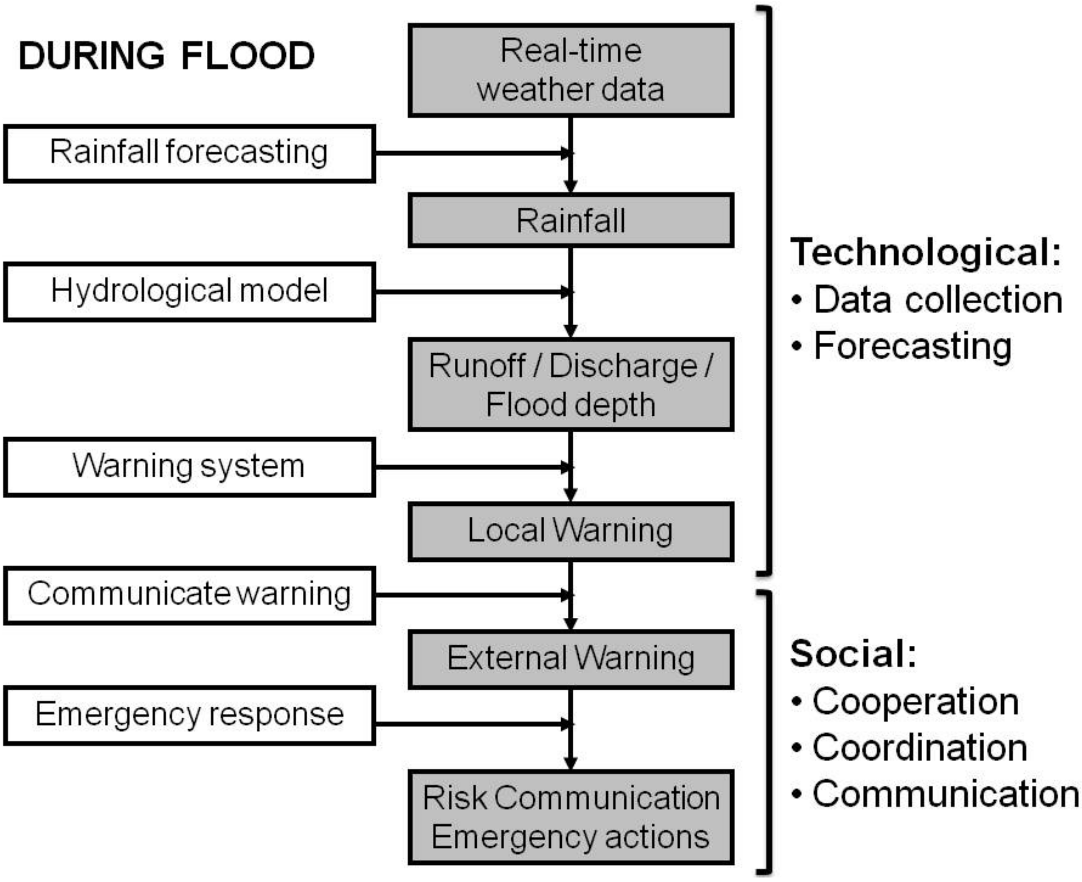
To reduce risk, all those elements should work well (Basher, 2006). In the case of the November 2013 Hayan typhoon that caused 5,823 deaths[iii] in the Philippines, the elements that mainly failed were the third and the fourth . In the case of the 2011 Japanese Tsunami and the resulting nuclear accident in Fukushima, the first component , proved to be lacking, despite the fact that Japan is widely recognized as one of the countries owning state-of-the art EWS and a strong technical capacity coupled with high level of population awareness on reaction measures.

There is evidence that a participatory approach in the design of people-cantered EWS is one of the most effective ways to assure appropriate responses on the side of the end-users (KULTURisk, 2011). Other studies, showed as well how participatory approaches to monitoring the effect of hazards such as droughts on food security, can be helpful not only in detecting the risk, but also triggering context-specific adaptive and risk reduction measures. This was what happened in drought-affected communities in Northern Laos and in the Philippines. Rural households were adapting their diet intakes and agricultural practices as a coping strategy to the warnings directly observed by the first signals of soil moisture scarcity (Innocenti, 2006).

This paper looks specifically at EWS for floods. These are complex and require a chain of components that are all necessary for the functioning of the overall warning system. An overview of the chain of components that form a flood EWS is shown in Figure 1. The level of detail and expected accuracy can be set for each component, depending on the available data, the underlying drivers of risk, available monetary and human resources and institutional capacity.

The components can be classified as technological, social and institutional. Technological components relate to data collection and forecasting. Rainfall forecasting is the first and most essential component. Real-time weather data is needed as input for forecasting algorithms. Weather data can be obtained through on-the-field measurements, satellite images and weather forecasts. Consequently, the weather data needs to be converted to runoff, discharge or flood depth by means of a hydrological model or alternatively an empirical equation. Finally, the EWS sends alerts according to user-defined thresholds of danger. The alert can range from a simple message to a map showing the zones at risk and even a full (automatically prepared) report. A warning will first be handled by an operator to exclude false warnings. If positive, the warning is submitted as an external warning to decision-makers. This gives decision-makers lead time to respond to the emergency and take actions to avoid (or minimize) damages, including the notification of the local communities and potential visitors.

Figure 1: Activity chain of an EWS for floods



(Based on: Cools et al., 2012)

In addition to the difficulties related to the technical implementation of an EWS, the use of a warning system depends to a large extent on the effective dissemination and communication of an alert and the response capabilities of authorities and communities. The following actions are examples of what which actions an EWS chain is composed.

- interpretation and validation of the alert by an operator
- issuing the alert, and applying the communication and emergency procedures
- understanding of what the alert says by those who are informed
- need to know what to do - including the need for a clear description of roles and responsibilities in case of an emergency
- trust the alert - link to false warnings & risk acceptance of public

- need to see the added value of an alert ; e.g. in Belgium, lay people have a high level of risk acceptance and assume that the authorities will deal with the emergency. In Mali, e.g. the public is more safety conscious.

The weakest link determines the strength of the entire EWS. Good logistics and a holistic approach are important. Emergency response planning is a first step in which communication systems and protocols are formulated. Clarifying roles and responsibilities of the stakeholders in a emergency is vital. Preparedness and emergency planning mostly exist prior to the implementation of an EWS and needs to be evaluated and revised in accordance to the additional lead time which is potentially generated by the EWS. One important aspect of an emergency response is the wide dissemination of an alert using commonly used information platforms, such as TV or radio. Websites dedicated to the EWS are mostly not the first information for stakeholders. Nonetheless, as mentioned in the introduction, social media are likely to gain more and more importance in the years to come.

The potentially damage depends on the preparedness of authorities and communities to a flood. Evidence exists that less prepared communities have suffered from more damage than the prepared ones (Wisner et al., 2004). Generally, it is known that the collective memory is short and the level of preparedness decreases rapidly after a flood event. EWS can boost preparedness and the response capabilities and while individual awareness is important, local authorities play a significant role to raise the level of their community's preparedness.

3. **What have we learned? Role of the HFA (Priority 2)**

The role of EWS's in DRR is recognized under the Priority 2 of the HFA[iv]: identify, assess and monitor disaster risks and enhance early warning (UNISDR, 2007). There is a specific indicator for the EWS included in the national HFA Monitor Report format: the core indicator *2.3: Early warning systems are in place for all major hazards, with outreach to communities.*

A global vision on what are the progresses in the development and use of EWS has been based on a survey carried out in 2006 (United Nations, 2006) and the follow-up Report of the UN Secretary-General (United Nations, 2007) that highlighted mixed results in the development of EWS, with developing countries still beyond in their forecasting and warning capacities. Compared to 2006, the situation seems to have improved. The 2010 Mid-Term Review (MTR) of the HFA (UNISDR, 2011) reports that with respect to advances in the HFA Priority 2[v] most of the countries (64 out of 83) have progressed in developing their forecast and EWS capacities. A driver for these improvements has been the technological progresses (and likely the technological transfers). However, the HFA MTR highlighted that main areas of improvements were related only to those EWS that concern intensive risks (such as tsunamis) rather than extensive risks (for example recurrent and localized floods).

Concerning the three case studies presented in this paper (Belgium, Egypt and Mali), Belgium is the only country that did not report its progresses using the HFA Monitor, however, it is recognized that its flood early warning system is among the most advanced in Europe. Egypt and Mali have reported under the HFA. In that report, In comparison to the progress of 25 all African countries that reported against the HFA indicators, Mali and Egypt have an average progress. In Europe, according to the regional Monitor Report of the HFA for the reporting cycle 2011-2013, the average score for indicators 2.3 is 3.9 (UNISDR, 2013). Each country reported specific examples of how their EWS are operating at the national level. Even within the EU there are relevant differences in the capabilities of the systems and different challenges in integrating different sub-national EWS in countries where the responsibilities for monitoring and warning are delegated to subnational authorities..

The European HFA Monitor Report appreciates that assessing progress in EWS is difficult. Emerging threats, migrations of population in hazard-prone areas, and changing in the technologies make state-of-the-art EWS rapidly obsolete.

Other limitations emerge using the HFA monitoring methodologies when comparing countries' achievements. Though countries that reported against the HFA Monitor indicators are able to use the same standards, terminology and formats, for the indicators, they might not use the same Means of Verifications (MoVs), or the same quality control criteria. There is an overall issue of subjectivity in assessing its own progress and results, which makes comparison among countries difficult. Countries do self-assessments , with no guidance on the "quality control", benchmarks or a checklist of performance measurements. There is neither availability of a baseline nor control-groups that could be used for assessing the impact of investments in EWS or other DRR measures.

These methodological shortcomings can be (partially) mitigated by an external review. In 2012 and 2013 the United Kingdom and Finland underwent HFA peer reviews[vi] . A team of peers (composed by national experts from other European countries) provided an independent feedback to the validity of the information reported in the host countries HFA Monitor reports. A peer review could also add value to assess the coherence of reporting across countries. In the EU, for example, a comparative analysis of EU-27 is being increasingly applied, e.g. under the Water Framework Directive (European Commission, 2012)

While an HFA Peer Review process can be seen as a value added, and possibly an element to be encouraged in the post-HFA framework, there is the overall need to improve the HFA monitoring system for EWS. While this paper does not include in its scope a revision of indicators proposed by the HFA for Priority 2, it recognizes the benefits for the new framework of a revision of a new set of measurements for assessing progress in the area of forecast and early warnings.

4. Case study descriptions

In all three case studies (table 1), an EWS is operational, meaning that a system is in place that issues forecasts upon which can be acted. The flood early warning system in **Belgium** is one of the most advanced in Europe. After 10 years of operational experience, real-time web-communication to the public and a rapid decision-making process is developed (Schelfaut et al., 2012). In addition, lessons learned from two case studies in a more data-scarce and (semi)-arid environment are presented. The EWS in **Egypt** is designed to reduce flash flood risk, but is also important for floodwater capturing (Cools et al., 2012). In the **Inner Niger Delta of Mali**, drought mitigation, food security and sanitation have more priority than reducing flood risk (Liersch et al., 2013, Cools et al., 2013). The EWS for the Inner Niger Delta, called OPIDIN (Zwarts, 2013), is an aid to crop and livestock farmers and estimates the best time for essential communal activities including planting and cattle river crossing. Both for the Mali and Egypt cases, the local communities had a role in the validation of the models (in absence of more quantitative data) and in setting up the risk communication. It was found that the information provided by a flood EWS could also be relevant for other sectors, including river basin and drought risk management, food security (Liersch et al., 2013) and health and sanitation in an urban environment (Cools et al., 2013).

The EWS in Belgium and Egypt are designed top-down and have a strong simulation component. In Egypt, due to limited availability of data, local knowledge of the Bedouins communities has been used to develop the flood risk model, especially with respect to field knowledge on the most flood risk prone areas, travel time, maximal observed flood depth, floodwave duration and actual damage. The EWS for the Inner Niger Delta is a bottom-up initiative, where local communities ask to have better estimates on the flood intensity, the date of the flood peak and the data of deflooding. In Belgium, substantial information is published online including rainfall, water depth and projected trends at various locations, high resolution flood maps (street level) and alert colour code (to indicate the severity of the alert).

Table 1 : Overview of the case studies

Indicators	**Lowland plains, Flanders, Belgium**[vii]	**Red Sea Mountains, Egypt**	**Inner Niger Delta, Mali**[viii]
Acronym	OBM	FLAFLOM	OPIDIN
Lead time provided	Up to 48 h	Rainfall: up to 48h Floodwave: up to 4h	Flooding & deflooding: up to 6 months
Operational since	2007 (pilot EWS in 2003, for Demer river basin)	2010 (pilot EWS in 2008, for Wadi Watir)	2013 (pilot EWS in 2009)
EWS design	Top-down; strong calculation core	Top-down, but with use of local knowledge for development of flood risk model	Bottom-up; for communal planning, need for better estimates of flood peak and deflooding under flow variability
Info communicated	Rainfall, water depth and projected trends at various locations, flood maps, alert code	Rainfall forecasts, alert code	Date and height of flood peak, date of deflooding
Reported under HFA	No, Belgium does not report under HFA	Yes	No, Mali reports on other EWS but not for floods

5. Comparative analysis of floods EWS in case studies in Africa and Europe

Below, the case studies from Belgium, Mali and Egypt are discussed in relation to five qualities that are important for flood risk management: risk knowledge, technological performance, acting on an early warning, local level preparedness and their fitness to be a multi-purpose EWS.

Risk knowledge

A prerequisite for an EWS is to have an understanding of the risk and a tool and /or services for monitoring (data acquisition) and generation of warnings. In the **Belgian** case study, advanced risk knowledge exists. High resolution (street level) flood risk maps are available and conceived as the combination of flood probability and potential damage maps. Scenarios of climate change, land use change and impact of measures also has resulted in the development of flood risk management plans, as required under the European legislative framework, the EU Flood Risk Directive, coordinated with the EU Water Framework Directive.

In **Egypt**, the main flash flood events are known as well as the storm events to which the flash floods are associated. While insights exist on the dynamics of storm events by weather forecasting and remote satellite precipitation estimates, limited understanding exists of the response of wadi to rainfall (harsh conditions and scarcity of events).

In the **Inner Niger Delta of Mali**, the flood intensity depends on well-measured upstream flow. Considering that floods are considered as essential for the economy and local livelihood, the term flood 'intensity' is used rather than the term flood 'risk'. The impact of flood intensity on socio-economic factors is well studied and found to be large scale, in terms of additional fish catch and rice production and potential for cattle grazing. Damage related to flooding is local and mostly considered to be minor compared to the benefits of a flood. For a better understanding of local stakeholders, a flood risk atlas has been developed, showing the flood extent and depth and time of deflooding linked to upstream water depth.

Table 2 : Overview of achievements and challenges in the case studies: Risk knowledge

Lowland plains, Flanders, Belgium	**Red Sea Mountains, Egypt**	**Inner Niger Delta, Mali**
Achievements: • High resolution flood risk maps (flood probability and potential damage maps) • Published on web-GIS	**Achievements:** • Understanding of most vulnerable areas • Historic analysis of storm and flash flood events	**Achievements:** • Good understanding of underlying drivers of flood risk • Impact of flood on socio-economic factors and biodiversity well studied • Flood risk atlas for local use

Challenges:	Challenges:	Challenges:
• Assessing social vulnerability is lacking • Disaster loss accounting is lacking	• Limited understanding of space and time dynamics of potential flash floods • Flood risk atlas is lacking	• Capacity to assess impact of measures & scenarios

Technological performance

In the **Belgian** case , all components are operational, regularly updated and tested to reflect changes in the basin. Ensemble rainfall forecasting is linked to a set of high resolution flood models, validated by long time series of flow and rainfall data, and supported by a dense network of real-time rain and flow gauges. Alert thresholds are validated on field, based on observed data of historic floods. Operators have a permanency 24/7. When critical, warnings are send out by SMS and email to the entitled emergency services, published on web portal and a press release is send to the media.

Table 3 highlights that a similar, though less extensive version is developed for the Red Sea mountains in Egypt. Flash floods are even in the EU difficult to cope with. First, because of the short time between the precipitation and the flood event. Second, because their high peak discharges and destructive force. For flash flood mostly, the observation data is scarce and model results too coarse to allow accurate predictions. However, an open source rainfall forecasting model, namely the Weather Research and Forecasting (WRF) Model is developed for the whole of Egypt (Cools et al., 2012, El Afandi et al., 2013). For a pilot area in the Red Sea Mountains, a lumped flood risk model has been developed. The lack of water discharge data in the pilot area prohibited a data-driven calibration of the flood risk model and alert thresholds. A limited network of rain gauges exist for ex-post evaluation of the forecasting accuracy. Model parameterization is done based on literature data, expert judgment and local knowledge of lay people (flood observers). The EWS is operated at national level and consequently issued by phone to local and regional authorities. The capacity in data handling and permanency however is limited. Ground radar is not available in the region.

The EWS for the **Inner Niger Delta** is based on statistical relationships between upstream observed water depths, flood depth and flood extent in the Inner Niger Delta. Considering that local rainfall is scarce, rainfall forecasting is omitted. The lead time is several months for the peak flood and the time of deflooding. Warnings are issued over radio and web (www.opiding.org) and phone to local key persons to reach villagers. Weekly news bulletins are also developed. Technical information on the flood intensity is converted to easy-to-understand labels of flood intensity as collectively understood by the population (very weak, weak, normal, strong, very strong).

Table 3 : Overview of achievements and challenges in the case studies: Technological performance

Lowland plains, Flanders,	Red Sea Mountains,	Inner Niger Delta, Mali

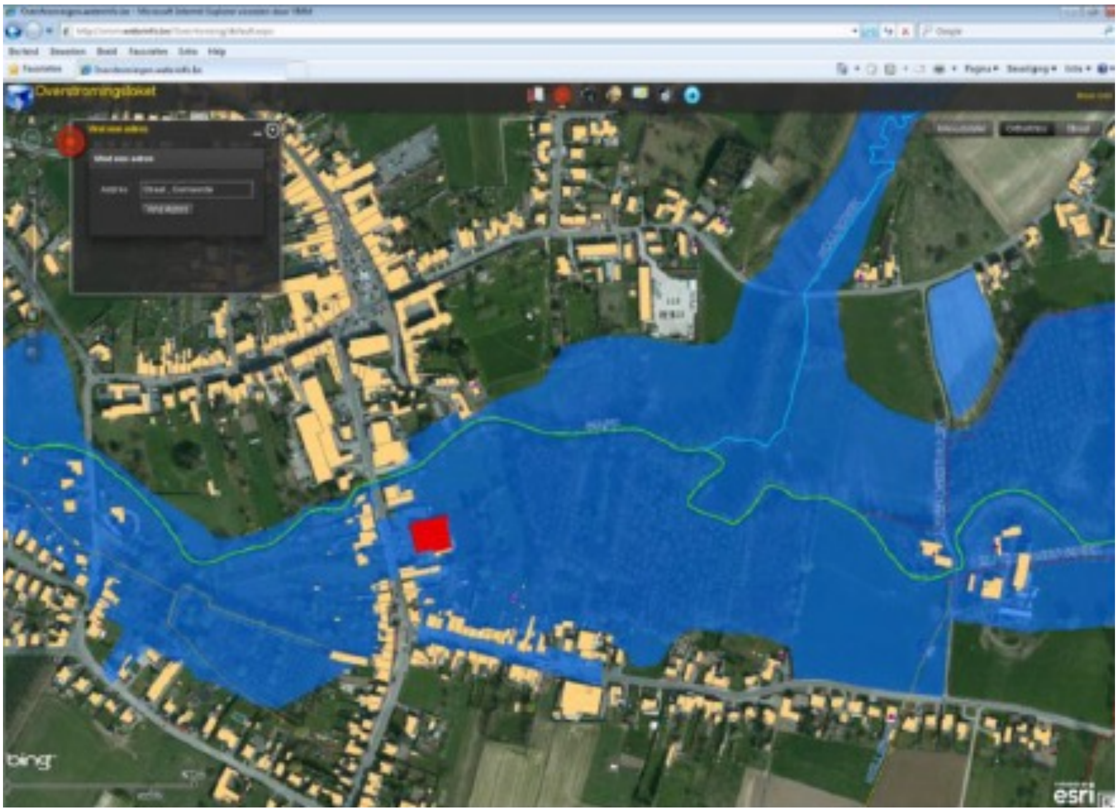
<table>
<tr><th>Belgium</th><th>Egypt</th><th></th></tr>
<tr><td>Achievements:
• Well performing EWS, operating for 10 years,
• Advanced real-time monitoring & forecasting technology
• Warning send by SMS and mail and published on web portal</td><td>Achievements:
• Success in issuing an alert for flash floods, based on forecasted rainfall maps
• Local knowledge used as qualitative data source in model development</td><td>Achievements:
• Statistical relationships based on upstream water stages
• Flood maps developed based on satellite images of flooded area
• Accurate forecasts with low data need</td></tr>
<tr><td>Challenges:
• Single web portal for warnings and info
• Dynamic maps of flooded area are lacking</td><td>Challenges:
• Validation/Update of EWS with field data needed
• Capacity in data handling of large volumes of real-time data streams to be increased</td><td>Challenges:
• Resolution and accuracy in some areas to be improved</td></tr>
</table>

Acting on an early warning

Even though improvements are always possible, the **Belgian** early warnings are acted on effectively. An assessment of how the EWS has been used during the 2010 flood in the Demer river basin (CIW, 2013) showed that after an early warning is automatically flagged, a chain of actions is taken, starting from the operator who checks the likelihood of the warning and consults local contacts before the warning is sent out to the network

. Secondly, the alert triggers a meeting of the flood emergency committee, composed of local and regional authorities, civil protection, local fire brigade, policy, medical staff, responsible for logistics and communication and the water authorities and other relevant stakeholders to plan for actions. Thirdly, action starts and can include filling of sandbags, preventive pumping, communication to the press and wide distribution. The local authorities, and especially the civil protection and local fire brigades have a high response capability. The EWS is an additional source of information, which supports their long lasting expertise with floods in the area, and in-depth local area knowledge. The EWS alerts are continuously followed-up by the emergency control centre. From a retrospective view, the EWS is working well and has gradually been accepted by the civil protection as a reliable source of information. The provided information by the EWS however has been criticised as it can be difficult to understand and use. The EWS alerts on the location and area flooded (maps) and expected trends (depths). In addition, two EWS's exist each covering a distinct geographical area (split in the upstream and downstream area of rivers) and information is not published on a single information portal. A single portal is currently being developed as part of a single crises emergency centre. The portal will become more intuitive and user friendly, and show dynamic maps of the flooded area, rainfall animations and economic assets on satellite images (Bing or Google Maps) background (FIG 2).

Figure 2: Extract of the EWS of the high-resolution flood risk maps as generated by the EWS in Belgium



Egypt

The EWS functions as the trigger in sending out an early warning. They EWS is operated by professionals at WRRI, a national water research institute under the Ministry of Water and Irrigation. When critical values are forecasted, the operator will notify the 'Disaster and Crisis Center' and the 'South Sinai Water Sector' immediately by phone and email a short report including the forecasted rainfall maps. They will call a meeting for the 'supreme committee for crisis management'. This committee is responsible for the decisions and actions during flash floods and existed prior to the operationalization of the EWS. The supreme committee is composed of representatives of the local (mayors) and regional (governors) authorities, the military, civil protection, crisis management centre, regional media and representatives from each of the sectors. Flash floods often come unexpected and can be very destructive. Through the EWS, more lead time is offered between the first sign of a possible storm event and the flash flood itself.

Before sending, a warning will first be handled by an operator to exclude false warnings. The latter is done through rapid desktop screening of simulation anomalies (e.g. errors in the input) and communication with experts on-the-field (e.g. based on cloud patterns and Bedouin traditional weather knowledge). For 'alert' warnings (such as the January 2010 event), the WRRI operator also warns the Sinai governors by phone. Decisions for actions are taken by the South Sinai governorate officials which upon their turn warn the municipal officials in Nuweiba. The EWS has proven its potential through the forecast of the flash floods on October, 24, 2008 and three flash floods in January and February, 2010 (Cools et al., 2012). Although the steps to come to a flash flood warning are elaborate, the system is designed to deliver forecasts in less than 15 minutes /24h in advance.

However, the lead time is still substantially lower as a consequence of the absence of an operator at night or in the weekends, power failures which inhibits the EWS to run, system crashes and inter-human communication and decision-making.

To secure a positive image of the EWS relative to the decision-makers and stakeholders, the sending out of false warning and lack of warnings (when a flash flood did occur) needed to be avoided. For this purpose, currently only the rainfall forecasting is used to send out official warnings.

From a social point of view, major challenges are the necessary participatory interaction with the local authorities for flash flood management and the local inhabitants (mostly Bedouins) and the coordination of communication pathways from the generated warning to actual decision-taking on the field. Egyptian officials and the Bedouins furthermore have a mutual distrust. As a consequence, in the past, rain gauges have been destroyed as some Bedouins felt it as an intrusion in their privacy. The latter adds to the logistic challenges of a flash flood EWS and endangers a long-term acquisition of field measurements, which on its turn inhibits a better understanding of the flash flood risk. Hyper-arid catchments are generally difficult to access, and especially during and soon after a flash flood.

From a communication point of view, it is challenging to reach villages in the mountains as there is no mobile phone communication network. Insufficient lead time is available to visit the Bedouin villages. Insufficient understanding furthermore exists to forecast which of the upstream valleys (and thus communities) will be targeted. The Bedouins however claim to be well prepared and forecast the floods themselves. The Bedouins also see higher benefits of a flood than costs. The latter is elaborated more in the section 'EWS as a multi-purpose tool'.

Mali

A strong flood is considered positive in the Inner Niger Delta and beneficial for the local economy and livelihoods. While extreme floods may cause minor local damages, the impacts of a weak flood are detrimental and on large scale. Living with floods is inherent to the population of the delta and as a result they have a strong degree of autonomous adaptation to floods. Due to the large variability of the flood in last decades, conflicts have arisen between fishermen, herders and farmers, who are counting on water availability for competing businesses and use commongoods such as public soils.

The EWS gives a more precise indication on how strong the flood will be and on the timing of the peak flood (important for fishermen) and timing of deflooding (important for cattle raising and rice farmers). The information is shared with key persons in the local communities and local authorities and used to fix the dates for the cattle crossing and dates for the entry of cattle to the 'deflooded land'. Warnings are released through local radio channels, and more recently also published online (www.opidin.org). The flood atlas developed together with the EWS, can be used together with the early warning to gain insights in which areas will be flooded and which will remain dry.

As a consequence of the longer lead time (several months), the level to which is acted on an early warning is closely related to the level of preparedness. The Mali flood EWS is conceived as a multi-purpose tool, rather than solely for emergency purposes, and will be further described in the section on 'EWS as a multi-purpose tool'.

The EWS is designed bottom-up. The local community have a collective memory on the flood level in the past years and know which areas were then flooded and which not and what the duration was of the flood. An appreciation exists on which flood was considered to be strong or weak, or completely disastrous (e.g. 1984). Together with local stakeholders and regional authorities, Zwarts (2010) and Liersch et al. (2013), a common understanding is made between the local perception of a flood and the observed water stage measurements in those years. Floods and consequent flood warnings are classified under 5 categories: very strong, strong, normal, weak and very weak flood. An overview of the floods since 1955 using this classification is shown in Fig. 3.

Figure 3: Classification of the floods since 1955 in the Inner Niger Delta, Mali according to user-defined categories

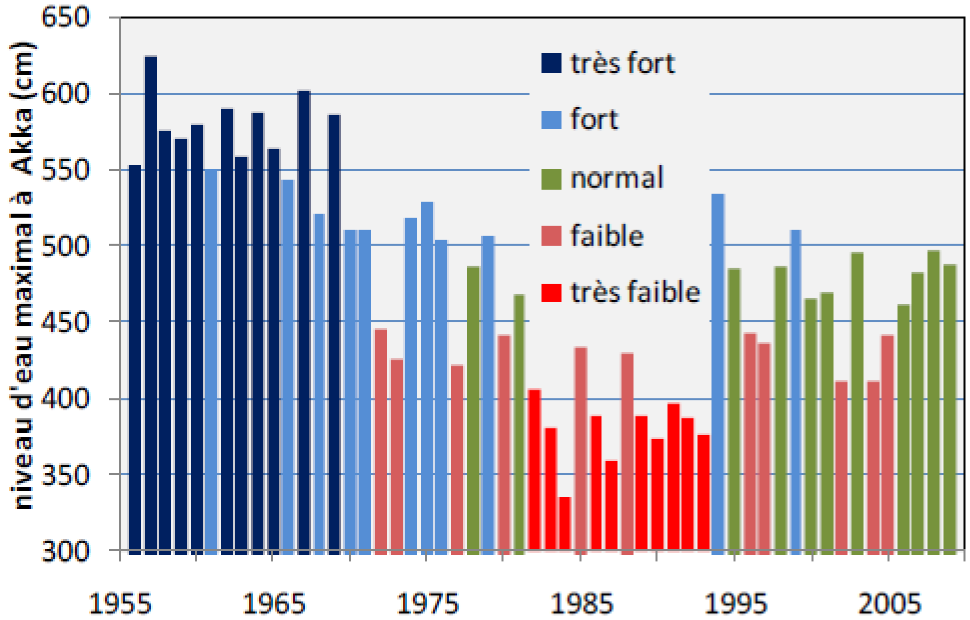


Table 4 summarises the achievements and challenges of the three cases in acting upon warnings.

Table 4 : Overview of achievements and challenges in the case studies: Acting on an early warning

Lowland plains, Flanders, Belgium	**Red Sea Mountains, Egypt**	**Inner Niger Delta, Mali**

Achievements:	Achievements:	Achievements:
• Good cooperation between EWS operators (24/24h) and crisis management team • Massive visiting of web portal by public during flood	• Warning communicated to disaster and crises centre • Field actions taken in limited lead time (road block; release of overflow water from dam)	• Communicated info based on end-user needs • Warning issued over phone, radio and web (www.opidin.org) • Long lead time
Challenges:	**Challenges:**	**Challenges:**
• Local authorities and civil protection not (yet) familiar with info from EWS • Secured line between EWS operator & civil protection	• Mismatch between model complexity, available data and institutional capacity • Redundancy of operations (24/24h permanency, power cut proof, backup for server crash)	• EWS is still in a testing phase

Local level preparedness

Belgium

The EWS was built following the major flood of 1998. People are warned through speaker phone by policy and fireman. Since 2007, the EWS and web portal is operational and lay people are encouraged to follow the flood on-line.

Results from a survey with risk prone population in 2009 showed that the majority (76%) of all respondents (about 200) were not aware of the existence of the EWS (Uyttendaele et al., 2011). The major flood in 2010 has been forecasted well by the EWS and for the first time intensively used in the emergency response. Results from the ex-post evaluation of the 2010 flood (CIW, 2011), reported on the conclusions summarized below:

- The EWS has performed well, the alert consisting of accurate information is widely distributed 48h in advance.
- The public massively visited the web-portal, especially after announcement on TV and radio news. In total, 2,5 million hits were counted in 4 days time, with a peak of more than 80,000 hit/hour. A permanent call centre answered questions of lay people.
- During the flood, permanent (24/24h) up-to-date (5-15min interval) information is shared with the emergency coordination team.
- The local emergency procedures have been used, good cooperation between sectors and scales has been observed, the involvement of municipal staff responsible for 'emergencies' was beneficial. Many lay people offered voluntary assistance.
- Good information exchange existed between the field team and EWS operators. Potentially critical areas were communicated and visited by the field team. Field information (on the actual flood state), from ground surveys and helicopter were

communicated to the EWS operators which is then entered in the model as a means to improve the forecast.

- The geo-referenced helicopter surveys are considered as an important tool during the flood and are used to map the actually flooded areas and ex-post evaluation of the flooded areas forecasted by the EWS.
- A second stakeholder survey (535 respondents), recently after the 2010 flood, showed that more than 90% found it useful to anticipate on a coming flood. About 2/3 wanted to receive alerts by SMS and asked for a smartphone application of the EWS warnings.

Following weaknesses were also observed along with some recommendations:

- Better communication is needed with the local authorities and civil protection as they are not (yet) familiar with the EWS. A contingency plan is to be developed together with training/rehearsals on how the EWS can provide better support to the local authorities and civil protection.
- The wide and repeated distribution on the coming flood on the downside created slight panic and increased demands for sand bags.
- It is suggested that the civil protection should have a secured line with the EWS emergency center, not prone to disconnection and overload as a consequence of the massive use of telecommunication lines during a flood.
- The existence of two EWS at different water authorities for distinct, but closely interconnected geographic areas (upstream and downstream areas) is confusing. A unique EWS portal should exist as well as better coordination between the operators of both EWS.

Egypt

The emergency plan existing in South Sinai is satisfactory to the decision makers. It has been revised to include the early warnings. The forecasted rainfall map is send daily by the operator to the Crises management unit along with, a short note on the possible rain intensity and geographic distribution is included in the message. This communication mechanism has been applied for the first time during the January 2010 storm and has received support from the Minister of Water and Irrigation and high officials from several Governorate confronted with the challenge of flash flood management including the Governorates of South and North Sinai, Red Sea and Aswan. Main actions related to the blocking of the 'flash flood' prone road to the Nuweiba city and port and the operation of overflow water from the Rawafa dam near El Arish city.

Getting the involvement of the local Bedouins was not straightforward. At first instance, Bedouins did not see any advantage of the early warning system for flash floods. They are confronted with flash floods all their life. Although most of them have lost already animals and fields, they see flash floods mainly as a positive fact which provides the only source of renewable fresh water rather than as a destructive force. As they face severe water scarcity, their major need is to capture floodwater. The Bedouins claimed to know how to forecast flash floods themselves, and said to know which areas are most dangerous, what to do in case of a flash flood and how to capture floodwater. Only they lack financial resources and equipment to do so. The interviewed Bedouins have in addition shown useful expertise (knowledge about the terrain, traditional forecasting techniques, historic floodwater heights…) for the development of the early warning system. Considering the lack of communication facilities to reach the isolated mountain villages, the role of the Bedouins has been to share their local knowledge and assist in developing the EWS and to guard and maintain the meteorological monitoring equipment, placed in their villages while the main benefit of the EWS is for the urban environment and critical infrastructure (e.g. including the roads, harbour, dams, electricity lines).

In addition, rain gauges where installed in the upstream areas, in/near the Bedouin villages which in the past have been known to be destroyed by vandalism. Meteo stations were perceived to be cameras to spy on them. Trust hence had to be created first if a monitoring network was to be installed. As a generally accepted/assumed custom in Bedouins regions, the investment in rain gauges had to be protected by hiring guards from their tribes to avoid the direct damage. As a result, it is highly important for the operational success of the project in the following implementation steps to build enough trust among the local population that guarantees the safety of any device that will be installed (e.g. rain gauges or GSM-receivers), and the clear explanation of the gained advantages of such devices for managing water needs (both on shortage and flood!) in their regions.

Mali

As a consequence of the longer lead time (several months), the level to which is acted on an early warning is closely related to the level of preparedness. The Mali flood EWS is conceived as a multi-purpose tool, rather than solely conceived for emergency purposes, and is described in the section on 'Early warning acted on' and 'EWS as a multi-purpose tool'.

Table 5 : Overview of achievements and challenges in the case studies: Local level preparedness

Lowland plains, Flanders, Belgium	**Red Sea Mountains, Egypt**	**Inner Niger Delta, Mali**
Achievements: • Multi-sectoral & multi-scale response mechanism • Strong local response capability	**Achievements:** • Agreed emergency & decision-making procedure • Installation of rain gauges in Bedouin villages	**Achievements:** • Local knowledge Traditional practice to decide on cattle calendars for sustainable pastoralism. • Use of risk assessment to protect against upstream development endangering the Delta •

Challenges:	Challenges:	Challenges:
• Rehearse use of early warning by local crisis management team • Improve preparedness under lay people	• Better cooperation between local/regional authorities and Bedouin communities needed • Better capturing of floodwater needed	• in testing phase

Multi-purpose EWS

It was found that the information provided by a flood EWS could also be relevant for other sectors, including river basin and drought risk management, nature conservation, food security and health and sanitation in an urban environment.

Belgium

In Belgium, flood risk management is strongly integrated in river basin management. The Flemish Decree on integrated water resources management (2003) focused strongly on flood risk management and provide the legal base to develop tools and management plans. The EU legal framework, the Flood Risk Directive, only made flood risk maps compulsory in Europe from 2014 onwards. Having a 10-year lead, Belgium is considered to be a leading country in Europe. This head start on flood risk management was triggered by the large losses caused by the 1998 flood in the Demer river basin. The pilot version of the EWS released in 2003 for the Demer river basin was a first important tool.

Similar simulation models and risk assessment are behind the EWS. As well as the need to bring sectors and stakeholders together were further used for the development plan for the Demer river (2005). The development included flood buffering capacity and safeguarding of other functions including navigation, recreation (mostly cycling) and farming Main actions included dike relocation (to give more room to the river) and the re-connection of disconnected river meanders. As part of the Sigma plan, flood retention basins are currently being constructed. The River Basin Management plans (RBMP's, 2008), as required under the Water Framework Directive put a large focus on floods, in line with the Decree. The further development and coordination of a flood EWS is included as a priority in the RBMP. In addition, the EWS can support the regulation of the water stages. It informs on opening/closing of the valves on the rivers also in non-critical times and support control of the water flows,

Egypt

Wadi Watier is considered as one of the most flash flood prone areas of Egypt. In the past, flash floods have caused serious damages a.o. to the city of Nuweiba, located in the Delta of Wadi Watier and the 'international road' between the mainland (Cairo and Suez) to the harbour of Nuweiba (traffic to Jordan and Saudi Arabia). Flash floods are hence seen as a disaster for which better protection is needed. Important here is the construction of diversion dikes in Nuweiba about 10 years ago. While some protection works have been constructed, residual risk remains, for which some damages and especially loss of life, can be avoided if an alert is given beforehand.

On the other hand, floodwater is a vital source of water for Bedouins. Most Bedouins in Wadi Watier have been confronted with flash floods all their life. Although most of them have lost already some of their belongings (animals, fields, destroyed drinking water wells etc.), they consider flash floods mainly a positive fact which provides fresh water rather than a destructive force more downstream.

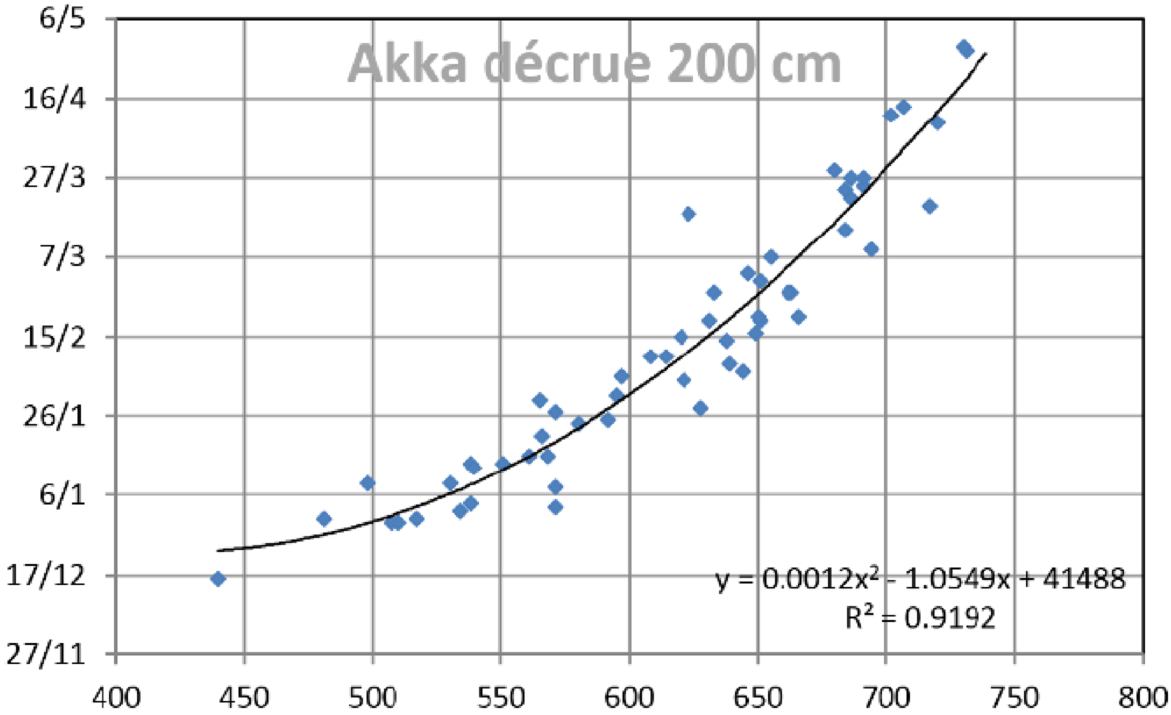
Floodwater from flash floods is the only renewable water resource. Floodwater however cannot be captured properly and in the past infrastructure has either been destroyed or filled with sediments, thereby rendering them useless in flood capturing. Risk modelling and early warning could help in better identifying the locations, timing and technology to capture floodwater, taking into consideration the water availability, the destructive force and the distance to the villages.

Mali

During and after the rainy season (June–October), large areas of the IND are inundated. Naturally, these floodplains provide vital habitats supporting livelihoods in fishing, farming, and stock farming (Zwarts et al., 2006). Reduction of flood losses is only of minor concern in the Inner Niger Delta. A strong flood is considered essential for the economy and local livelihood, while a weak flood increases competition for natural resources and social conflicts and reduce the generation of income. In general, the higher the flooded area, the higher the food and fodder production (Zwarts et al., 2006). The Inner Niger Delta offers home for 1,5 million people and 2 million of cattle and is in addition characterised by high annual migration. The maximum flooded area varies from 5,000 km² to 20,000 km² depending on the flood intensity (Liersch et al., 2013).

An EWS is to support the traditional decision-makers in fixing the dates when the culturally important cattle crossings can take place and when cattle consequently can get access to the dried up (deflooded) land. Hereby, the date at which the water level has declined (deflooding) to a certain level is even more important than the flood itself (Zwarts et al., 2009). An example is shown in Fig. 4. It shows the date at which a depth of 200 cm is reached in Akka (upstream) in relation to the flood peak in Mopti (at the entrance of the IND).

Figure 4: The time at which the water level in Akka has declined to 200 cm as a function of the peak flood level in Mopti some months before. (from Zwarts, 2010).



The dates for cattle crossing and access to the dried-up pastures is defined by the time of deflooding, which is highly variable between years. An early deflooding, typical for weak floods, gives rise to conflicts between rice farmers and herders. If the peak flood has been low, most of the floodplains have dried up in the second half of December, but if the flood has been high, this occurs in April, four months later. When the deflooding is late, cattle may need to cross an unexpectedly high water level and bring themselves in danger while crossing the Niger river, more than 1 km wide and flood depths varying between 1 and 6m over the year. Yet, the pressure to enter the Inner Niger Delta is much larger in dry years. The EWS aims to reduce social conflicts and sustainable management of the Delta. Considering that it can take the upstream variability into account, the EWS can also be considered a tool to address climate change adaptation.

Local knowledge has been used for long time as a type of traditional EWS to decide on the date to access the dried-up (de-flooded) grazing lands and date of the cattle crossings (Zwarts, 2009). Local chiefs come together from across the IND, one month or more before the flood peak is reached, to discuss on the flood and fix the calender for cattle crossings and access to the pastures. However, flow patterns into the Inner Niger Delta have become more irregular, and unreliable, and become increasingly influenced by climate change, upstream developments (irrigation, hydropower) and population growth (Liersch et al., 2013).

It is currently being assessed whether a flood EWS for the IND could also be used for early warnings on disease outbreaks such as cholera and diarrhoea. Confronted with the lack of sanitation and waste disposal facilities, an urban wetland typically serves as dump site for solid waste and faecal sludge, or waste water treatment facility for excreta or waste water, both resulting in water contamination and the spread of pathogens. The seasonal floods dilute the contaminated water, flush the stagnant water and thus improve water quality and reduce the presence of stagnant water bodies. Data are lacking to assess the water quality in the high flood season. Persistent cholera outbreaks during the flood season (e.g. in 2011) show that the diluted water still contains pathogens for diarrhoeal diseases (Cools et al., 2013). According to the Joint Monitoring Program (JMP) of WHO/ UNICEF (2012), in 2010, on average 35% of the urban population and 14% of the rural population in Mali had access to improved sanitation. In the IND, 6–37% (median 19%) of the population practises open defecation, 45– 80% (median 61%) of households still use poor sanitation facilities. For this purpose, the Global Information Management System (GIMS) is under development at the World Health Organisation (WHO), which is developing predictive tools and vulnerability maps at the global scale linking disease outbreaks and sanitation data to extreme events. In a next phase, GIMS is planning to downscale the vulnerability assessment and develop local/regional Early Warning Systems (EWS) to expected outbreaks for diarrhoeal diseases in selected pilot areas (not decided yet). The EWS will contribute to the improvement of the resilience of water supply and sanitation in the face of climate change and is therefore in line with the WHO's Vision 2030.

Table 6 : Overview of achievements and challenges in the case studies: Multi-purpose EWS

Lowland plains, Flanders, Belgium	**Red Sea Mountains, Egypt**	**Inner Niger Delta, Mali**
Achievements: • Good integration of river basin & flood risk management • Use of simulation models for impact assessment	**Achievements:** • Floodwater is valuable, not only destructive • Protection works included in EWS	**Achievements:** • EWS supports traditional decision-making on cattle river crossing and access of cattle to dried-up (deflooded) pasture •
Challenges: • Capacity in the implementation of River Basin & Flood Risk Management Plan	**Challenges:** • Develop better strategies for capturing floodwater • Identification of best locations and timing for floodwater capturing	**Challenges:** • To improve the models alsofor scenarios on food security and disease outbreaks

6. Recommendations for post 2015 – HFA +

The presentation of the three case studies and the discussion in the previous sessions, lead to the proposal of nine recommendations for the post-2015 DRR framework (so called HFA +) in the area of EWS and flood risk management.

a. **Better use of science and local knowledge in disaster risk reduction: people-centred EWS**
The HFA + represents a momentum for global awareness of EWS and local knowledge in DRR. As shown in the case of Egypt and Mali, local knowledge supports and complements scientific knowledge. Extensive field knowledge often exists with local experts and communities, on locations the flood prone areas. In the development of the EWS in Mali and Egypt, the absence of substantial formal research was compensated by the local knowledge especially to determine the most effective preparedness planning measures. Documenting the local knowledge is instrumental to strengthen communities' collective memory and maintain high the level of awareness.

Community-based EWS shall further put at the centre of effective system the identification of existing vulnerability and avoid creation of new risk accumulation (building on risk areas or with the wrong materials or design). As well, it is important that gaps in institutional capabilities in risk governance at the local level are identified (policies, legislation, organizational arrangements, ethical approaches, education, awareness, training, research, scientific and technological capacities, etc.) prior to the design and development of a EWS.

Providing early warnings on vulnerability existence or development is the best way to have communities building a culture of prevention. This can be similar to health prevention programmes, in which the emphasis is on sanitation, nutrition, exercise are focusing on what can be done for preventing rather than curing a disease or illnesses (quote from Briceno, S. interview 2013).

b. **Better risk communication: the new frontiers of risk communication**
Emerging areas in risk communication that shall be further explored in the post-2015 DRR framework is the use of new technologies and social media in risk communication.
In Indonesia, the role of the end-users in re-twitting the warning issues for tsunamis has been analysed by Chatfield (2013) and offer an example of a new frontier in risk communication. Social media open up to a new role for the early warning end-users not only seen as active beneficiary but also crucial players in the dissemination process that traditionally belonged to the relevant authorities.

c. **Local authorities and communities at the centre.**
Involvement of local authorities is essential to act on alerts. Because of decentralisation policies, local governments have more and more often been given substantial responsibilities in disaster risk management with not enough capacity and resources to effectively act. There is a need to guide community-based initiatives for disaster risk reduction. Initiatives such as the use of self-assessment tool at local scale as the Local Governance Self-Assessment Tool (LGSAT) of the UNISDR 'Making the cities resilient' campaign can play a role in assessing the needs and suggesting the gaps that have to be addressed in making EWS efficient at the local level.

d. **The business case for EWS**

Evidence suggests that EWS have large cost-benefit ratios and multiply the invested money in terms of avoided damage. Yet, the initial investment is large and so is the operational cost (institutional capacity, need for regular updating and maintenance). Alternative financing mechanisms can be piloted looking at development of strategic public-private partnerships (such as with the insurance sector) under the guidance of the HFA +.

e. Better loss accounting and vulnerability analysis will further boost the added value of an EWS

A better identification of the vulnerable areas, groups or assets can help to focus on particular zones and define zone-specific prevention, risk reduction and preparedness measures. The HFA + shall call for scaling up investments in loss accounting, needed to improve insights on the costs and benefits (avoided loss) of an EWS and other flood risk management measures. Well-established and maintained national databases on disaster damages and losses contribute to enhance deterministic risk assessment models and in turn, more accurate risk assessments improve the effectiveness of EWS in informing risk management planning

f. Highlight the use of EWS in prospective and corrective risk management while connecting the DRR to the climate change global agenda.

EWS do not only reduce existing risks, but also have a value in adapting to the future risks. Compared to 2005, when the HFA was endorsed, the knowledge on the emerging risks posed by climate change has significantly increased. The scientific literature on the connections between extreme events and climate change, summarized by the 2012 IPCC Special Report "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)" is an important synthesis for defining the role of the HFA + vis-à-vis climate change issues. Consequently, the HFA + has the possibility to better link DRR to the global climate change agenda and, in this regard, EWS can play a significant role in advising climate adaptation measures, especially in floods and droughts management in rural areas, as showcased in the Inner Niger Delta case study presented in this paper.

g. Think of multiple purposes for an EWS, preferably from the design phase

A flood EWS is not only relevant for flood emergencies, but offers added values and important information for other sectors including river basin management, climate change adaptation, health, nature conservation and livelihood.

While the HFA adequately highlighted the need for multi-hazards EWS, the HFA + can further explore the multi-dimensional applications of a sector specific EWS (for example floods) and see its application in sectors such as public health as presented in the case study from Mali.

h. Match the complexity of an EWS to the existing resources, institutional and technical capacity and the available data: the role of open-source risk information and software.

Collecting real-time weather data requires specific and high-tech expertise and high-performance computer facilities. Rainfall maps, whether from NWP or satellites are large files. Without an intelligent data storage and retrieval technique, the data volumes may become useless. NWP furthermore uses highly specialised simulation software and products data formats specifically developed for weather forecasting. The best performance is usually offered by combination of models. The latter is referred to as "ensembles" forecasting. Most NWP models are very expensive. There is one NWP software however that is freeware and proven to be successful (amongst others in the FlaFloM project), namely the Weather Research and Forecasting Model (WRF).

The HFA + can guide and encourage the national hydromet institutes in seeking partnerships with the scientific community and the private sector, to encourage the use of open-source resources, such as WRF and the production of accessible data and risk information.

i. **Pro-active decision-making under uncertainty and the role of people-centred EWS**

In the start-up phase of the EWS it should be kept in mind that there is still a relatively large factor of uncertainty in the prediction. This can lead to two types of failures: a false warning and a lack of warning. A warning is false when an event such as a flash flood is forecasted but does not happen in reality. A lack of warning gives no warning when an event such a flood is actually coming. Considering that errors might occur, "working with uncertainty" is an important skill that needs to be enhanced by operators and decision-makers. The choice regarding the expected level of accuracy - linked to what level of risk is acceptable - is thus not only a technical question, but also a social/management question. Biased forecasts can lead to a loss of trust in the system by decision-makers and end-users, if they are not properly informed. People-centred EWS shall be further encouraged under the implementation of the HFA +. It is observed that for tsunamis[ix], whose false warning rate is intrinsically high as there are a number of individuals who, following reception of false warnings, decide to ignore future notices. Building a culture of preventions, means as well make the population aware of the possibility of false warnings and build their trust on the fact that reacting to the warning is still the best option given the risks of losses that are at stake.

7. Conclusions

In the past three decades, improved forecast and EWS have been the drivers of the reduction in vulnerability and mortality risks at the global level. The HFA has played a key role in creating this awareness among policy makers, practitioners and the scientific community and contributed to a stronger coordinated approach among hydrometeorological forecasters, civil protection practitioners and end-users.

Efficiency in forecasting, modelling and dissemination of the warnings is a field which is still far from reaching a "plateau" of knowledge creation. Innovation and technological advances will keep pushing the boundaries of the state-of-the-art knowledge on EWS, even in the most advanced countries such as in Belgium.

There is already evidence of the positive economic return of investments in EWS, and the HFA + can create the momentum for scaling up investments in research and development of EWS and promote technological transfer among countries.

The HFA + can further highlight the necessity of community based and people-centred EWS, and the need for a coordinated approach not only internationally (as already emerged in the HFA) but also intra-country at different level of governance.

The three case studies presented in this paper highlighted a series of opportunities to further expand the use of EWS for disaster risk management into the sphere of other disciplines such as health and climate change adaptation. They also reiterated the importance of local knowledge in designing, planning and implementing EWS. The involvement of the communities and end-users is the only option to reach an impact once the warnings are released.

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Endnotes

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[i] More information can be found at http://www.wmo.int/pages/prog/drr/projects/Thematic/MHEWS/MHEWS_en.html

[ii] More information can be found at: http://www.unisdr.org/2006/ppew/whats-ew/basics-ew.htm

[iii] Assessment of the Hayan typhoon damages is still ongoing at the time of writing. Source for the number of deaths is the Philippines National Disaster Risk Reduction and Management Council.

[iv] Full information on the HFA goals and priorities of actions can be found at: http://www.unisdr.org/files/8720_summaryHFP20052015.pdf

[v] Detailed information on the achievements on HFA Priority 2 from the HFA National monitor reports 2009-2011 can be found at: http://www.preventionweb.net/english/hyogo/progress/documents/hfa-report-priority2-3(2009-2011).pdf

[vi] Available at: https://unisdr.org/we/inform/publications/32996

[vii] Currently 2 EWS in Belgium, this paper targets "www.overstromingsvoorspeller.be"; An unified portal is under development at www.waterinfo.be (expected in 2014)

[viii] Web portal and more information at www.opidin.org

[ix] For example: http://www.theguardian.com/world/2007/jun/07/indonesia.ianmackinnon