DEWFORA

IMPROVED DROUGHT EARLY WARNING AND FORECASTING TO STRENGTHEN

PREPAREDNESS AND ADAPTATION TO DROUGHTS IN AFRICA

DEWFORA

A 7th Framework Programme Collaborative Research Project

Final Project Report

March 2014

Page intentionally left blank

DOCUMENT INFORMATION

Title	Final Project Report
Lead Author	Micha Werner
Contributors	Sophie Vermooten
Distribution	CO: Confidential, only for members of the consortium (including the Commission Services)
Reference	Periodic Report No. 2

DOCUMENT HISTORY

Date	Revision	Prepared by	Organisation	Approved by	Notes
16 March 2014	1	Micha Werner	Deltares	Sophie Vermooten	

ACKNOWLEDGEMENT

Page intentionally left blank

EXECUTIVE SUMMARY

This report is the final project report of the EU-FP7 project "improved Drought Early Warning and FORecasting to strengthen preparedness and adaptation to droughts in Africa (DEWFORA)". The project was initiated in January 2011 and was completed at the end of December 2013. The project had a special focus on drought forecasting and warning in the African continent, and was developed by a team of 19 leading institutes across Africa and Europe. The principal achievement of this major EU-FP7 research effort has been the development of a comprehensive framework for drought forecasting, warning and response. Within this framework a protocol has been established that can guide the development and implementation of effective drought forecasting and warning. This protocol provides four key question that are to be addressed, with the research conducted in the project contributing to helping answer each of these.

- *What is the science available?* In response to this question the project has contributed significantly to the state-of-the-art in meteorological, hydrological and agricultural drought forecasting. The ability to forecast drought indicators and thresholds across Africa and in particular in four basin case studies has been established in detail. Results show clear potential in forecasting relevant indicators at medium-range to seasonal time scales, though predictability is shown to differs across the continent depending on climatology. Research on expected changes to drought indicators due to the changing climate also shows a varied picture in terms of precipitation, with confidence equally being geographically distributed across the continent. Increases in heat waves were projected with greater confidence.

- *What are the societal capacities?* An approach has been developed to evaluate vulnerability of society to drought. This is one of the first approaches developed in assessing vulnerability to drought, and application to continental and national scale show reasonable reflection of impacts of past droughts.

- *How can science be translated into policy?* The project has analysed current drought capabilities across the continents. Current gaps and impediments to the implementation of effective drought forecasting and warning, such as lack of technical and human capacity.

- *How can society benefit from the forecast?* Research in forecasting drought has taken a user-oriented approach. Through forecasting indicators that are relevant to the end-users, these are supported in taking decisions on implementing measures through which drought impacts can be mitigated.

The framework for establishing drought forecasting and warning, through the protocol and the research that supports the protocol provides a comprehensive approach in developing effective drought forecasting and warning. This contributes to the development of policy in establishing drought forecasting and warning as an effective drought impact mitigation strategy, as well as to the state-of-the-art in drought forecasting. A pre-operational map server, extending the technology developed of the European Drought Observatory operational at the Joint Research Centre provides a "pre-operational" drought forecasting system for Africa that provides information both on drought hazard as on drought vulnerability.

This final report provides an overview of the main Science and Technology advances in the DEWFORA project. The report also gives insight into the societal impacts and socio-economic benefits of the project and how the results of the project can be exploited. Overviews how the results of the project are disseminated, including 20+ peer reviewed publications, an information relevant to the science-policy interface are provided.

Page intentionally left blank

TABLE OF CONTENTS

LIST OF FIGURES

Page intentionally left blank

LIST OF ABBREVIATIONS

AGM	Annual General Meeting
AGRHYMET	Regional Training Centre for Agro-meteorology and Operational Hydrology
AR4	Fourth Assessment Report of the IPCC
CARE	Cooperative for Assistance and Relief Everywhere
CFU	Commercial Farmers Union
CCAM	Conformal Cubic Atmospheric Model
CGMS	Crop Growth Monitoring System
CICs	Community Information Centres
DESA	Drought Emergency in Southern Africa
DEWFORA	Improved drought early warning and forecasting to strengthen preparedness and adaptation to droughts in Africa
DG-ENV	Directorate General Environment
DG-DEVCO	Directorate General Development Cooperation
DG-RTD	Directorate General Research and Development
DG-CLIMA	Directorate General Climate Action
DMC	Drought Monitoring Centre
DMN	National Directorate of Meteorology
DPA	Regional Directorates of Agriculture
DPPA	Disaster Prevention and Preparedness Agency
DWA	Department of Water Affairs
DVI	Drought Vulnerability Index
ECMWF	European Centre for Medium Range Weather Forecasting
EDO	European Drought Observatory
ENSO	El Niño – Southern Oscillation
EWRD	Early Warning and Response Directorate
EWWG	Early Warning Working Group
FAO	United Nations, Food and Agricultural Organization
FEWSNET	Famine Early Warning Systems Network
FP7	Seventh Framework Program
GDIS	Global Drought Information System
GEO	Global Earth Observation
GEOSS	Global Earth Observation System of Systems
GHARCOF	Greater Horn of Africa Climate Outlook Forum
GWAVA	Global Water Availability Assessment
ILRI	International Livestock Research Institute
IPCC	Intergovernmental Panel for Climate Change
LEWS	Livestock Early Warning System
LIMCOM	Limpopo Commission
LIU	Livelihoods Integration Unit
LPCI	Livelihood Protection Cost Index
MINAGRI	Ministry of Agriculture
NAO	North Atlantic Oscillation
NDVI	Normalised Difference Vegetation Index
NGOs	Non-Governmental Organizations
OPIDIN	Outil de prédiction des Inondations du Delta Intérieur du Niger

RBO	River Basin Organisation
RRC	Relief and Rehabilitation Commission
RRSP	Regional Remote Sensing Project
SADC	Southern Africa development community
SAP	Early Warning System
SARCOF	Southern Africa Regional Climate Outlook Forum
SAWS	South Africa Weather Services
SWAT	Soil and Water Assessment Tool
SPI	Standard Precipitation Index
SSD	Secretariat for the Drought Disaster
SST	Sea Surface Temperature
SWIM	Soil and Water Integrated Model
UN	United Nations
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
VAC	Vulnerability Assessment Committees
VCI	Vegetation Condition Index
VAM	Vulnerability Analysis Mapping
WB	World Bank
WHO	World Health Organization

1.   SUMMARY DESCRIPTION OF THE PROJECT AND ITS MAIN OBJECTIVES

1.1   INFORMATION FROM ANNEX I OF THE GRANT AGREEMENT

Grant Agreement number: 265454

Project acronym: DEWFORA

Project title: Improved Drought Early Warning and FORecasting to strengthen preparedness and adaptation to droughts in Africa

Funding Scheme: Collaborative Research Project

Period covered: from 1st January 2011 to 31st December 2013

Name of the scientific representative of the project's co-ordinator,

Title and Organisation: Dr. Micha Werner, Deltares

Tel: +31-6-20006389

Fax: --

E-mail: Micha.Werner@deltares.nl

Project website address: www.dewfora.net

1.2   GENERAL DESCRIPTION OF THE DEWFORA PROJECT, GOALS AND ACTIVITIES

Drought is one of the major environmental disasters in several parts of the world, including parts of Europe and Africa, and droughts have resulted in extensive damage to the environment, the economy, and livelihoods. The extent of such impacts was very evident during recent droughts, such as that which affected the horn of Africa in 2010/2011. The Mediterranean region both in Europe and North Africa has been struck by a number of extremely dry seasons, and this trend is expected to continue.

Drought is quite different to other natural hazards in that a drought event is slow evolving, and impacts large geographical areas. In essence drought is a departure from normal climatic conditions, and as all climates are variable, drought is a normal part of any climate, and occurs both in arid and humid areas. In many cases drought leads to water scarcity but it is good to bear in mind that water scarcity is not always a result of drought but may also be caused by over-allocation and/or poor management of available water resources.
While the impacts of droughts are often related to agriculture, there may be much wider societal and economic repercussions. For instance, droughts may lead to restrictions on drinking and industrial water use, lower hydropower production, navigation problems,

reduction in ecological quality, increase in occurrence of forest fires, and reduction in income from tourism.

To deal with the risk posed by drought an adequate policy response is required, such as the establishing of a drought management plan. Such a drought management plan deals with how communities, economic and environmental assets may be affected by drought, and perhaps more importantly drought mitigation actions that may help reduce impacts. Monitoring of drought is a key step in detecting its occurrence and prerequisite to the timely enacting of drought management plans and the implementation of drought impact mitigation actions. Early warning can improve the timelines with which drought management planning can be enacted and can therefore help substantially increase the effectiveness of drought impact mitigation.

Despite the recognition of the benefit, drought early warning is currently little developed, with a focus on drought monitoring. The objective of the DEWFORA project has been to develop a framework for the provision of drought early warning and response. This framework has been developed with a main focus on Africa, though the project has been closely connected to similar research efforts in Europe and globally. The framework that has been developed covers the full chain from monitoring and vulnerability assessment, to forecasting, warning, response, and knowledge dissemination. A key part of the framework developed includes a protocol for drought forecasting and warning in which the main questions to be addressed are:

- What is the science available? This is answered through evaluating how forecasting can be used in the detection of the signs of impending drought. Defining risk levels and analysing the signs of drought in an integrated approach that considers both hazard and vulnerability.

- What are the societal capacities? This is answered through evaluating the institutional framework that enables policy development.

- How can science be translated into policy? This is answered through linking science indicators into the actions/interventions that society needs to implement, and evaluating the policy implementation.

- How can society benefit from the forecast? This is answered in taking a user oriented approach to evaluating how the provision of information can be of benefit to potentially affected groups.

Figure 1 Key questions in the protocol for drought forecasting and warning

The project involved nineteen research partners, including ten in Africa and nine in Europe, with these partners working jointly across the different themes of the project. The research work was organised in four thematic work-packages in which the scientific developments were focused, and a set of some six case studies which worked conjunctively in the development and application of the science. Additional to the development of the science in the project, significant attention was paid to dissemination and interaction with the users of drought early warning information and dissemination of project results to both the policy community as the scientific community. The project was structured in eight work packages, each with its own specific objectives (see also Figure 2):

▪ **WP1** focused on consortium management and liaison with the European commission.

▪ The objective of **WP2** was to provide a review of existing drought monitoring and warning capacities in Africa and to assess mitigation practices and adaptation strategies. A gap analysis was made that helped understand current constraints as well as identify opportunities for improvement.

▪ In **WP3** a risk based approach to characterising drought through newly developed indicators has been developed, which has been applied in the case studies in WP6 both at the continental as at the regional scale in the greater Horn of Africa. Also this work package addressed the expected impacts of climate change on drought risk across the continent, with a focus on selected case study basins.

▪ The work in **WP4** constituted primarily the progression of forecasting of meteorological, hydrological and agricultural drought at medium range to seasonal time scales. Both statistical and physically based model approaches were explored, with a significant focus on developing an understanding the skill with which drought can be forecasted.

▪ The conceptual framework for drought early warning was developed in **WP5**. This framework was developed based on the concepts in previous work packages, and

comprises of answering four key areas, (i) the science available, (ii) the societal capacities, (iii) the translation of science into policy, and (iv) the benefit to society.

- **WP6** connected the advances made in work packages WP2 to WP5 to the four basin scale case studies, as well as in a prototype pan-African drought monitoring and forecasting system. A comparison between European and African practices in drought forecasting and warning was also made.

- **WP7** focused on knowledge disseminating and embedding of knowledge with stakeholders and water resources capacity building programmes. This included stakeholder meetings, conferences, the development of training courses (including an online course), and even two video documentaries for the general public.

- **WP8** was dedicated at synergies and exchange with related research projects in Europe and Africa (primarily within the context of the Africa call projects), and outreach to policy networks in Africa and Europe. Science-Policy briefs aimed at Africa and at Europe were developed.

This final report provides a summary of the work done and achievements of the DEWFORA project, with a focus on the advances made in the project, how the results from the project can be disseminated and exploited.
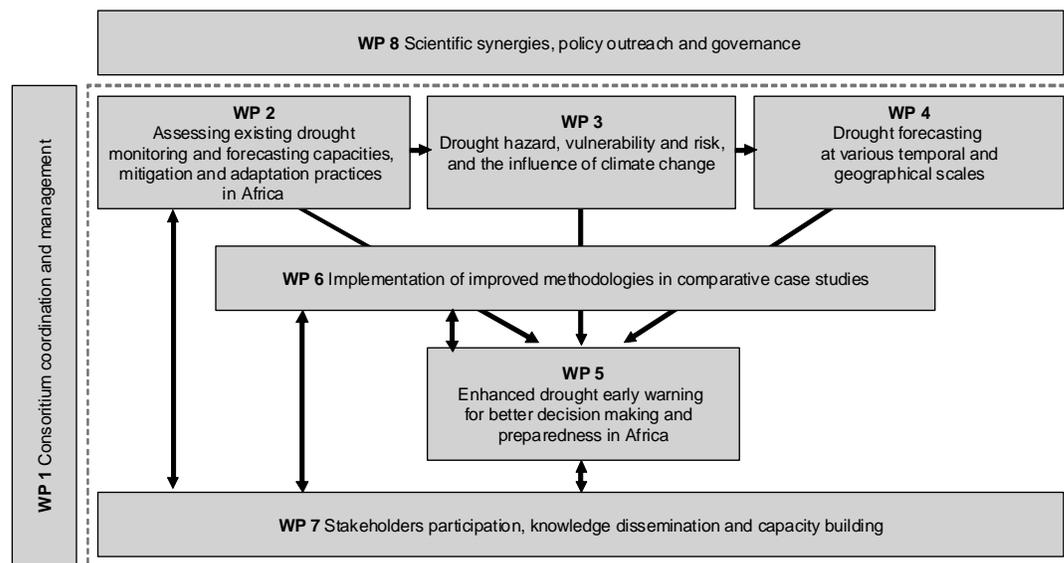
Figure 2 Graphical representation of the components of the project and their interdependencies

1.3   MAIN S&T RESULS

1.3.1   Overall

Within the DEWFORA project the main goal has been to develop a framework for drought forecasting and warning. One key part of the framework that has been developed is an evidence based protocol, in which four key questions are to be answered. The first is the assessment of the science available that can be used in forecasting drought. In response to this question the project has developed drought forecasting methods for forecasting meteorological, hydrological and agricultural drought. In developing these, specific attention has been paid to the skill of forecasting relevant drought indicators, thus revealing the predictability of drought across the different climatological conditions found in Africa. This shows that there is clear skill, though there are distinct variations across the continent. The impact of climate change on the occurrence and severity of drought across Africa has also been assessed, showing confidence in thee increase of heat waves across the continents, while the signal for precipitation is less clear, with confidence in project increase in Eastern Africa, and a decrease in Southern and Northern (Mediterranean) Africa. The signal across Western Africa has found to less certain. In each of the four basin case studies, advances made in the scientific work package have been applied in practice.

The most important scientific results of the DEWFORA project are:
- A comprehensive assessment of the current state of drought forecasting and warning across Africa,
- The development of an approach to assessing vulnerability of exposed societies to drought, and validation of the framework at both a continental and a regional scale,
- The development of projection of changes in frequency of occurrence and severity of droughts across Africa through the use of very high resolution simulations,
- An assessment of the skill with which meteorological and hydrological and, to a more limited extent, agricultural models can be used to forecast relevant drought parameters across Africa,
- The development of a protocol that can be used to develop drought forecasting and warning that is based on scientific evidence but also benefits society,
- 15+ articles in peer reviewed, several of which have been developed in the context of a special issue on drought forecasting and warning in a leading, open access, journal.

1.3.2   Reviewing the state of the art in drought forecasting and warning in Africa

An important starting point to exploring improvements in drought forecasting and warning across Africa has been the review of existing drought monitoring and warning capacities and to assess mitigation practices and adaptation strategies that has been undertaken in the context of WP2. Within this work package, a comprehensive review of these existing capacities has been completed, providing a unique overview of the current state of the art in drought forecasting and warning across Africa. This has been undertaken in five steps; (i) establishing an inventory of drought monitoring and forecasting systems in Africa, (ii) establishing an inventory of institutional frameworks and drought mitigation and adaptation; (iii) assessing drought warning experiences. These assessments have led to the development of the final two parts; (iv) a gap analysis on drought monitoring and forecasting systems in Africa, and (v) a gap analysis on existing drought mitigation and adaptation practices.

The review identified a large number of institutions at local level, though at that same local level it was found that in practice traditional knowledge is applied more than formal systems. This points to the need to link formal monitoring and early warning systems to local knowledge systems coupled with methods that support learning and adaptation. A lot of institutional involvement was found at the local level, though this decreases when moving from in-situ observations to the development of new tools and methods. Additionally the latter is hindered by the low level of technical and scientific personnel in most organisations issuing early warning products, thus suggesting limitations in the potential application of methods, tools and data.

A key finding of the review was that most drought mitigation actions implemented in Africa are food aid, drought relief programs, growing of drought tolerant crops, saving livestock, improving water use efficiency and installation of boreholes, wells and small dams. These mitigation actions are implemented mostly by institutions involved in agriculture extension services, food aid, policy, advocacy and water supply. Common adaptation interventions include water harvesting, construction of water infrastructure, traditional/cultural practices and technologies, water conservation, increased crop monitoring and crop diversification. The number of institutions and actions involved in adaptation was, however, found to be far less than those involved in mitigation.

While it was found that several initiatives were providing drought forecasts across Africa, both from within Africa as well as global scale efforts, the uptake and actual use of these forecasts has hitherto been limited, rendering most systems ineffective from the point of view of the stakeholder. Several deficiencies were noted, including the spatial scale of information

which makes it of limited use to local stakeholders, as well as the difficulty in accessing products. A more complete documentation of the review of existing capacities can be found in five reports that are deliverables to the project. These can be downloaded from the project website.

1.3.3 Assessing drought vulnerability at continental and regional scale

Many of the indicators used in monitoring drought focus on hazard aspects, including the frequency and severity. There has as yet been little attention in the drought community to take a risk based approach that takes not only the drought hazard into account, but also the consequence of the occurrence of drought. There is, however, a growing realisation that the understanding of drought risk to needs to include not only the hazard itself, but also an understanding of the vulnerability of those affected. In this part of WP3 a white paper was developed that can be used for the definition of drought risk that incorporates both natural and social aspects and their evolution over time, combining a hazard, exposure and the capacity to cope with the impacts of drought (see *Figure 3*). The proposed approach is significant from the operational point of view as it links the hazard with the propagation of drought effects across water resources, water sectors and society.

Patterns of drought vulnerability across Africa were examined through mapping of a selection of the indicators proposed. This was first done at the country level, given that much of the data required to establish the developed vulnerability indicators is available at the country level. The method was additionally applied and validated at the regional scale in the case studies, including at the national level in Kenya, and in the Oum-er-Rbia basin in Morocco. The white paper that was developed describes the proposed indicators in detail and is available on the DEWFORA project website, as are the results of mapping vulnerability at the continental scale.

Vulnerability analysis
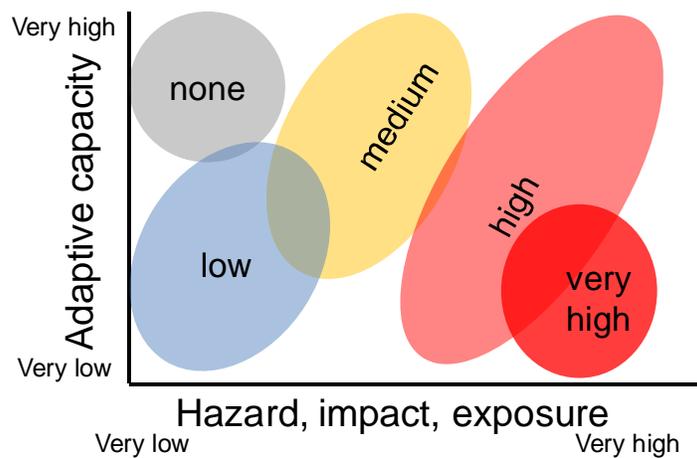
Figure 3 A risk based approach to drought vulnerability

1.3.4   Drought hazard across Africa a changing climate

To develop an understanding of the evolution on drought risk, the impact of the changing climate was researched in the second part of WP3. In this the impact of enhanced anthropogenic forcing on the indicators that can be used to describe of meteorological and hydrological drought over the African continent was explored. The analysis presented is largely based on very high-resolution projections of climate change over Africa. These were performed as part of DEWFORA, and were obtained using a variable-resolution global model to downscale the projections of a number of coupled global climate models (CGCMs) over Africa. The variable-resolution conformal-cubic atmospheric model (CCAM) model was applied for this purpose. CCAM was developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia. The model was integrated on the computer clusters of the Centre for High Performance Computing (CHPC) of the Council for Scientific and Industrial Research (CSIR) in South Africa. Simulations were performed for the period 1961-1990 under the A2 scenario of the Special Report on Emission Scenarios (SRES) of the Intergovernmental Panel on Climate Change (IPCC). The regional model simulations were first bias-corrected using observed monthly "climatologies" from the climatic research unit (CRU), before being used to study a selected drought metrics and their projected changes. The research conclusions were further strengthened through the analysis of CGCM simulations of Assessment Report Five (AR5) of the IPCC, and on the conclusions drawn from the CGCM projections described in Assessment Report Four (AR4).

The research revealed that the southern African region is projected (under the low mitigation or strong growth in emissions) to experience a general increase in the number of years with below-normal rainfall, although a decrease in dry years is also plausible over the central interior regions. The analysis of CGCM simulations reveal that an increase in extreme wet years over the region is also plausible, that is, climate variability over the region is projected to increase. In the case of the Limpopo river basin (a DEWFORA case study area), the regional projections are particularly robust in indicating an increase in years with below-normal rainfall. The Limpopo basin has been shown to be the part of the African continent that experiences the highest frequency of heat-waves under present-day climate, and drastic increases in heat-wave frequencies are projected for the basin, for both the mid- and far-futures. In fact, drastic increases in heat-wave frequencies were found to be plausible over large parts of southern Africa by the end of the century. Most of the region is consistently projected to experience an increase in the frequency of high fire danger days. There is a consistent and robust message across the downscalings performed of East and tropical Africa experiencing a decrease in the number of years with below-normal rainfall. The CGCM simulations analysed confirm this result, also indicating an increase in the number of wet years for the region, and reduced rainfall variability. These results are also valid for the DEWFORA case study region of the Blue Nile river basin (see Figure 3). Heat-waves do not occur over much of the tropics under present-day conditions, due to the tropics being prone to frequent convective rainfall events. However, under future anthropogenic forcing, critical temperature thresholds over the tropics are being exceeded in response to general regional warming, resulting in an increasing frequency of occurrence of heat-waves over this part of the continent. The number of high fire danger days is also consistently projected to increase over these regions.
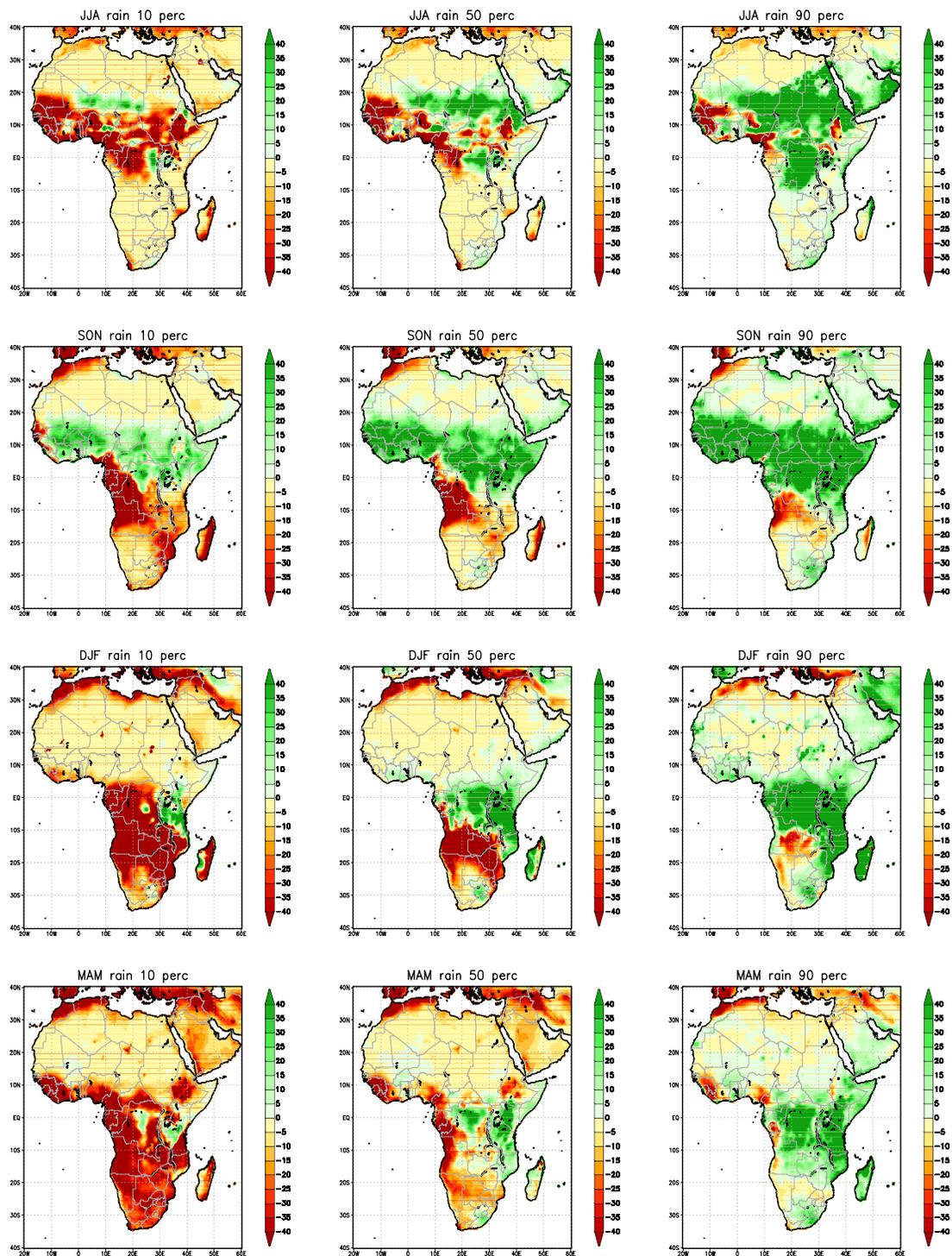
Figure 4. Projected changes in seasonal rainfall totals (mm) over Africa, for the period 2071-2100 relative to 1961-1990. The 90th percentile (upper panels), median (middle panels) and 10th percentile (lower panels) are shown for an ensemble of six downscalings of CGCM projections, for each of the seasons. The downscalings were generated using the regional model CCAM. All the CGCM projections contributed to AR4 of the IPCC and are for the A2 SRES scenario (from deliverable D3.5)

More uncertainty surrounds the projected futures of the number of years with below-normal rainfall over West Africa, including the DEWFORA case study region of the Niger basin. A mixed signal of both increases and decreases in the number of years with below-normal rainfall is projected. However, further to north over North Africa and its Mediterranean coast, another robust signal exists in the projections. These regions are projected to see drastic increases in the number of years with below-normal rainfall, and a decrease in wet years. Signals of drying and more years of below-normal rainfall are also valid for the DEWFORA case study of the Oum-er-Rbia basin. These North African regions are also robustly projected to experience drastic increases in heat-wave frequencies during the 21st century.

Given the ample evidence of plausible increases in the frequency of occurrence of years of below-normal or above-normal rainfall over much of the continent, and the robust signal of heat-wave frequencies increasing over Africa under climate change, the skilful projection of these quantities at seasonal timescales may be expected to become more important. These aspects were explored in some detail over the Limpopo river basin, a case study region with a long history of quality atmospheric observations that allow for in depth model verification studies. It was shown that the state-of-the-art ECMWF seasonal forecasting system can skilfully predict the intra-seasonal variability of heat-waves and spells over the region, at seasonal time-scales. This is an encouraging result, indicating the potential of skilful seasonal forecasts as an adaptation mechanism to climate change.

Additional to the impact on meteorological drought, the impact on hydrological drought was also assessed. Hydrological models were forced with the simulations of climate models, in order to investigate the potential impacts of climate change on the hydrological cycle over Africa. The river basins of the Niger, Blue Nile, Atbara, Ubangi and Limpopo, covering a wide spectrum of climates, topographies and ecological conditions, were studied in this regard. In order to compare climate-change induced trends in river discharge over the different basins, the semi-distributed eco-hydrological model SWIM, the PCR-GLOBWB, and the Nile Forecasting System (NFS) were set up and adapted to the particular conditions and requirements of each basin. For each of the hydrological models, the set-up procedure involved specialized model calibration procedures as well as the adjustment of input data. The modeling systems also incorporated for each basin representations of water management infrastructure, such as reservoirs and irrigation schemes as well as wetlands and their inundation dynamics. In order to project changes in the hydrology of the basins under climate change, the models were driven by downscaled climate projections of different CGCMs. Comprehensive validation revealed model efficiencies ranging from adequate to good, depending mainly on quality and availability of input and calibration data. The trends in mean discharges, seasonality and hydrological extremes were subsequently compared,

across the different downscalings and hydrological models employed. The projections agreed mostly regarding the direction of changes, however, the range of uncertainty of the simulations driven by different climate models is large as far as the magnitude of the projected changes is concerned. Despite the strong warming of the African climate system, a considerable probability for an increase in river discharge for means and extremes is projected across all five basins.

1.3.5   Forecasting drought at the medium to seasonal time scales

One of the key aspects of the research in the DEWFORA project concerned the scientific advance in forecasting meteorological, hydrological and agricultural drought at the medium range to seasonal time scales. Research was organised around three key aspects; meteorological, hydrological, and agricultural drought, with each clearly being sequentially connected.

Development of meteorological drought forecasting models at continental/regional scale
Research on the available science in meteorological droughts focused on the use of existing forecasting products, including the ECMWF System 4 seasonal forecasts, and the CSIR seasonal forecast based on the CCAM model. The reference dataset used was the ECMWF ERA-Interim re-analysis dataset.

Based on these seasonal forecasts, a set of meteorological drought indicators have been calculated for the African continent. A multi-model evaluation of seasonal forecasts of precipitation for the African continent suggested that the multi-model ensemble did not consistently outperform any particular model. Although this would seem inconsistent with conventional scientific literature on the skill of multi-model ensembles (mainly focused on Sea Surface temperature forecasts), only four models were used, and the intrinsic noise of precipitation fields on the seasonal scale generated by dynamical models was considered to be a potential reason. An evaluation of global precipitation datasets over the African continent highlighted the large uncertainty in these products, which poses a limitation in the verification of seasonal forecasts.

A prototype of an integrated drought monitoring and forecasting was developed and applied to the different case studies regions. This prototype was designed using near-real time products and as it is based on existing operational products it itself has the potential to be become operational. This will be discussed further on in this section in the context of the African Map server developed as a part of the case studies. An initial evaluation of the system in terms of skill and reliability was performed, showing encouraging results for some

regions in Africa where the seasonal forecast of precipitation are skilful. An example was an evaluation performed for forecasts the 2010/11 drought in the Horn of Africa.

The methodologies and datasets developed were applied in Nile test catchment. Droughts and floods over the upper catchment of the Blue Nile and their connections to the timing of EL Nino and La Nine Events was studied, along with numerical simulations using a climate model. The Blue Nile originates from Lake Tana in the Ethiopian Highland and contributes about 60-69% of the main Nile discharge. Previous studies investigated the relationship of sea surface temperature (SST) in the Pacific Ocean (Niño 3.4 region) to occurrence of meteorological and hydrological droughts in the Nile basin. In the work developed here the focus is on the dependence of the occurrence of droughts and floods in the upper catchment of the Blue Nile on the timing of El Niño and La Niña events. Different events start at different times of the year and follow each other exhibiting different patterns and sequences. The impact of this timing on temporal patterns of droughts and floods in the Blue Nile were studied. The comparison between the discharge measurements (1965-2012) at the outlet of the upper catchment of the Blue Nile and the El Niño index shows that when an El Niño event is followed by a La Niña event there is a 67% chance for occurrence of an extreme flood. Furthermore, it was also found that 83% of El Niño events starting in April-June resulted in droughts in the upper catchment of the Blue Nile. Although the study was limited by a reduced number of samples, observations as well as global model forecasts of SST during the April-June period could be used in seasonal forecasting of the Blue Nile flow.

The observed statistical relationship between ENSO and the hydrology of the Blue Nile were simulated using the tropical-band version of the regional climate model RegCM4 (or Reg-TB) for the 28 year period 1982-2009. An ensemble of 9 simulations was completed to investigate the role of ENSO in the hydrology of the Blue Nile catchment. Reg-TB results show good skill in simulating the climatology of temperature, outgoing long-wave radiation patterns as well as related atmospheric circulation features during the summer season (i.e. the rainy season over the Blue Nile catchment). The model also succeeds in reproducing the observed negative correlation between Pacific SST and rainfall anomalies over the Blue Nile catchment, and in particular the association of droughts over the Blue Nile with El Nino events that start during the April-June period. Based on this it be concluded that the use of observations as well as model forecasts of Pacific SST during this season can provide a good basis for seasonal forecasting of Blue Nile flows.

Development of hydrological drought forecasting models at river basin scale
To support the prediction of hydrological drought, hydrological models were developed at both the continental scale as well as at the scale of the case study river basins. The models

selected were largely based on an evaluation made of hydrological models that are suitable to drought forecasting. The evaluation found that while there are several global hydrological models currently available with different levels of complexity and data requirements, not all of these models sufficiently represent all the water balance components that are particularly relevant in arid and semi-arid basins in sub-Saharan Africa. The major criteria used for assessing the suitability of the models are (1) the representation of the processes that are most relevant for simulating drought conditions, such as evaporation, surface water-groundwater interactions in wetland areas and flood plains and soil moisture dynamics; (2) the capability of the model to be downscaled from a continental scale to a river basin scale model; and (3) the applicability of the model to be used operationally for drought early warning, given the data availability of the region. Among the sixteen well known hydrological and land surface models selected for this review, PCR-GLOBWB, GWAVA, HTESSEL, LISFLOOD and SWAT show the best potential and suitability for hydrological drought forecasting in Africa.

The continental scale hydrological models were subsequently downscaled for the case study basins (Limpopo, Eastern Nile and Upper Niger), and linking these to the high resolution seasonal forecasts to establish the skill of hydrological forecasts, as well as to the high resolution climate scenarios. Skill in these assessments was evaluated in several ways, considering both skill scores used widely in literature, as well as scores that provide user oriented metrics. These user oriented metrics focus on the decisions that users such as rain-fed farmers need to take.

For the Limpopo basin a finer resolution version of the continental scale hydrological model PCR-GLOBWB was developed. The model was downscaled from a 0.5° to a 0.05° grid resolution, and an irrigation module was included to account for the highly modified hydrological processes in the irrigated areas of the basin. The Limpopo basin is one of the most water stressed basins on the African continent. This makes hydrological modelling extremely challenging as the runoff coefficients are extremely low in the natural situation, and even lower in the basin as it is extensively modified through reservoirs and irrigation. The downscaled model was first used to analyse the history of droughts in the Limpopo river basin in the period 1979-2010 with a view to identifying severe droughts that have occurred in the basin. The model was forced with daily precipitation, temperature and other meteorological variables obtained from the ERA-Interim global atmospheric reanalysis product from the European Centre for Medium-Range Weather Forecasts. Results show that a carefully set up process-based model that makes use of the best available input data can successfully identify hydrological droughts even if the model is largely un-calibrated. Indicators calculated were found to be able to represent the most severe droughts in the

basin and to some extent identify some the spatial variability of the hose droughts. Moreover, results show the importance of computing indicators that can be related to hydrological drought, and how these add value to the identification of droughts/floods and the temporal evolution of events that would otherwise not have been apparent when considering only meteorological indicators. In some cases, meteorological indicators alone fail to capture the severity of the drought. The model was also applied to forecasting droughts, using different meteorological forecast products. This included the model based ECMWF System 4 model, as well as two products based on resampled climatology. The first of these products considered a standard Ensemble Streamflow Prediction approach where all climatological years were considered equally important, while the second selected these based on the proximity of the ENSO index in the historical year to that of the forecast year. Results showed that the skill improved significantly when using either of these three products for lead times greater than 1-2 months – with the System 4 model providing the best skill. Of the two ESP products the conditionally sampled product was found superior, in some cases as good as those achieved with the ECMWF System 4 product, despite its simplicity.

Additional to the physically based model, a seasonal forecast based on a statistical approach was also developed for the Limpopo basin. Statistical models were set up to provide three month lead time forecasts based indices calculated in tele-connected ocean regions. Multiple linear models and an artificial neural network model were compared for major stations in the basins. The artificial neural network model was found to have the best performance in fitting the calibration data. However, the multiple linear models were found to be more robust in cross validation. However, the prediction skill of these models is still low. The best results are achieved for the station at Combomume in Mozambique, as it drains a large catchment of the upper Limpopo (see *Figure 5*).

For the case of the Niger case study, the eco-hydrological model SWIM was applied to reproduce past drought events with monthly bias corrected reanalysis climate datasets. The existing model was extended to include reservoir management, wetlands and floodplain dynamics to account for specific hydrological patterns encountered in the Niger case study, in particular the Inner Niger Delta. The results of the calibration and validation processes of the model SWIM show satisfactory results to further extend analyses of drought variability and impact in the Niger case study. The model was subsequently employed to simulate short-term hydrological forecast and long term hydrological projections in order to assess drought persistence and risk under a range of upstream water resources management scenarios. Model results were compared to the forecasts from OPIDIN (Outil de Prédiction de l´inondation dans le Delta Intérieur du Niger), an operational tool used in the basin based on simple statistical relationships between historical water level observations at different

gauging stations along the Inner Niger Delta. Compared to the SWIM model it was found that OPIDIN demonstrates less skill to predict extremes and tends to overestimate (for dry episodes) or underestimate (wet periods) peak flood levels. However, at the shorter lead times it shows better skill in capturing extreme events. Moreover, OPIDIN shows to better capture the peak levels than the timing of the peaks.
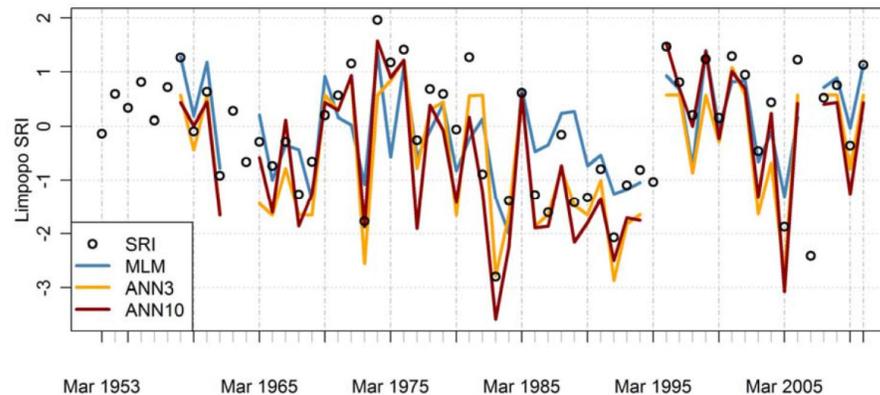
Figure 5 Combomume: Fitted statistical seasonal forecasts models of standardised rainy season runoff (SRIONDJFM) in June by a multiple linear model and artificial neural networks (ANN) with two degrees of complexity, one with 3 neurons (ANN3) and the other one with 10 neurons (ANN10).

Development of agricultural drought forecasting models

The third type of drought forecasting considered was that of forecasting agricultural drought. In the approach tested, the focus was not to develop forecasts of indicators of agricultural drought, but rather to provide forecasts of crop yields, as a function of the expected drought. This is clearly a variable of direct interest to farmers and agricultural organisations. Statistical agricultural forecasts have been considered in two of the basin case studies, the Oum-er-Rbia basin in Morocco, and the Limpopo basin in Southern Africa. Statistically downscaled NCEP re-analysis data and sea level pressure fields from a coupled model (the IRI's ECHAM4.5-GML-CFSSST initialised in April for MJJ forecasts) were used to forecast observed crop yields of three mountain locations in the basin. Results showed that the North Atlantic Oscillation (NAO) can be used to explain the variability for seasonal rainfall variability over the basin, and this can then be linked to crop yields.

This work was extended to include seasonal forecasts of crop yield indices in both basins, based on forecast meteorological parameters such as the 850 HPa level in the ECMWF

System 4 forecast. Results of the statistical downscaling show skill in forecasting crop yields for both deterministic (over 26 years) and probabilistic (over 16 years) skill estimates of statistical downscaling models for crop yields over both basins for forecast lead-times of up to 4 months. It was found that the low-level circulation data of the ECMWF S4 can be successfully downscaled statistically for certain dry-land crop production areas.
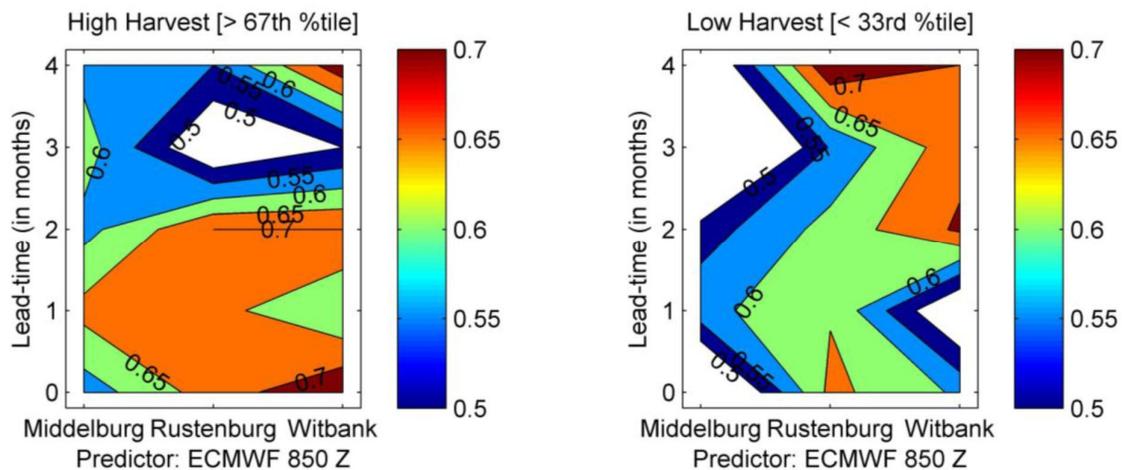
Figure 6. ROC values obtained for the Limpopo basin by retro-actively predicting high-yield (>67th percentile of the climatological yield record) and low-yield (<33rd percentile) seasons probabilistically over 16 years (1993 to 2008). The x-axes show the names of the agricultural districts of the basin considered here, and the y-axes show the forecast lead times in months. Values above 0.5 are considered to have skill, while perfect skill is at a value of 1.0.

1.3.6   Developing the framework for drought forecasting and warning

To be effective, the drought forecasting, warning and response process requires a holistic approach. In the previous section advances made in the forecasting of hydrological, meteorological and agricultural drought were discussed. However, in order to reduce the impact of drought a framework is required for using that forecast to initiate a warning if a drought is foreseen, and ensure there is an adequate public response. In work package 5 a framework has been developed for improving drought early warning and response in Africa.

The framework for drought warning and mitigation in Africa proposed will assist in establishing policy priorities based on scientific evidence that also strengthen existing institutions. Overall, a science-based approach is considered a useful guideline, but a number of challenges are recognized. Risk-based approaches to preparing for drought are focused on acquiring accurate probabilistic information about the events themselves. When this is not possible, the strategy fails. In contrast, understanding and reducing vulnerability does not demand accurate predictions of the incidence of extreme drought. Nevertheless, if may be politically difficult to justify drought vulnerability reduction on economic grounds. To

define an evidence-based approach the framework developed includes a protocol for drought forecasting and warning. In this protocol the main questions to be addressed are:

- What is the science available? This is answered through evaluating how forecasting can be used in the detection of the signs of impending drought. Defining risk levels and analysing the signs of drought in an integrated approach that considers both hazard and vulnerability.

- What are the societal capacities? This is answered through evaluating the institutional framework that enables policy development.

- How can science be translated into policy? This is answered through linking science indicators into the actions/interventions that society needs to implement, and evaluating the policy implementation.

- How can society benefit from the forecast? This is answered in taking a user oriented approach to evaluating how the provision of information can be of benefit to potentially affected groups.

Figure 7 Key questions in the protocol for drought forecasting and warning

Existing institutional practices and mandates in the case studies were assessed against the protocol and discussed in terms of gaps and opportunities for development of drought early warning systems in each region. It was recommended that drought monitoring is incorporated in all institutions involved in drought management in the time chain in order to anticipate drought impacts. To complement this in the context of a drought early warning system, the focus on vulnerability is considered very effective since it includes the evaluation of the capacity to anticipate and compensate the adverse effects of drought. If a drought forecast is available, drought managers gain time and can come closer to real drought impacts in their analysis. Within the drought forecasting and warning framework, the chart of organizational responsibilities for drought mitigation and communication lines will improve

coordination and strengthen existing institutions. The proposed science-based approach is a useful guideline, though it is recognised that some countries in Africa constraints on resources and capacity remain a challenge.

In a detailed review of drought preparedness at the local and regional scale in the Niger and Nile case study basins, and a comparison to what is considered the state of the art in drought forecasting and warning, several of these challenges were recognised. Deficits were found regarding data quality, data sharing, limited skills, including human resources/knowledge and technical resources, and particularly in the Niger case study recommendations on improving preventive and mitigating actions that could be applied, as well as improving the translation of the available science into policy which remains a challenge. The detailed analysis also pointed out that the "state of the art" should explicitly incorporate the local knowledge for forecasting and early warning systems should be adequately implemented on the one hand, while also regarding the influences of climate change and how this may influence future hazard on the other.

1.3.7   Drought forecasting and warning in the case studies

Eastern Nile Basin

The main activities in the Eastern Nile Basin case study were oriented towards researching the influence of El Niño anomalies on the occurrence of drought in Ethiopia and the Blue Nile and the analysis of different drought forecasting schemes. For assessing meteorological drought, the Standardized Precipitation Index (SPI) was applied to three "observed" rainfall datasets to assess the applicability in the study area. The three datasets are the Climatic Research Unit (CRU) rainfall dataset, the ECMWF Rainfall Reanalysis dataset (ERA40), and the gauge-satellite merged rainfall dataset produced by the Nile Forecast System (NFS dataset). The historical study period in 1961-1990 or beyond has been selected (except for the NFS dataset which starts in 1992). Future rainfall is taken from an ensemble of 6 dynamically downscaled climate simulations for the period 2021-2050 performed using the PRECIS regional climate model. The SPI has been calculated for different lead times from one month to one year.

The analysis shows that ERA40 overestimates rainfall for the Eastern Nile region compared to the CRU and NFS rainfall datasets for the early part of the record, distorting the rainfall distributions, and to a lesser extent the SPI distributions. CRU rainfall is higher than NFS for the region during the peak rainfall period, and thus has higher flood probabilities but similar drought probabilities. When PRECIS is run using ERA40 boundary conditions (which do not include precipitation), it overestimates rainfall over the whole year, resulting in different seasonal rainfall distributions compared to ERA40 rainfall. This has an effect on the SPI as

some dry years may be seen as wet and vice versa. Such biases need to be corrected, but their effect is somewhat reduced in calculating SPI due to the normalisation of rainfall distributions.

The current set of climate simulations indicated a general increase in rainfall over the region, though this does not exclude the increase of drought probability on the scale of the hydrologic year. The uncertainty bandwidth (defined by the range across the different simulations) increases near the ends of the SPI probability distributions, though this was not apparent for all lead times.

In terms of hydrological drought, a set of three indices has been applied to observed as well as simulated and forecasted flows using the Nile Forecast System (NFS) hydrological and forecasting components respectively. The three indices include the (i) drought classification of the Ministry of Water Resources and Irrigation (MWRI) of Egypt, the Surface Water Supply Index (SWSI), and the Standardized Discharge Index (SDI). The results show a general agreement of drought classification between observed and simulated flows for the Blue Nile, despite discrepancies for some years.

The impact of sea surface temperature (SST) in the Pacific Ocean (Nino 3.4 region) on droughts and floods was investigated in the upper catchment of the Blue Nile. Discharge measurements (1965-2011) at the outlet of the upper catchment of the Blue Nile in relation to the El Niño index were analysed. A important conclusion is that JJAS rainfall in the upper catchment of the Blue Nile is highly sensitive to the sea surface temperatures (SST) in the early season of AMJ in Niño 3.4. Additionally, the performance of the regional climate model RegCM4.1 was tested for a 28 years period (1982-2009). The model succeeds in reproducing the observed negative correlation between Pacific SST and the Blue Nile flow, and in particular the high correlation with El Nino that start during (April-June) period. Based on the results found it is proposed that observations as well as global models forecasts of SST during this season should be used in seasonal forecasting of the Blue Nile flow.

Limpopo Basin Case Study
In the Limpopo basin case study the improvements in the institutional framework and procedures from Work Package 5 were tested as well as the technical developments from Work Packages 3 and 4. Tests were conducted on the flow on information from the warning system through the institutional framework from regional to local scale. The Limpopo Case Study was therefore a pilot for the application of DEWFORA's drought early warning framework. Improvements in the institutional framework, procedures and technical developments put forward in this document can be taken up and implemented by

stakeholders. Analysis of current practices in the basin shows that several deficiencies, including poor infrastructure and maintenance, and low scientific and technical capacity. In terms of forecasts that are available, these were found to often be of low skill, and difficult to interpret by end users such as farmers. Also integration with traditional and indigenous knowledge was recommended to be improved.

To characterise drought in the basin a spatial analysis was carried out, investigating drought duration, frequency and severity. Drought Severity-Area-Frequency (SAF) curves were constructed, with the Limpopo River Basin subdivided into four homogeneous regions based on topographic and climate variations in the basin. The Standardised Precipitation Index (SPI) was used as an indicator of drought in each of the homogeneous region. Monthly and annual SAF curves and maps of probability of drought occurrence were produced. Results show that localised severe droughts occur at high frequency in the basin, while moderate to severe low frequency droughts are more widespread. This investigation showed that the western part of the basin faces a higher risk of drought compared to other regions of the Limpopo Basin in terms of the medium-term drought patterns.

A study was made of a drought early warning and forecasting system taking into account indigenous knowledge in the Mzingwane catchment in Zimbabwe. The study identified and documented traditional drought indicators used by local communities. A calendar was developed to provide a framework to implement, monitor and review these indicators. It was found that traditional indicators accurately predicted the 2012/13 season, as well as that there are links between specific local indicators used and scientific parameters. The study showed that there is a potential to use this framework to integrate traditional knowledge indicators with meteorological parameters. Despite this potential, it was noted that changing climate variability reduced the accuracy and the reliability of traditional drought forecasting.

Other studies in the Limpopo basin were closely connected to the work on climate change (work package 3), and seasonal meteorological, hydrological and agricultural drought forecasting and have been reported in previous sections.

Oum-er-Rbia basin Case Study
In the Oum er-Rbia case study different approaches to improving drought mitigation and preparedness strategies in the region were researched. Three different analyses were carried out; the assessment of the skill of medium range to seasonal forecasts, a test on statistical agricultural drought forecasts, and a drought vulnerability assessment at the rural community level, based on the approach developed in work package 3.

The skill assessment of medium range weather forecasts, which focused on the growing season in the rainfed areas (planted with cereal crops), showed that both, daily and medium-range forecasts appears were not able to predict rainfall amount accurately. These did show better skill in forecasting dry periods. Indeed, significant potential exists for both early warning and mitigation measures. This is particularly so for herders that cannot afford major food purchases to save their cattle, but also for crop imports, subsidies, and some agricultural practices. It was shown that an efficient drought early warning system would allow farmers to evaluate more accurately their production options and insurance companies anticipate payments to farmers.

A statistical-dynamical approach to estimate durum wheat yield over the Oum er-Rbia basin was outlined. Different low level circulation fields were used as predictors using a principal component regression to test the predictability of seasonal crop yields in the region. Both deterministic and stochastic approaches hold a good potential for yield predictions over the mountains and coastal areas. Particularly, with a two months lead-time, high and low yield are well discriminated for both areas. On the other hand a very low predictability was identified over the plains areas of the basin

.

The drought vulnerability study aimed to assess and map agricultural drought vulnerability at the rural community level in order to help drought management authorities prioritise efficient mitigation actions, tailored to the needs of each rural community. The approach used in this assessment was that which was developed in Work Package 3. This entails computing a Drought Vulnerability Index (DVI) that integrates several variables into four dimensions: Renewable Natural Capital; Economic capacity; Human and Civic Resources; Infrastructure and Technology.

The drought vulnerability map that was derived from the computation of the DVI shows that except for the provinces of Azilal, Khenifra, Settat and El Kelaa, most of the Oum er Rbia basin is highly vulnerable to drought. The provinces of Azilal and Khenifra are mountainous areas that present the most favourable annual rainfall, and thus helps explain their low DVI. Although being more arid than coastal areas, the inner plains of Settat and El kelaa have lower DVI's. This should be, however, considered carefully and needs to be analysed further

.

The analysis of the four dimensions (Renewable Capital, Economic Capacity, Human and Civic Resources, Infrastructure and Technology) of the drought vulnerability index showed that at the river basin level, the following sub-indicators represent the major drivers of vulnerability, and can therefore be targeted in prioritising mitigation and adaptation actions.

Niger Basin Case Study

Research in the Niger case study aimed at formalising the links between climate variability, hydrology, food security and sustaining biodiversity in the Inner Niger Delta in order to address drought vulnerability to upstream water resources and river basin management under climate change and variability, and to strengthen adaptation strategies. In a first part, the uncertainties to reproduce the climate distribution and trends were outlined for the past climate, seasonal weather forecast and climate change projection. The aim was to assess the current state of art by comparing the spatial-temporal variability of the different climate data sets for temperature and rainfall and to assess the performance in reproducing monthly, seasonal, annual or decadal climate variability.

In a second part of the research the hydrological characteristics of the basin are established, highlighting the current structure with past to emerging conflicts of the different water uses by introducing the societal status, the right of use and the spatial dynamics of the activities ruling the Niger river Basin and the Inner Niger Delta. Two modelling applications are considered, the Soil and Water Integrated Model (SWIM) model, which was used to project long term hydrological drought patterns using ISI-MIP Earth System Models in the Upper Niger Basin and the Inner Niger Delta under upstream river basin management scenarios. SWIM incorporates different scenarios of for water management in the river basin (reservoirs and water uptake from irrigation schemes) as well as an inundation module accounting for flood propagation processes in the Inner Niger Delta. The second tool considered was the statistical model OPIDIN (Outil de prédiction des Inondations du Delta Intérieur du Niger). Compared to the SWIM model it was found that OPIDIN demonstrates less skill to predict extremes and tends to overestimate (for dry episodes) or underestimate (wet periods) peak flood levels. However, at the shorter lead times it shows better skill in capturing extreme events. Moreover, OPIDIN shows to better capture the peak levels than the timing of the peaks. These results would suggest that these models can be used to complement each other in providing medium range to seasonal forecasts of drought and floods in the inner Niger Delta.

The last part of the research explored regional drought vulnerability and adaptive capacities. introducing the Integrated Water Resources Management frames in the river basin and in the focus case study focus delivering further details on water-use, stakeholder and stakeholder platform as well as the current forecast, early warning system and preparedness plan in place at different levels. It also presents the advancement and the constraints in the development of drought vulnerability indicators for the Inner Niger Delta using SWIM outputs. The last part discusses substantial solutions to strengthen drought preparedness first, with

concrete action plans from the Inner Niger Delta to the community scale and second to enhance integrated drought adaptations at the scale of the Niger River Basin.

Integration of drought forecasting tools for Africa into the Pan African map server
As a part of the case study at the continental scale, meteorological and hydrological seasonal forecasts were integrated into a "pre-operational" drought monitoring and seasonal forecast system. An initial verification of the seasonal forecast clearly identified the regions and time scales that benefit from using precipitation forecasts from a dynamical model. These regions are mainly located in the tropics where climatic signals, such as El Niño-Southern Oscillation (ENSO), provide long-term predictability. On the other hand, results also identified regions where the use of ERA-Interim for drought monitoring generates significant reductions of the forecasts skill. It was shown that the use of specific drought indicators such as the Standardized Precipitation Index (SPI) instead of raw precipitation can be of benefit to local climate outlook forums, as the Greater Horn of Africa Regional Climate Outlook Forum (GHARCOF), reliable information about the intensity of the conditions expected in the forthcoming rainy season when available. Such information could then be used to support the decision process when issuing advisories for drought mitigation or adaptation actions within the region.

The Pan-African Map Viewer integrates drought monitoring and seasonal forecasting related information in an innovative approach for Africa, following a similar system developed for Europe through the European Drought Observatory (EDO). Such a monitoring and forecasting system provides multiple meteorological and hydrological drought products together with vulnerability and risk maps derived from socio-economic indicators. This information can be a useful input for existing and future drought early warning systems since it provides information on drought magnitude and extent, as well as understanding the potential drought impacts. Although the system is still under development it is already in a demonstrative pre-operational phase, with a variety of tools and drought related products that are accessible to end users and stakeholders interested in drought information in Africa. The system can be used through the following link (see also *Figure 8*):
http://edo.jrc.ec.europa.eu/dewfora/php/index.php?id=4000
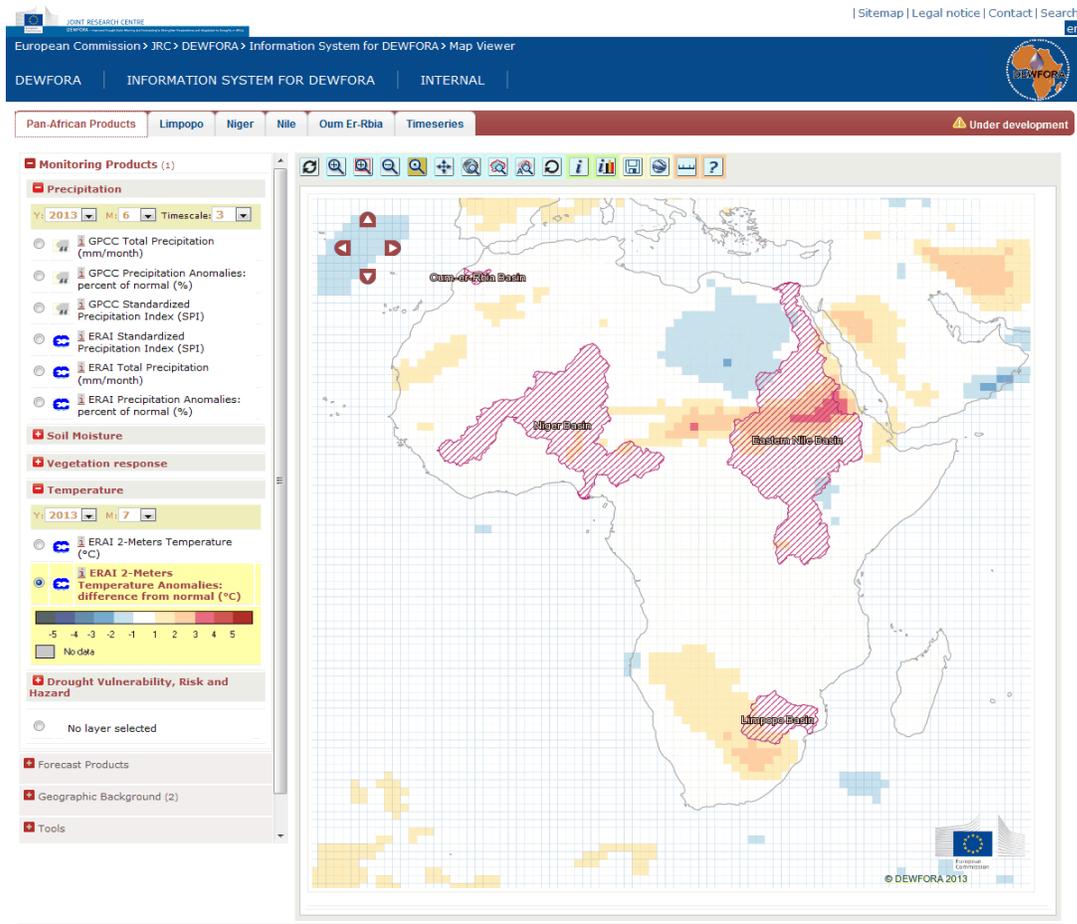
Figure 8 Front page of the Pan-African Drought Map Server

Assessing drought vulnerability at the continental scale

A drought vulnerability index based on the approach developed in work package 3 was constructed for the African continent using socio-economic data at the country level. This indicator is able to represent the complex processes that could lead to social drought vulnerability. However, it must be used critically taking into account that its construction relies on a level of subjectivity and theoretical assumptions. The analysis showed that the countries classified with higher relative vulnerability were Somalia, Mali, Ethiopia, Niger, Burundi and Chad. At the regional scale, the basins with high to moderate drought risk were found to be the Mediterranean coast of Africa (comprising most of the Moroccan and Algerian basins and the Nile Delta); the Sub-Sahara and the south of Sahel regions (including the Volta, Niger, White and Blue Nile); the Serengeti and the Eastern Miombo woodlands of Tanzania and Mozambique. Additionally, the eastern part of the Zambezi basin, the South-eastern border of the Congo basin and the belt of Fynbos in the Western Cape should also be included in this category. Even if the results are not conclusive, a good agreement was observed between the drought vulnerability and risk maps and the number of persons impacted by

(recent) droughts. There is a need to validate the vulnerability indicator with appropriate disaster data in order to measure and improve the robustness of the indicator and explain why in some cases extreme droughts can lead to disasters while in other cases their impact is much lower.

Assessing drought vulnerability at the national scale

Additional to the continental scale, the approach to assessing drought vulnerability also applied to the country scale, focussing on Kenya, using available data at the county level to determine the most important indicators for characterising vulnerability to drought in Kenya. The discussion arising from the correlation between the selected indicators and drought vulnerability, and the relevance of socio-economic indicators for determining drought vulnerability in Kenya was highlighted. To confirm their relevance, these were confirmed in a workshop to reflect the opinion of local Kenyan economists, sociologists, hydrologists, agronomist, and meteorologists. Results of the analysis using the indicators proposed show that at the county level Kenya has a heterogeneous distribution of drought vulnerability. Counties in the North-East, bordering Somalia are shown to be very vulnerable to drought (see *Figure 9*). These include the counties of Wajir and Mandera, which are characterised by low incomes, low population, and low literacy percentages, as well as little rain. In contrast, other counties such as Nairobi or Lamu, present low vulnerability to drought. The impacts of the 2011-2012 drought across the greater horn of Africa broadly reflect the geographic distribution found in the vulnerability assessment, thus corroborating to some extent the geographic distribution found using the proposed indicators. This suggests that the vulnerability assessment can be used effectively in identifying drought vulnerability at the local scale, and using this to inform prioritisation of measures to reduce drought risk.
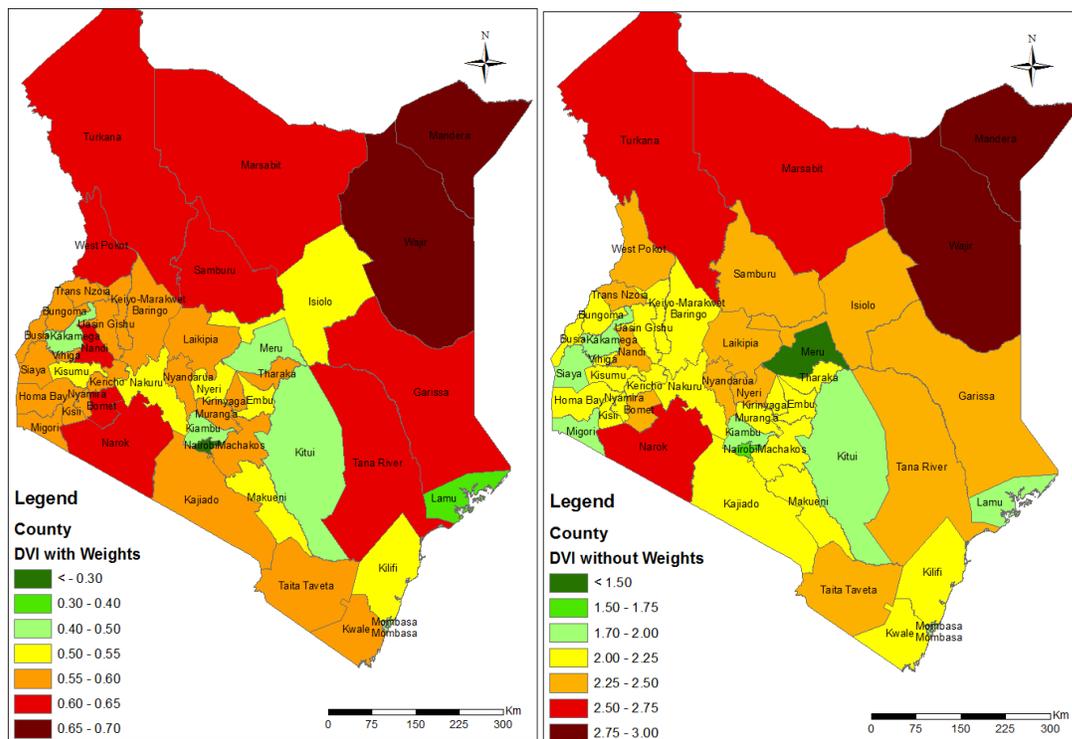
Figure 9 Drought Vulnerability Index Map of Kenya. Right: with weighted indicators. Left: without weighted indicators

European-African intercomparison Case Study

In this last case study a comparative review of drought forecasting in Europe and Africa was made. It was found that with regard to drought management process, the European and African perspectives present various differences, namely concerning policy and technical capabilities. In most European countries there is an increasing effort to implement Drought Management Plants, to involve all the European countries, and to coordinate and facilitate the development and application of drought risk management tools. The continuous improvement of the European Drought Observatory, the possible improvements on drought early warning systems and other initiatives contribute to drought preparedness and to minimising the impacts of drought. In the case of Africa, some gaps were identified regarding policy issues, since there is no guideline/law that is standardised for all countries. Regarding technical capabilities there is also a lack of technical capacity, with insufficient human resources available and inadequate training and financial resources. Different problems were encountered with data collection (inadequate data networks, density of stations, quality, limited availability and high cost of historical data); at organisational level (lack of coordination and interaction amongst institutions), as well as a lack of equipment and technology to generate reliable information, including forecasting systems, models and software.

1.4 POTENTIAL IMPACT AND MAIN DISSEMINATION ACTIVITIES AND EXPLOITATION RESULTS

1.4.1 Potential impact

The principal aim of the DEWFORA project has been the development of a framework for the provision of early warning to drought in Africa. At the start of the project, drought forecasting and warning was very much in its infancy. The importance of drought forecasting and warning as an integral part of reducing drought risk has been clearly recognised in the final declaration adopted by policy makers and government representatives at the High Level Meeting on National Drought Policy (HMNDP), convened by the WMO in Geneva in March 2013.

The DEWFORA project contributes to the advance in scientific knowledge with respect to the effectiveness with which drought forecasting, warning and response can be provided. More importantly the project contributes to the science policy dialogue that has become increasingly important in the past years. Worldwide drought is a hazard with an increasing impact and the tragic consequences of droughts in Africa are a reality. The improved knowledge and implementation of the DEWFORA results in regional and national decision making processes will have a socio-economic and environmental impact in areas vulnerable to droughts. Early warning systems and the use of local knowledge can contribute to reducing the impacts of drought, make planning more robust and reducing social vulnerability. Early warning systems also provide an additional opportunity to planning adaptation to climate change.

The potential impact of drought forecasts depends as much on the institutional setting and the process of making decisions (social component of the forecast) as on the forecast technology itself. At the case study level, DEWFORA has provided clear messages for moving forward and recommendations for improving monitoring and data collection, capacity and awareness, organisational structures, and developing a long term drought strategy. The case studies also underline a consensus amongst experts that the social component of drought forecasting and warning needs to be emphasized for it to be effective.

Impact on scientific research
The science of drought monitoring, weather forecasting and climate change is advancing every day. By developing new concepts, protocols, models and data systems, DEWFORA is impacting on the community of European and African drought research. It brings the international drought research a step further towards a potential future operational forecasting system where drought early warnings can be declared at sufficient lead time and drought mitigation planning can be implemented at an earlier stage.

Through the publicly available deliverables, the peer-reviewed publications, the many abstracts presented at congresses and the "Special drought issue" in the high ranking peer reviewed HESS journal (expected to be completed by mid-2014), DEWFORA is disseminating its most important results and impacting on the scientific community. The most important research topics were impact is expected are the research on skill of seasonal and meteorological forecasts, the public availability of high resolution simulations of the projected future climate in Africa, the protocol for developing early warning systems in Africa and the research on vulnerability assessment. With respect to social sciences, impact is expected on the research of the social capacity to implement early warning systems. Vulnerability assessment contributes to identify the limitations of the social capacity and therefore provides crucial information to policy development.

Additionally, DEWFORA is contributing to the GDIS (Global Drought Information System) through the DEWFORA Pan-African Drought Map Server. GDIS is an initiative of GEOSS, and is currently aimed at coupling existing and future continental drought forecasting systems.

Impact on Policy; science policy interface
DEWFORA has dedicated a Work Package to science-policy interfacing.
Through interaction with relevant policy (development) groups and publishing of targeted policy briefs, the project disseminates its most policy relevant results. Two science-policy briefs were produced to disseminate the key policy messages for the European and the African context. Through presenting the briefs at conferences and use it in communication with relevant policy groups, DEWFORA intend to impact on the policy development of drought management and preparedness.

The main targets for the European policy briefs are:
1.　　European Commission; DG RTD, DG ENV, DG DEVCO and DG CLIMA
2.　　CIS Water Scarcity and Drought Expert Group
3.　　At the Mediterranean level through the Mediterranean Joint Process Water Scarcity and Drought working group
4.　　European parliament (eventually STOA)
5.　　United Nations agencies; WMO, UNESCO, FAO in particular

The main targets for the African policy briefs are:
1.　　At continental level; AU, AMCOW, AMCEN

2.   At the regional level at the level of technical groups; RBO's (LIMCOM (Limpopo), Nile
        basin, Niger basin), economic zones (SADC, ECOWAS, IGAD), NELSAP (Nile
        Equatorial Lakes Subsidiary Action Program)

3.   NGO's and IGO's such as the International Committee of the Red Cross, the Food
        and Agricultural Organisation (FAO).

4.   National governments through African DEWFORA partners

The High Level Meeting on National Drought Policy (UN HMNDP) that was held in Geneva in
March 2013 was a good momentum for DEWFORA to present relevant results for Policy
makers and decision makers. The presentation was on the economic evidence and the policy
linkages of enhancing drought preparedness and mitigation. The Final Declaration of the
HMNDP encouraged all Governments around the world to develop and implement National
Drought Management Policies, consistent with their national development laws, conditions,
capabilities and objectives. A key element in the recommendations was to promote greater
collaboration to enhance the quality of local/national/regional/global preparedness for
drought.

Potentially DEWFORA can impact on several policy processes through new insights with
respect to vulnerability assessment. To develop effective drought policy, understanding
vulnerability is important. Vulnerability assessment is crucial to identify relief, coping and
management responses that will reduce vulnerability and contribute to a more resilient
society. The need for vulnerability assessment is addressed in DEWFORA by analysing a
large number of indicators related to drought impacts and with synergies to long term
sustainability.
Drought vulnerability information reinforces the policy process of:
• Improving the implementation of Integrated Water Resources Management (UN
Conference on Sustainable Development (Rio +20)).
• Promoting sustainable development by mitigating the effects of drought and promoting
national drought policy (UNCCD, COP10).
• Delivery and application of suitable science-based climate prediction and services (decision
of governments to create the Global Framework for Climate Services (GFCS)).

DEWFORA can also contributes to the effectiveness of development policies on access to
water and food security by ensuring that investments made will not fail under drought
conditions. For example drought response actions such as increased efficiency in water use
or recommendations on the type of crops to cultivate, also contribute to environmental
conservation, rural development, and climate adaptation.

DEWFORA participated in the First and second pan-EU Drought Dialogue forums, organised by the FP7 project DROUGHT R&SPI with the aim to "create an exchange platform among policy-makers, stakeholders and the scientific community on science-policy interactions". (http://www.eu-drought.org/search/item/10813457/The-1st-pan-European-Drought-Dialogue-Forum). Through these forums, the drought research community hopes to transfer a common message to policy makers in the EU. In 2014, a third dialogue forum in Greece and a concluding forum in Brussels will take place where DEWFORA hopes to again communicate on its key policy messages.

In 2011, the FP7 projects focusing on water related issues in Africa that were awarded under this ''Africa Call' joined forces in the AU EU Africa cluster. The objective of this cluster are to facilitate exchange of information and knowledge between African and European scientists, stimulate synergies and increase the impact of the projects through coordinated dissemination actions. Important joint dissemination products were the 4 BBC movies from "Africa turns green". The one featuring DEWFORA is titled Water in Africa in a changing climate (see https://vimeo.com/78933012)

Socio-economic impact and impact on society
The scientific advances of the DEWFORA project that advance the state-of-the-art in drought forecasting contribute to improving the evidence base with which forecasts at the seasonal scale can be developed. Such evidence is a clear prerequisite in building trust in both practitioners and stakeholders (for example farmers or reservoir managers) that is required when responding to drought forecasts.

The impact of the DEWFORA project, however, goes beyond the science required to develop meteorological, hydrological and agricultural drought forecasts. The project has considered the full chain from drought monitoring and forecasting through to the required institutional responsibilities and approaches drought mitigation and adaptation.

A key part of the project is the protocol that can be used as by policy makers and practitioners when improving and developing drought forecasting and warning capabilities. The protocol clearly outlines an evidence based approach, with the importance of including and developing the science to enable reliable forecasting at lead times that are useful to stakeholders such as farmers, reservoir operators, agricultural extension services. The protocol outlines the importance of not only the science, but also of developing understanding on how society is impacted by droughts, and understanding the capacity of

society to cope with drought. The approach to assessing drought vulnerability as developed within the project is perhaps one of the first such approaches developed.

The protocol developed, and the scientific basis on which this is founded is a clear benefit to water managers in Africa, but also in Europe and other continents, as it helps guide the process of developing an efficient and effective approach to drought forecasting and warning. <u>When responded to drought warnings effectively, society stands to benefit substantially</u>. Drought is a recurrent natural disaster that has widespread adverse socio-economic effects, and these can be substantially mitigated through response to advanced warnings. Additionally project has provided insight in the influence of climate change on droughts, which will help decision-makers develop adequate adaptation strategies.

Though the scientific advances in drought prediction and drought vulnerability analysis stand to benefit society, the approach taken in the project has assured that recommendations and knowledge are embedded in the policy, professional and academic communities.

The research developed in the project clearly identified that lack of capacity is one of the key elements hampering the effective use of drought forecasting and warning across Africa. The training courses developed in the project, delivered in traditional taught form, as well as being freely available online, are contributing to building the capacity of water professionals in Africa and elsewhere that is required to help build a more effective drought forecasting and warning.

1.4.2   Main future dissemination activities

Scientific dissemination
The EGU and WATERNET symposia (2012, 2013 and 2014) are the main scientific events where DEWFORA disseminated many of its scientific results. In 2014, seven oral presentations or posters will be presented at the EGU conference in sessions "Assessment and management of water resources in the Mediterranean and (semi-)arid regions" and "Drought and water scarcity: hydrological monitoring, modelling and forecasting to improve water management".

In 2014, a special issue "Drought forecasting and warning" will be published in the HESS journal (Hydrology and Earth System Sciences) an interactive Open Access Journal of the European Geosciences Union. Most of the editors are from the DEWFORA project; S. Maskey, E. Toth, A. Opere, M. Werner, F. Pappenberger, and L. Samaniego.

In October 2013, DEWFORA organised its final event at the 14th Waternet conference in Dar-es-Salaam with a special session and a continental end-user workshop. DEWFORA is also planning to attend the 15th WATERNET symposium in Malawi in October 2014, using that opportunity to disseminate the Science-policy briefs for Africa.

Policy interface

The Science Policy Briefs are available through the DEWFORA website and will in the future be continuously distributed at relevant events and with relevant policy relations such as the drought policy officer at DG Environment.

General public/awareness

After the project ends, the website will act as the main communication medium towards the general public. All deliverables, policy briefs, newsletters, posters and flyers are reachable and downloadable from the website. Additionally two short movies produced by Euronews (translated in 12 languages*), www.euronews.com/2013/06/17/africa-is-always-at-risk-of-drought/) and BBC "Africa turns green" (https://vimeo.com/78933012) are used as media to disseminate the main aim and results of the project towards a broader audience.

Professional community

Three training courses are available focussing on 1) Drought vulnerability and risk in Africa , 2) Drought forecasting at different geographical scales and 3) Implementation of drought early warning systems and developing the institutional framework for effective response in Africa. Based on the three training courses, an online training course was compiled and made available to the professional community for free through the website of IAMZ. The training course can be found under this link: http://intranet.iamz.ciheam.org/dewfora-e-learning.

All other dissemination activities carried out during the project are reported in Table A2.

* Euronews documentary on DEWFORA (in 12 langauges)

English: http://www.euronews.com/2013/06/17/africa-is-always-at-risk-of-drought/

French: http://fr.euronews.com/2013/06/17/comment-mieux-lutter-contre-la-secheresse-en-afrique/

German: http://de.euronews.com/2013/06/17/achtung-duerre-eu-projekt-will-trockenheit-in-afrika-voraussagen/

Italian: http://it.euronews.com/2013/06/17/sistemi-di-allerta-preventivi-contro-il-pericolo-siccita-in-sudafrica/

Spanish: http://es.euronews.com/2013/06/17/alerta-de-sequia-en-africa/

Portuguese: http://pt.euronews.com/2013/06/17/alerta-de-seca-em-africa/

Russian: http://ru.euronews.com/2013/06/17/africa-is-always-at-risk-of-drought/

Arabic: http://arabic.euronews.com/2013/06/17/africa-is-always-at-risk-of-drought/

Turkish: http://tr.euronews.com/2013/06/17/afrika-da-kuraklik-alarmi/

Persian: http://persian.euronews.com/2013/06/17/africa-is-always-at-risk-of-drought/

Ukrainian: http://ua.euronews.com/2013/06/17/africa-is-always-at-risk-of-drought/

Greek: http://gr.euronews.com/2013/06/17/africa-is-always-at-risk-of-drought/

APPENDIX I: LIST OF PARTNERS AND DESCRIPTION

#	Participant organisation name	Acronym	Country
1	Deltares	DELTARES	Netherlands
2	UNESCO-IHE Institute for Water Education	IHE	Netherlands
3	European Centre for Medium-range Weather Forecasts	ECMWF	Europe
4	Joint Research Centre	JRC	Europe
5	Potsdam Institute for Climate Impact Research	PIK	Germany
6	German Research Centre for Geosciences	GFZ	Germany
7	Universidad Politecnica de Madrid	UPM	Spain
8	Mediterranean Agronomic Institute of Zaragoza	IAMZ	Spain
9	Faculty of Engineering, University of Porto	FEUP	Portugal
10	Nile Forecast Center	NFC	Egypt
11	Wetlands International – Sahelian Sub Regional Office	WISO	Mali
12	Dinder Center for Environmental Research	DCER	Sudan
13	IGAD Climate Prediction and Applications Centre	ICPAC	Kenya
14	Faculty of Engineering, University Eduardo Mondlane	UEM	Mozambique
15	Council for Scientific and Industrial Research	CSIR	South Africa
16	WR Nyabeze & Associates	WRNA	South Africa
17	Institut Agronomique et Vétérinaire Hassan II	IAV	Morocco
18	WaterNet Trust	WATERNET	Botswana
19	Hydraulic Research Institute - Nile Basin Capacity Building Network for River Engineering	NBCBN	Egypt

Partner 1: Deltares (DELTARES)

Deltares is an independent institute for applied research with a unique combination of knowledge and experience in the field of water, soil and the subsurface. It is frontrunner in the development, distribution and application of knowledge for meeting the challenges in the physical planning, design and management of vulnerable deltas, coastal areas and river basins. Deltares is the result of a merger between WL | Delft Hydraulics, GeoDelft, part of TNO Built Environment and Geosciences, and the research units of the Ministry of Water Management in The Netherlands. In addition, Deltares hosts the International Groundwater Resources Assessment Centre (IGRAC), a UN centre that facilitates and promotes global sharing of information and knowledge required for sustainable groundwater resources development and management.   Deltares is actively involved in water-related issues worldwide and is the leading institute in development and implementation of state-of-the art operational forecasting and warning systems across Europe, USA, Asia and Africa. Unique to the approach of Deltares in operational water management is its experience and ability to integrating advances in science in operations.

Partner 2: UNESCO-IHE (IHE)

UNESCO-IHE is dedicated to scientific research, postgraduate education and training in the field of water. The Institute is globally active in solution-oriented research, education and capacity building operations. The Institute currently has 170 employees (90 academic staff), 100 PhD students and about 350 MSc students (four MSc programmes with a total of 14 specialisations). The groups involved in DEWFORA will be the Hydrology and Water Resource group and the Water management and governance group. Water security, environmental integrity and water management and governance are among the key themes for institute's education and research.   IHE has a long and rich track record in projects, research, cooperation and capacity building in Africa. Through its large network of Alumni in Africa, IHE has a very rich connection to water practitioners and researchers across Africa. As an institute it has stood at the foundation of both the WaterNet and Nile Basin Capacity Building Network (NBCBN) knowledge networks that are also partner to the DEWFORA project.

Partner 3: European Centre for Medium Range Weather Forecasting (ECMWF)

The European Centre for Medium-Range Weather Forecasts (ECMWF) is an international organization supported by 31 State. ECMWF pursues extensive scientific and technical collaboration, in particular with its Member States, with satellite agencies and with the European Commission. It participates in several programmes of the World Meteorological Organization (WMO) and contributes to climate monitoring. ECMWF has developed strong scientific and technical expertise in the processing of observations, the monitoring and

assimilation of satellite data, the optimisation of the observing system, the non-hydrostatic dynamical cores, the physical parameterizations, the multi-model ensembles, the atmospheric composition and the verification methods for severe weather.

Partner 4: Joint Research Centre – Institute for Environment and Sustainability (JRC – IES)

IES is one of the institutes of the JRC of the European Commission. The combination of expertise in experimental sciences, modeling, geomatics and remote sensing related to air, water, soil and land cover/land use as well as experience in handling large continental and global datasets puts IES in a strong position to significantly contribute to research projects at regional and continental scale.

Partner 5: Potsdam Institute for Climate Impact Research (PIK)

PIK is a government funded research institute (approx. 200 multi-disciplinary scientific staff members) with the main role of targeting problems related to global change. Primary funding (over 5 million EURO per year) is provided in halves by the Federal Government of Germany and the Government of the Federal State of Brandenburg. This is complemented by considerable third-party funds for project support. PIK scientists play central roles in the International Geosphere-Biosphere Programme (IGBP) and occupy several critical authorship functions for the Intergovernmental Panel on Climatic Change (IPCC). The Institute has excellent technical capabilities in relation to the project, it operates a supercomputer (IBM SP parallel computer with 2500 processors). PIK maintains global and regional databases and state-of-the-art models and tools for global change studies, including climate, water and vegetation issues. PIK has a strong record of research sponsored by the European Union.

Partner 6: GFZ German Research Centre for Geoscience

As the national research centre for geosciences, the GFZ investigates the "System Earth" with the physical, chemical and biological processes taking place in the Earth's interior and on its surface. The interdisciplinary geoscientific research at the GFZ aims at a process-based understanding on all temporal and spatial scales. The GFZ examines our planet and the manifold interactions between its subsystems, the geosphere, hydrosphere, atmosphere, and biosphere. The incorporation of surface processes extends GFZ's research work to "System Earth-Man" as our human habitat. In this context natural hazards are one of the main research fields of GFZ in general and of the Section 5.4 Hydrology in particular. GFZ has about 900 employees and is a member of the Helmholtz Association of German Research Centres.

Partner 7: Universidad Politecnica de Madrid (UPM)

UPM is one of the leading universities in Spain. The multidisciplinary Research Group of Hydraulic Systems includes members of the Departments of Civil Engineering and Agricultural Economics and has a long record of joint collaboration leading research on environmental, rural and food science and policy. Research activities of the UPM Team focus on development and application of economic models of environmental policy, with special emphasis on water management and climate change.   UPM has 21 Centers, 42,000 students, and 4,000 faculty, 420 million € total funds and 120 million € external funding for research each year.

Partner 8: Mediterranean Agronomic Institute of Zaragoza – International Centre for Advanced Mediterranean Agronomic Studies (IAMZ)

IAMZ is one of the four Institutes of the International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM), an Intergovernmental Organization comprising Albania, Algeria, Egypt, France, Greece, Italy, Lebanon, Malta, Morocco, Portugal, Spain, Tunisia, and Turkey. The objectives of CIHEAM are post-graduate education and promotion of research in the fields of agriculture and natural resources.

IAMZ has long-standing experience in the coordination of European Research Projects, with 15 Projects coordinated in the CAMAR, AIR, INCO and MEDA Programmes. Of these projects, MEDROPLAN (Mediterranean Drought Preparedness and Mitigation Planning; 2003-2008; EC MEDA Water Programme), is the most closely-related with this proposal. The overall objective of this project was the improvement of the capacities of Mediterranean countries to prevent and mitigate impacts of drought. A methodological approach for drought proactive management has been developed and disseminated, through Drought Management Guidelines published in 6 languages and validated with water decision-makers and stakeholders. IAMZ promotes and supports, together with FAO and ICARDA, the NEMEDCA Network of cooperation on drought management in the Near East, Mediterranean and Central Asia.

Partner 9: Faculdade de Engenharia da Universidade do Porto (FEUP)

The Faculty of Engineering of the University of Porto (UP) was created in 1926 and is the largest Faculty of the UP, serving a community of approximately 7.000 students by means of 9 Departments, one of them the Department of Civil Engineering that integrates the Hydraulics, Water Resources and Environment Division ("Hydraulics Division"). FEUP also includes almost 30 Research Centres – one on Hydraulics and Environment, CEHRA – and Interface Institutes – namely the Hydraulics and Water Resources Institute, IHRH. Both CEHRA and IHRH are integrated by the "Hydraulics Division" members. The key researchers

have been participating in several international, European and national projects and studies embracing many areas related with (fluvial and marine) hydraulics, water resources and environment. More specifically, Prof. Rodrigo Maia (as team leader) and his team have been applying and developing their skills on, namely: (i) fluvial hydraulics (hydrology) (ii) water resources (floods, water scarcity, droughts and decision support systems application); and (iii) transboundary rivers' issues. IHRH has developed studies in Africa, namely in Angola and Mozambique, mostly on coastal management issues.

Partner 10: Nile Forecast Center (NFC)

The Nile Forecast Center (NFC) was established as part of the planning Sector of the Ministry of Water Resources and Irrigation (MWRI) in 1992. The main task of the NFC is to monitor, simulate, and forecast the rainfall and flow processes over the whole Nile Basin. As such it receives real-time satellite (METEOSAT MSG) as well as gauge data (WMO SYNOP stations) from which rainfall is estimated over the basin. These data are then used to run a conceptual distributed hydrological model of the whole basin (NFS) to simulate the current status of the basin. Historical rainfall is used as a proxy for the future to generate an ensemble of future flows that are statistically analysed to provide estimates of the probable flows. These are fed into a decision support system of the High Aswan Dam (HAD-DSS) and the results are reported to decision makers within MWRI to help plan the releases from the dam and anticipate any necessary spillage/cuts. The NFS hydrological component has also been adapted to study the impacts of climate change on the river flows. GCM and RCM climate scenarios of rainfall and potential evapotranspiration has been used to drive the NFS in various ways; either directly, or after some sort of downscaling. A statistical downscaling model has been developed at NFC in 2004 and has been used to generate such scenarios from GCM monthly data. Currently, data from the UKMet Regional Climate Model (PRECIS) are being used to drive the NFS to assess the impacts of climate change on river flows.

Partner 11: Wetlands International – Sahelian Sub Regional Office (Mali)

Wetlands International opened its offices in Mali in 1998, with a focus on Mopti/Sévaré, located within the Inner Niger Delta. The multi-disciplinary team since then has implemented, in collaboration with national partners (government structures, national NGOs, Local Authorities, and local populations), national research institutions
(IER and CNRST) as well as foreign research institutions (Altenburg & Wymenga, Institute for Environmental Studies, IVM) several projects and programmes in the River Niger Basin and the Inner Niger Delta financed by the, Netherlands (DGIS). Amongst others;
- Project on the management of wetlands and water birds in the Inner Niger Delta;
- Water for Food and Ecosystems Programme: Efficient management of the scarce waters of the Upper Niger River Basin;
- Wetlands and Poverty Reduction Project (WPRP): Biorights projects, including

Improvement of the Income of Bozo women groups, involved in the exploitation of water birds;
- Establishment of an eco-guards network and building their capacity for the protection of the Crowned Crane: financing of income-generating activities.

The outputs and achievements of these projects are currently used in decision-making in several Ministries, research institutes, universities, NGOs, and Decentralized Authorities. IUCN NL is the largest national platform of Dutch environmental NGOs and government institutions.

Partner 12: Dinder Center for Environmental Research (DCER)

The Dinder Center for Environmental Research is a new private not-for-profit research institution founded in Sudan by Professor Elfatih A. B. Eltahir. (Dinder is a small tributary of the Blue Nile). The vision of Dinder Center is a world where the old regional interest in the study of water is revived, by enhancing the local interest and capacity for doing research on water and the environment. The goal of The Dinder Center for Environmental Research is to promote, initiate, and advance scientific research on water and the environment in the arid and semi-arid regions of Africa and the Middle East. The objectives of the Dinder Center are: (1) to conduct high quality research on the critical problems related to water resources, environmental degradation, and climate change; (2)to educate locally a new generation of scientists who are well trained in the latest technology, aware of global and regional environmental trends, and focused on local and regional problems related to water and the environment; and (3) to establish a regional center of excellence that brings together, through projects and collaborations, scientists from the region with those from some of the world's finest research institutions. The center is located in Menshya neighborhood of Khartoum, Sudan. The center resources include office space, a library, and computer facilities. The Dinder center was recently awarded a grant from the International Center for Theoretical Physics (ICTP) in Trieste Italy to study the hydrology of the Nile River.

Partner 13: IGAD Climate Predictions and Applications Centre (ICPAC)

IGAD Climate and Applications Centre (ICPAC) is a specialized climate risk reduction centre active in ten Greater Horn of Africa countries, including the seven countries that are members of Intergovernmental Authority on Development (IGAD) plus Tanzania, Rwanda and Burundi. ICPAC is mandated to provide timely early warning weather and climate information for supporting specific sector applications for the mitigation of the impacts of climate variability and change, and to improve the technical capacity of producers and users of weather and climatic information for the enhancement of the use of climate monitoring and forecasting products in climate risk management. The Centre is also mandated to develop an improved, proactive, timely, broad-based system of information/product dissemination and feedback.

Partner 14: Faculty of Engineering, University Eduardo Mondlane (UEM)

EMU is the oldest and leading engineering teaching University in Mozambique. Teaching and research in Hydraulic and Water Resources Management at EMU is mostly done at two main faculties of the University namely the Faculty of Engineering-FEUEM through its Department of Civil Engineering and the Faculty of Agronomy and Forestry Engineering-FAEF through its Department of Soils and rural Development. A number of multidisciplinary research groups in Hydraulics and water resources management exists which includes members of the Departments of Civil Engineering, Department of soils and rural development and the Department of Geology of the Faculty of Sciences. Within the Department of Civil Engineering, a long history exists of many different research projects in the field of Water Resources Management with individual research studies conducted in the fields of Hydrology, Ground Water Exploitation and Management Drinking Water & Wastewater Treatment , Irrigation and Drainage and on Environmental Impact of Industrial Wastewater discharges. Research activities at UEM in general and at the Faculty of Engineering in particular are mostly donor funded and are focused on post-graduate research training. EMU has 10 Faculties 4 higher education schools and about 4 research and consultancy Centers.

Partner 15: Council for Scientific and Industrial Research (CSIR)

The CSIR in South Africa performs multidisciplinary research and technological innovation with the aim of contributing to industrial development and improving the quality of life of people of South Africa, and increasingly on the African continent. CSIR employs experts from many fields and who are passionate about creating a better future through science. Constituted by an Act of Parliament in 1945, the CSIR is one of the leading science and technology research, development and implementation organizations in Africa. The CSIR's main offices are based in Pretoria, while it is represented in other provinces of South Africa through regional offices. The CSIR transfers the knowledge generated through research activities by means of technology and skilled people. The generation and application of knowledge reside at the core of the CSIR. This takes place in domains such as biosciences; the built environment; defense, peace, safety and security; materials science and manufacturing; and natural resources and the environment.

Partner 16: WR Nyabeze & Associates (WRNA)

WRNA is a private engineering consulting firm registered in South Africa. It was set up to deliver complete solutions for resource planning, operation and management to clients in Southern Africa through deployment of specialist technical and management skills. The focus of WRNA is in Water Resources Planning, Operation and Management, early Warning Systems for Droughts and Floods, IT Systems Integration, Database and Information Systems Development, Strategic Planning, Research and Training.

Partner 18: WaterNet Trust (WATERNET)

WaterNet is a regional network for capacity building in Integrated Water Resources Management (IWRM) in Eastern and Southern Africa, with a membership of 64 University Departments and Research Institutions in fifteen countries. WaterNet has five objectives: (i) To forge a strong, demand driven and sustainable network of universities and research institutions in Southern Africa in the field of IWRM, (ii) To deliver and strengthen the jointly-owned regional Masters degree programme in IWRM, (iii) To develop and deliver demand-driven training and education for practicing water sector professionals in Southern Africa, (iv) To stimulate, regionalise and strengthen - research in the field of IWRM in Southern Africa, and (v) To raise awareness and understanding of IWRM and its implementation at local, national and trans-boundary scale. WaterNet implements its programme through an executive management team, four SADC-WaterNet Professorial Chairs at national universities and academic staff from member departments.

Partner 19: Hydraulic Research Institute - Nile Basin Capacity Building Network for River Engineering (NBCBN)

The Hydraulic Research Institute (HRI) of Cairo will participate in DEWFORA through the Nile Basin Capacity Building Network for River Engineering (NBCBN-RE). The main objective of NBCBN-RE is to develop a mature and sustainable regional knowledge network for River Engineering professionals from all ten Nile Basin countries, applying the concepts of Knowledge Networking and CoP's and to support initiatives in other related domain areas in the development of similar knowledge networks. The NBCBN-RE knowledge network has much potential and can contribute through its multi-national, multi-disciplinary and multi-stakeholder research to sustainable solutions for integrated water management, the achievement of the Millennium Development Goals and the Nilotic water & climate dialogue. The goals of this demand driven network is to support its Communities of Practice, to build a sustainable knowledge base, to generate and implement joint research with tangible outputs, contributing directly to production of knowledge in water resources management and utilization into diverse external processes, to disseminate its lessons learned and to co-create sustainable ways of collaboration, knowledge dissemination and knowledge networking.