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Final report on

Nile Basin drought early warning system needs assessment

Photo from the NBI drought early warning system needs assessment Regional Workshop – Debre Zeit/Bishoftu Ethiopia, 25-26 July 2022

Prepared for the Eastern Nile Technical Regional Office (ENTRO)

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Eastern Nile Subsidiary Action Program

Eastern Nile Drought Risk Mitigation (EN-FRM) Project

Nile Basin drought early warning system needs assessment

ENTRO

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List of acronyms

AFD – *Agence Francaise de Developpement*

AOI – Area of Interest [related to GIS systems]

CDI – Composite Drought Index

CHIRPS – Climate Hazards Group InfraRed Precipitation with Station data

CNN – Convolutional Neural Network

DEWS – Drought Early Warning System

DRM – Drought Risk Mitigation [refers to NBI project]

ECMWF – European Centre for Medium-Range Weather Forecasts

ENTRO – Eastern Nile Technical Regional Office

FEWSNet – Famine Early Warning System Network

GIS – Geographical Information System

GPM – Global Precipitation Measurement

HBV - Hydrologiska Byråns Vattenbalansavdelning (hydrological model)

ICPAC – IGAD Climate Prediction and Application Centre

IMERG – Integrated Multi-satellitE Retrievals for GPM

IT – Information Technology

LST – Land Surface Temperature

MSWEP – Multi-Source Weighted-Ensemble Precipitation

NBD – Nile Basin Discourse

NBI – Nile Basin Initiative

NCCR – Nile Cooperation for Climate Resilience

NBD – Nile Basin Discourse

NBDF – Nile Basin Discourse Forum

NDVI – Normalized Difference Vegetation Index

NELSAP-CU – Nile Equatorial Lakes Subsidiary Action Programme – Coordination Unit

NMME – North American Multi-Model Ensemble

PCA – Princeton Climate Analytics

SPEI – Standardized Precipitation and Evapotranspiration Index

SPI – Standardized Precipitation Index

SWOT – Surface Water and Ocean Topography [satellite mission]

TOR – Terms of Reference

TRMM – Tropical Rainfall Measuring Mission

USAID – United States Agency for International Development

WMO – World Meteorological Organization of the United Nations

Executive summary

Project objectives and approach

The objective of the drought early warning system (DEWS) needs assessment project is to strengthen the capacity of Nile basin centers and Nile basin countries in DEWSs inclusive of monitoring and forecasting components. The project meets this objective by:

- Reviewing the NBI's existing and piloted DEWSs;
- Undertaking a stakeholder needs and capacity assessment; and
- Developing a comprehensive Terms of Reference (TOR) for the Drought Risk Mitigation (DRM) project including a Nile DEWS that will cover the entire Nile Basin and that will be hosted and implemented at ENTRO.

The project included review of NBI documents (technical and strategic), wider literature, and participatory research – surveys, interviews, focus groups, and a regional workshop – with NBI centers, NBI focal points, and the NBD. The approach considered technical components of the DEWS as well as its information generation, sharing, and user engagement components.

Conclusions – priority impacts and intended users and uses of DEWS information

Key stakeholders for the Nile DEWS are basin countries' ministries of water and civil society organizations (especially NBDF members) in basin countries. These stakeholders consider that the DEWS should provide usable information that supports interventions to manage:

- Macro-level hydrological drought and its impacts on national and transboundary water resources management and large-scale infrastructure operation; and
- The meso- and micro-level impacts of hydrological drought on rural and agro-pastoral communities' water and food security.

This focus for the Nile DEWS would make it complementary to, rather than duplicative of, existing and trusted regional drought monitoring systems such as FEWSNet and ICPAC.

Stakeholders consider intended users of information from the Nile DEWS system to include technical experts (e.g., water resource engineers), policy advisors and/or decision-makers who may not be technical experts, and people who directly undertake drought management and/or interact with affected communities such as national NBDF members and local government officials. They desire for the DEWS information to support policy advice to Ministers, inter-agency collaboration, agencies' and civil society organizations' operational drought management responses, and eventually provide public-facing guidance.

Stakeholders recognize that meeting these objectives will take time, but they believe that with concerted efforts to engage with users during the DEWS development process, adequate training on interpretation and use of the DEWS information, and ongoing user engagement, it will be possible to achieve them.

Conclusions – existing and piloted DEWS in relation to stated needs

The existing and piloted DEWSs could likely be modified to meet most of these objectives; the gap is related to micro-level drought impacts, and there are opportunities to fill this gap through development of remote sensing tools for identification and change detection of micro- and small-scale surface water storage.

The existing NBI DEWS is suited to address macro-level hydrological drought impacts given its integration with the Nile Decision Support System (Nile DSS), which enables, among other things, scenario analyses incorporating various flow and infrastructure operation conditions. The piloted PCA system is well-suited to address meso-level drought impacts, and to a much lesser extent micro-level impacts. It is likely a better hydrological modelling framework overall, largely due to model setup and customization characteristics. However, to address macro-level impacts, it would need to have the capacity to integrate with the Nile DSS or otherwise have comparable scenario analysis functionality.

Both systems would require significant improvements in technical components, particularly related to seasonal precipitation forecasting, as well as robust validation. Several proposals are made for principles to underpin, and possible approaches to facilitate, data sharing and/or access to relevant in-situ observation data (especially streamflow data) for validation, and this report recommends that validation of the DEWS must also include 1.) assessment of model outputs in relation to other indicators of drought impacts, and 2.) user engagement following appropriate training and development of relevant technical and coordination mechanisms.

Both systems would also require significant engagement with end users to ensure that the information generated is usable and used. At present, the information generated from both systems is useful for technical experts and perhaps also policy advisors, but not for people who directly undertake drought management and interact with affected communities.

<u>Core recommendations for near-term development of the DEWS to meet stated needs</u>

Priority drought impacts for the Nile DEWS and associated DEWS composition

1. The Nile DEWS should focus on the following priority drought impacts:

    a. Macro-level hydrological drought and its impacts on national and transboundary water resources management and large-scale infrastructure operation; and

    b. The meso- and micro-level impacts of hydrological drought on rural and agro-pastoral communities' water and food security.

2. The immediate priority for DEWS development is on meso- and micro-level impacts of hydrological drought. This is due to pre-existing investment and capability in monitoring and forecasting macro-level drought impacts. Still, new investment should seek to improve DEWS related to both priority impacts.

3. The Nile DEWS should consist of 3 primary components:

    a. Hydrological modelling (streamflow monitoring and forecasting) related to macro- and meso-level impacts;

    b. Meteorological and agricultural drought analytical workflows (monitoring and forecasting) related to meso- and micro-level impacts; and

    c. Remote sensing-based tools for drought monitoring and impact assessment related to micro- and meso-level impacts.

Hydrological modelling

4. Nile DEWS hydrological model outputs should be based on catchment units not bigger than 500km^2 (or river reaches associated with comparable sized catchment areas) and generally aligned with the existing 203 catchments within the DSS.

5. Nile DEWS hydrological streamflow forecasts should focus 1 to 3 months in the future, but it should also include elements for 4-6 months in the future.

6. The Nile DEWS hydrological model will ideally produce data that can be integrated into the DSS, but this is not a requirement, especially if other information generation requirements are met (see Recommendations 10-11)

Meteorological and agricultural drought analytical workflow improvements

7. Nile DEWS improvements on meteorological and agricultural drought analytical workflows should focus on:

a. Seasonal forecast skills for both precipitation and temperature;

b. Observed precipitation bias correction; and

c. Satellite data pre-processing and post-processing improvements for precipitation, temperature, evapotranspiration or proxies for it, and vegetation indices.

Development of tool for small surface water body identification and change

8. The Nile DEWS should include a remote-sensing based tool to identify and assess changes in small surface water bodies (expected minimum threshold size 50-100m^2), which are significant sources of community-level irrigation, household, and/or livestock water supply.

Generation of usable information for different intended users

9. The Nile DEWS should produce data and information that is usable to support decision-making on interventions related to the targeted priority drought impacts. Therefore, it must be accessible and meaningful to both technical experts as well as:

a. Policy advisors and/or decision-makers; and

b. People who immediately undertake drought management and interact with affected communities such as national NBDF members and local government officials.

10. DEWS developers should therefore engage with different intended users during the DEWS development process to design specific aspects (i.e., website, software, bulletins, etc.) to meet their needs.

11. The DEWS must also have engagement mechanisms and tools built into it, especially validation and/or impact reporting functionality.

12. As the DEWS is implemented, intended users will need training on how to interpret the information generated, how to provide validation feedback, and how to use the information to support their decision-making on drought management interventions.

Recommendations for medium- to long-term work associated with the DRM project

Further, to achieve NBI Strategic Goals and meet stakeholders' stated needs, it is recommended to develop a medium- (2-5 years) to long-term (5-10 years) phase of work that builds on the near-term DRM project that includes the following components:

- Develop a drought impact reporting network in each country to support DEWS improvement over time[1];
- Additional DEWS validation through drought impact assessment and subsequent refinement of the DEWS;
- Development of operational (repeated regularly and easily) remote sensing analytical tools for:
  - Small surface water body identification and change detection (if not progressed through the upcoming TOR);
  - Crop type mapping;
  - Irrigation area mapping;
  - Deforestation mapping;
  - Wetland change detection;

- Pursuit of a strategic partnership in relation to the upcoming SWOT satellite mission;
- Undertake drought vulnerability assessments and support policy planning processes:
  - Quantitative and spatial hydrological drought vulnerability analyses incorporating biophysical and socio-economic, demographic, and other data types;
  - Support NBI focal points in a policy process that incorporates the DEWS (or locally modified versions of it) into their national drought management policies – especially related to hydrological drought impacts, and inclusive of "trigger thresholds for action"; and
  - Establish appropriate procedural mechanisms and policy framework, and then develop a basin-wide drought preparedness, mitigation, and/or response policy that incorporates information generated by the Nile DEWS.

Other ideas to consider

In the medium- to long-term, it is recommended that NBI:

- Consider the integration of staff who deal with flood and drought monitoring and forecasting, within a functional unit across the NBI;
- Explore integrated modelling framework and data architecture for flood, flash flood, and hydrological drought monitoring and forecasting, at least in relation to macro- and meso-level; and
- Explore a strategic partnership with ICPAC focused primarily on seasonal precipitation and temperature forecasting.

[1] Also, consider the integration of flood and drought impact reporting networks *if* the stakeholders involved (whether institutions or individuals) are likely to be the same.

1. Introduction

To meets its Strategic Goals, the NBI seeks to develop improved drought monitoring and forecasting capacity both internally and for national agencies and civil society stakeholders. Through the Nile Cooperation for Climate Resilience (NCCR) project, ENTRO leads the drought component of the Flood and Drought Risk Mitigation (DRM) project. To support the DRM project, ENTRO contracted this work to:

1. Review the existing drought early warning system (hereafter called NBI DEWS) and piloted forecasting system (hereafter called the PCA system);
2. Undertake a stakeholder needs and capacity assessment; and
3. Developing a comprehensive Terms of Reference (TOR) for the DRM project including a DEWS that will cover the entire Nile Basin and that will be hosted and implemented at ENTRO.

This report stands alone, but it builds on and makes frequent reference to the Inception report delivered in September 2022.

1.1 Scope of work

Specifically, the review includes technological, institutional, information-generation, sharing, engagement, and capability components. Recommendations on future development of the DEWS, and revisions to the DRM Concept Note, are then made after the stakeholder needs assessment, which includes the following components:

- Assessment of the use of, and feedback on, the existing NBI DEWS;
- Information on drought impacts and vulnerability, information exchange mechanisms for affected and/or vulnerable communities to receive early warning information, and existing drought management policies and systems in the countries; and
- Desired technical and engagement improvements for the DEWS.

Based on the needs assessment and associated recommendations, the DRM TOR includes the following elements:

- Scope of work for development of the DEWS;
- Mandated and/or potential approaches to deliver the scope of work;
- Qualifications of experts required to deliver the scope of work; and
- Draft work plan for delivery of scope of work.

Thus, following acceptance of this report inclusive of the revised Concept Note (Annex 2), the remaining Task is to develop the DRM TOR.

1.2 Conceptual approach

Meeting the objectives of the project requires consideration and explicit description of:

- what a DEWS consists of;
- how the DEWS is developed and operated, and by whom (as individuals and institutions);
- how the data and information outputs from the DEWS are intended to be used and by whom;

- how the DEWS links to wider drought risk management needs within the DRM project and within national systems in Nile Basin countries; and
- how DEWS stakeholders and users are meant to engage, interact, and ultimately enable the refinement of the DEWS over time to better suit their own needs.

Therefore, the considerations relate to technologies, institutions, information, and people and their interactions[2].

As shown in Figure 1, a narrow conception of the DEWS consists of technical work, information generation, information dissemination, and user engagement.

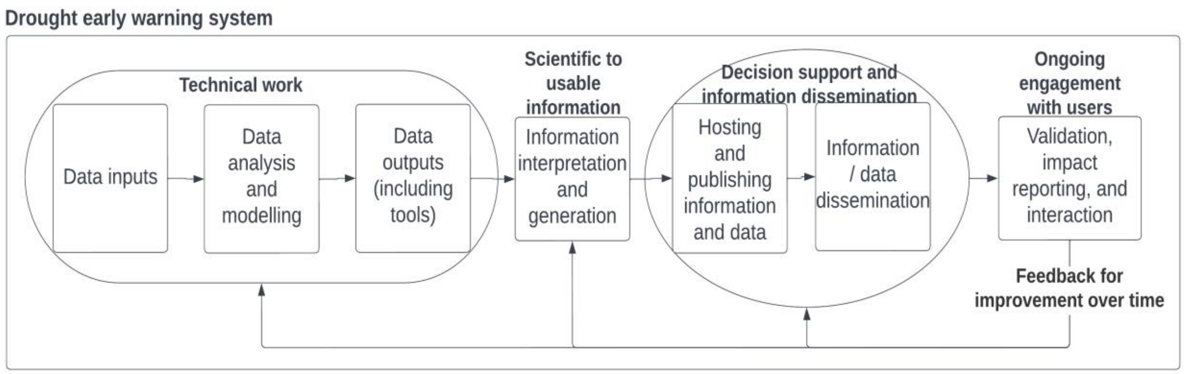

Figure 1: Drought Early Warning System Components

Priority stakeholders, priority impacts, and intended users and uses of DEWS

The views of priority stakeholders are shaped by their own remits, those to whom they are accountable, issues of political economy, etc. For example, if a country's food production is almost entirely reliant on irrigated agriculture, the priority impacts for the ministry of water and the ministry of agriculture will be different than if livestock production and aquaculture are key. The Inception report concluded that ENTRO's key constituencies are 1.) ministries of water in basin countries, and 2.) civil society organizations in basin countries (NBD Forum members). NBD Forum members' own key constituencies include a.) their internal boards, b.) communities with whom and where they work, and c.) their funders.

The priority drought impacts that stakeholders wish to monitor and predict through the DEWS – as well as their intended uses of the data coming out of it to support drought management efforts – shape specific components of the DEWS. In this assessment, specific stakeholders considered include NBI centers (especially ENTRO and Nile-SEC), national governments, and civil society as represented by the Nile Basin Discourse (NBD) and its national bodies (NBD forum members).

[2] This report modifies the "conceptual approach" described in the Inception report through addition of the "ongoing engagement with users" component, but otherwise has no major changes to the conceptual approach.

Three pillars approach to drought risk management

Further, this project is approached through the Integrated Drought Management Program's "three pillars of drought risk management" framework[3]. In this framework, Pillar 1 is drought early warning (monitoring and forecasting), Pillar 2 is drought impact and vulnerability assessments, and Pillar 3 is preparedness, mitigation, and response planning.

1.3 Documents consulted

The preparation of this report included review of the following NBI documents and systems, with bolded items reviewed following delivery of the Inception report:

- **Conceptual Design of the Nile Basin Flow Forecasting System (NBI-RFFS);**
- **NBI River Flow Forecasting Inception Report;**
- **NBI River Flow Forecasting Final Report;**
- **Flood and Drought portal;**
- **Concept Note – Enhancing Availability and Use of Water Quality Data in the Nile Basin;**
- NBI Strategy 2017-2027;
- NCCR Stakeholder Engagement Framework;
- Nile Basin Regional Hydro-Meteorological Network;
- Draft DRM Concept Note;
- DHI Drought User Guide [for the operational NBI DEWS];
- Advancing Drought Monitoring, Prediction, and Early Warning System in the Eastern Nile Basin (hereafter called PCA report);
- Eastern Nile Flood Forecast and Early Warning Enhancement; and
- Bulletins of the NBI DEWS.

2. Methods – stakeholder assessment and technical review

The needs assessment was undertaken through two primary methods: participatory research and technical review.

2.1 Participatory research

The participatory research involved people from:

- NBI centers (ENTRO, Nile-SEC, and NELSAP-CU);
- NBI focal point ministries (hereafter called NBI focal points) in charge of water resources or similar in Nile Basin countries;
- National government officials from various ministries; and
- NBD members.

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[3] https://www.droughtmanagement.info/ ; World Meteorological Organization (WMO) and Global Water Partnership (GWP), 2014. *National Drought Management Policy Guidelines: A Template for Action*. Integrated Drought Management Programme (IDMP) Tools and Guidelines Series 1. WMO, Geneva, Switzerland and GWP, Stockholm, Sweden.

The participatory research included several components: four surveys, key informant interviews, a regional workshop, and focus groups. Table 1 below shows which types of participants were involved in which of the specific participatory research components.

Table 1: Participatory research summary

Participant type	Surveys	Interviews	Regional workshop (2 days)	Focus groups	Review of inception report	Stakeholder type participation total
NBI centers	All centers, 2 of 4 surveys (n=2; n=3)	Nile-SEC and ENTRO only (n=8)	All (n=10)	No	Flood and Drought Technical Working Group (F&D TWG) members	23
NBI focal points	2 of 4 surveys (n=11; n=6)	No	Yes (n=10)	No	F&D TWG) members	27
National government officials other than NBI focal points	No respondents	Ethiopia (n=5) and Uganda (n=6)	No	No	No	11
NBD members	1 of 4 surveys* (n=51);	Nominated members from countries (n=5)	NBD regional monitoring and evaluation officer (n=1)	Uganda NBDF members (n=19)	NBD regional monitoring and evaluation officer	77
Participatory research total participation rate	73	24	21	19	N/A	

*Note that the NBD regional monitoring and evaluation officer also responded to the needs and capability assessment surveys that were provided to NBI focal points.

Results reported from the participatory research are presented as a synthesis from all components with more detail in the appendices and annex:

- Detailed summary notes are provided for each key informant interview and summary in the Annex;

- Summary notes from the NBDF member focus groups in Uganda are shown in Appendix B; and
- A summary table of national presentations at the regional workshop is in the Annex.

2.1.1 Surveys

The Inception report provides detail on the first three surveys that were distributed to NBI centers and NBI focal points. In summary, those surveys focused on two main themes: 1.) DEWS modelling capability (including computing and human resources) and associated institutional relationships, and 2.) DEWS needs and linkages with wider DRM elements including policy.

Since then, one additional survey was undertaken: that for NBDF members. The purpose of this survey was to determine the following:

- Priority drought impacts for NBDF members to address;
- Current sources of drought-related monitoring and forecasting information (including views on the existing NBI DEWS if they indicated familiarity with it);
- Their interventions for drought management and interactions with other stakeholders involved in drought management; and
- Views on how they can improvement drought management responses.

The NBD provided the survey to national NBD board members and/or technical support experts who subsequently distributed it to their members via email and soft copy. All respondents used the SurveyMonkey link. Appendix A provides more information on survey respondents.

2.1.2 Interviews

The Inception report describes the context of key informant interviews in detail. In total, key informant interviews were conducted with:

- Four ENTRO staff including senior management (1) and project managers, and modelling, engineering, knowledge management, and social science specialists (3);
- Four staff from Nile-SEC with expertise in water resources modelling, water quality, remote sensing, and IT data infrastructure;
- Nominated NBDF members from five countries – Burundi, Democratic Republic of Congo, Ethiopia, Rwanda, and Tanzania;
- Five Ethiopian government officials, one each from:
  - National Disaster Risk Management Commission,
  - Ethiopian Meteorological Institute,
  - Ethiopian Agricultural Research Institute,
  - Ministry of Water and Energy (WASH Directorate),
  - Ministry of Irrigation and Lowlands; and
- Six Ugandan government officials:
  - four from the Ministry of Water and Environment with roles related to
    - wetland management,
    - water supply for agricultural production,

    - water resources monitoring and modelling,
    - water storage infrastructure development and management,
  - one from the Ministry of Agriculture focused on agricultural water management; and
  - one from the Disaster Preparedness and Management directorate within the Office of the Prime Minister.

2.1.3 Regional workshop

The Regional Workshop included 21 participants from the F&D TWG from ENTRO, NELSAP-CU, NBD, the World Bank, and NBI national focal points. Its purposes were to 1.) introduce the DRM project to the F&D-TWG members, and 2.) gather relevant information for the development of the DRM TOR. The information sought was the same as described for the surveys and interviews (see the inception report), with the only additional theme being intra-governmental Nile DEWS needs versus Nile Basin-wide needs from the DEWS.

The first day included the following components:

1. Overview of the specific DRM project;
2. Overview of drought risk management as a conceptual theme, including recent activities of relevance in the Middle East and North Africa region undertaken through the MENAdrought project[4]; and
3. Summary descriptions of national activities and information related to drought monitoring, forecasting, and management.

The second day included the following components:

1. Report back from day 1 focused on summary and synthesis of national contexts;
2. Small group activities focused on descriptions of how the Nile DEWS will contribute to members' and NBI's long- and medium-term objectives;
3. Survey related to priority impacts (survey); and
4. Small group activities focused on the DEWS data and information output requirements (related to both technical and information sharing and engagement components per Figure 1), and DEWS modelling requirements.

2.1.4 Uganda NBDF focus groups

With support from the Uganda NBD national technical support expert, two focus groups were conducted with 19 Uganda NBDF members. The focus groups included the following components:

Discussion about priority impacts and existing early warning systems

- Introduction of self and organisation represented;
- Priority drought impacts, with a focus on those that link food and water security;
- Current sources of drought monitoring and forecasting information;
  - Indicators that relate to priority impacts described above; and

[4] https://menadrought.iwmi.org/

- Drought management systems and interactions with central and local government officials.

Discussion about the existing NBI DEWS bulletin and what's needed in a DEWS website

- Review the existing NBI DEWS bulletin and then discuss in relation to the bulletin as well as an associated website[5]:
  - The types of information presented (is this type of information useful generally?);
  - How the information is presented and communicated (is it understandable?);
  - Realistically, how can you use this information? What will it help you to do?;
  - What more would you want the bulletin to help you do?;
  - How could the bulletin be different to help you do these things?; and
  - What will enable you to convey meaning of what you find to the groups you work with. local communities. and your own stakeholders?

The first group included 14 participants, and it lasted 3 hours, and the second group included 5 participants, and it lasted about 90 minutes. The Uganda NBDF technical support expert participated in both sessions.

2.2 Technical review

Since delivery of the Inception report, the following additional technical review components were completed:

- Reviewed the Conceptual Design of the Nile Basin Flow Forecasting System (NBI-RFFS);
- Reviewed the NBI River Flow Forecasting Inception Report;
- Reviewed the NBI River Flow Forecasting Final Report;
- Accessed the NBI Flood and Drought portal as a user; and
- Interviewed key Nile-SEC staff who operate the existing NBI DEWS and the Nile DSS as well as helped establish and maintain the data architecture for them.

For clarity, the NBI-RFFS is a component of the existing NBI DEWS that incorporates river flow forecasting; it is run operationally, but the data is not released as described further in Section 4.1

3. Results – stakeholder assessment

The results reported here synthesize findings from all of the participatory research components. They supplement and sit alongside the extensive results already shown in Section 4 of the Inception Report that relate to:

- Strategic and long-term objectives for development of the DEWS that will take a decade or more to materialize;
- Priority impacts for the DEWS;
- Key users and uses of the DEWS; and

[5] Focus group participants did not log into the Flood and Drought portal but did have a printout of the NBI DEWS bulletin from October 2022.

- Stated needs for DEWS output and analytical requirements.

New results are reported in the same order and structure as the Inception report, and then additional thematic components are introduced. The annex includes full NBDF survey results and summaries of interviews undertaken following delivery of the Inception report, Appendix B includes a summary of the Uganda focus group discussions, and more detailed regional workshop outputs and other survey results were included in the Inception report.

3.1 Long-term objectives for the Nile DEWS and link between its development and NBI strategy

In all, participants described the following groups of long-term objectives for the Nile DEWS:

1. Provides early warning information that
    a. Supports governmental drought response decision-making and intervention planning;
    b. Is available to the private sector, civil society, and the general public and thereby enables them to improve their own drought risk management activities;
    c. Includes advice on specific drought risk management activities to all types of actors (governmental, civil society, etc.)*[6];
    d. Is incorporated in operational policy mechanisms at the regional (Nile Basin / Eastern Nile / Equatorial Lakes), national, sector (e.g. hydropower), and unit of infrastructure (e.g. dam operation) levels;
    e. Incorporates local indigenous knowledge;
    f. Is tailored to groups that interact with affected communities or undertake drought management interventions. Such groups include local government officials and NBDF members.
    g. Is relevant to protected and/or critical environmental systems (e.g., wetlands, lakes, and rangelands); and
    h. Incorporates drought impact reporting as well as validation feedback loops with users to improve the data and information, and their use, over time*.

2. Provides relatively long-term data and information on hydrological, meteorological, and agricultural drought conditions that:
    a. Enables hazard mapping;
    b. Is incorporated in planning processes for strategic water management and solicitation of funding for it;
    c. Supports development of fundable projects to improve drought risk management
    d. Supports implementation of national economic development plans and specific projects therein; and
    e. Supports climate change adaptation.

3. Development and implementation entails building capability in:
    a. Scientific / technical analysis and modelling;

[6] Themes with an asterisk (*) were particularly emphasised by NBDF members.

b. Data and information sharing systems inclusive of technical and institutional / governance aspects;
c. Improvement of hydrometeorological observation and integration with remote sensing and modelled data;
d. Supporting operational management (in the public and private sector) and policy implementation with technical information;
e. Coordination between various levels of government, and with civil society organisations;
f. For NBI, interaction with local government officials and civil society stakeholders; and
g. Tools for engagement with users such as for validation, impact reporting, and other user feedback mechanisms.

In general, these objectives are relevant at both the basin, national, and sub-national levels. Indeed, many participants explicitly stated the DEWS would support international policy agreements and implementation collaboration as much as sub-national drought risk management planning.

3.2 Priority impacts

NBI and governmental stakeholders (including NBI focal points) had consistent views across the surveys, interviews, and workshop: the Nile DEWS should focus on hydrological impacts of drought, followed closely by agricultural impacts. They indicate this despite interviews and workshop discussions clearly indicating that those types of participants consider the agricultural and directly associated socio-economic effects of drought to be more important than hydrological and directly associated socio-economic impacts of drought in relation to national political economy.

Table 2 shows workshop results about priority impact "themes" (broad categories) and Table 3, also from the workshop, shows priority specific impacts. Table 4 from the needs assessment survey shows the top 12 (of 31) weighted responses to a question related to the importance of specific impacts for the institution.

Table 2: Workshop results showing weighted priority impact themes. Weighting was such that responses of "priority 1" have a score of 3; priority 2 = score of 2; priority 3 = score of 1; n=18 and not all respondents put more than one impact theme.

Priority impact themes	Weighted total
Hydrological	37
Agricultural	34
Environmental	19

Table 3: Workshop results showing weighted specific priority impacts. Weighting was as for Table 2, n=18, and not all respondents put more than two impact themes. Note that respondents were asked to put their first specific priority impact within the impact theme they listed as highest priority but otherwise did not have specific directions

Priority specific impacts	**Weighted total**
Reduced streamflow	28
Rainfed crop failure	19
Reduced surface water storage	11
Ecosystem degradation	9
Reduced livestock water	7
Desertification	7
Water quality problems	6
Irrigated production declines	6
Reduced spring discharge	3
Farmer income losses	3
Decline in fisheries	3
Hunger and migration	3
Groundwater drawdown	2
Forest fires	2
Environmental flows	1
Social conflict related to water access	1
Health problems	1
Livestock disease and/or mortality	0
Pest insects	0
Price increases	0
Reduced energy generation	0
Reduced municipal nad household water supply	0

Table 4: Survey 2 question 5 results: "how important are the following drought impacts for your organisation to be able to monitor, forecast, and/or manage"; n=12, number of responses per item ranges between 8 and 10.

Answer Choices	Irrelevant	Unimportant	Moderately important	Very important	Critical	Weighted Average
Hydropower production	0	0	1	4	4	3.33
Dam storage	0	1	0	4	4	3.22
Streamflow / river levels	0	0	1	6	3	3.2
Lake levels	0	0	2	4	3	3.11
Municipal supply water availability	0	0	1	6	2	3.11
Wetland condition	0	0	1	7	2	3.1

Groundwater recharge and/or drawdown	0	0	1	7	1	3
Degradation of freshwater fisheries	0	0	4	2	4	3
Municipal supply water consumption	0	0	3	4	2	2.89
Rural unemployment / reduced rural incomes	0	1	2	3	3	2.89
Irrigated agriculture production	0	0	4	4	2	2.8
Surface water quality	0	0	3	5	1	2.78

The NBDF survey, interviews, and focus groups revealed slightly different patterns of emphasis related to priority impacts and monitoring needs to improve management of them. For example, the drought impacts with the highest and second-highest cumulative scores across all themes for needing improved monitoring information had close scores. They were “agricultural water management (irrigation or water conservation practice)” and “ecosystem degradation (wetlands, grasslands, forests, etc.)”. The third and fourth highest themes were “social conflict related to water access” and “food and water price increases”. Full responses are shown in Figure 2.

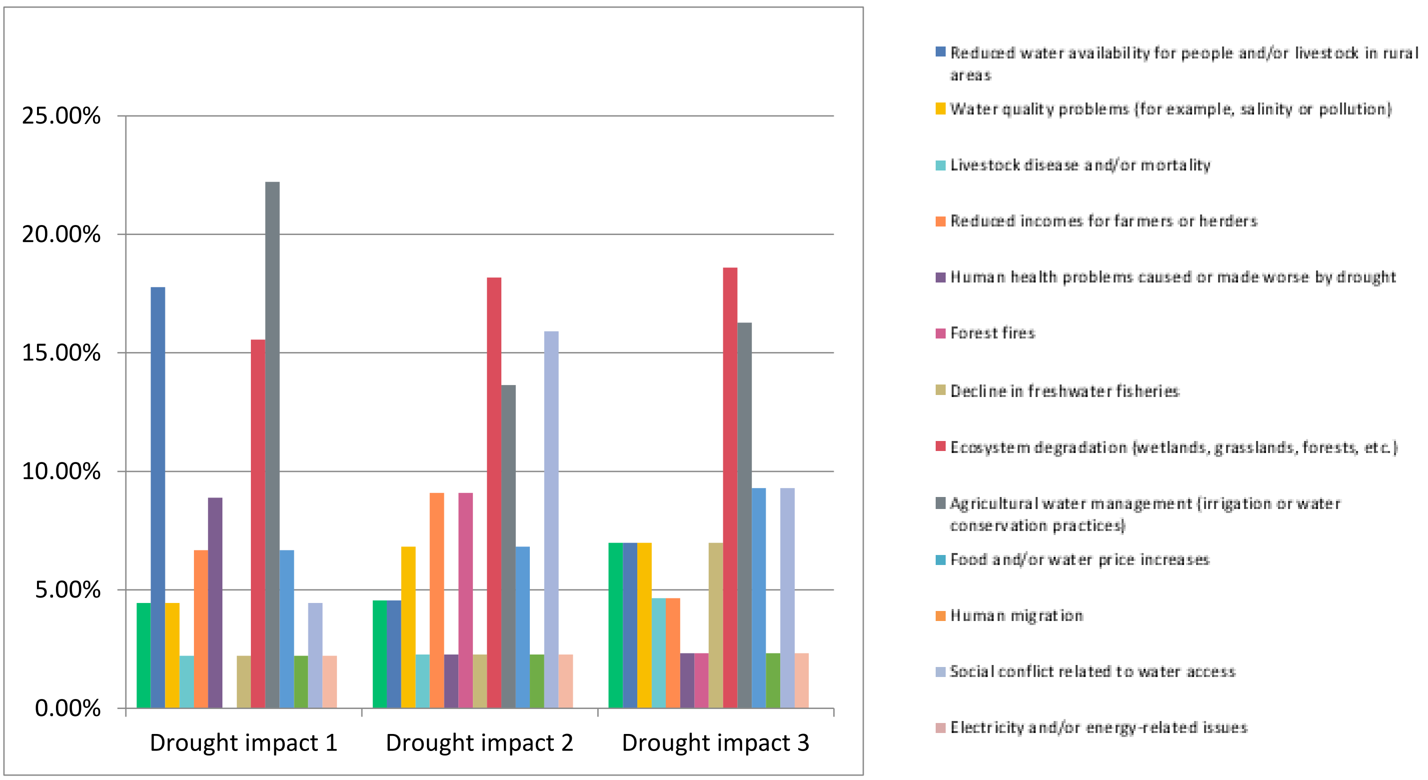

Figure 2: NBDF survey responses to question 10 “Of those drought impacts your organisation addresses, which are the top 3 you think you could manage more effectively with better drought

These results indicate that civil society organizations prioritize food and water security elements – as do government and NBI respondents (centers and focal points) – but also that civil society organizations desire higher prominence of ecosystem management themes for the Nile DEWS.

Results reflect very important differences in organizational remits of NBDF members and NBI focal points

Whereas NBI focal points focus primarily on water management themes and work within a constellation of government agencies that each focus on specific other matters, NBDF members tend to have much wider remits related to sustainable development writ large.

For example, NBDF members frequently undertake or support interventions related to all of the following: agricultural water management and environmental conservation (2/3 of survey respondents undertake these interventions), hunger, reduced water available for people and livestock, related to these themes), and wider human and economic development. In other words, NBDF members tend to consider drought monitoring and management holistically across socio-ecological domains whereas NBI focal points, by legislative or policy direction, consider compartmentalized aspects of it. In some cases, the national platforms for disaster preparedness and risk management (see Section 3.5.2) or comparable entities have such holistic considerations, but they work through line ministries with specific remits and receive information from those line ministries (and often also from NBD board and/or other members). This web of relationships is illustrated in a general manner (not specific to any country, and broadly representative of all NBI countries) in Figure 3.

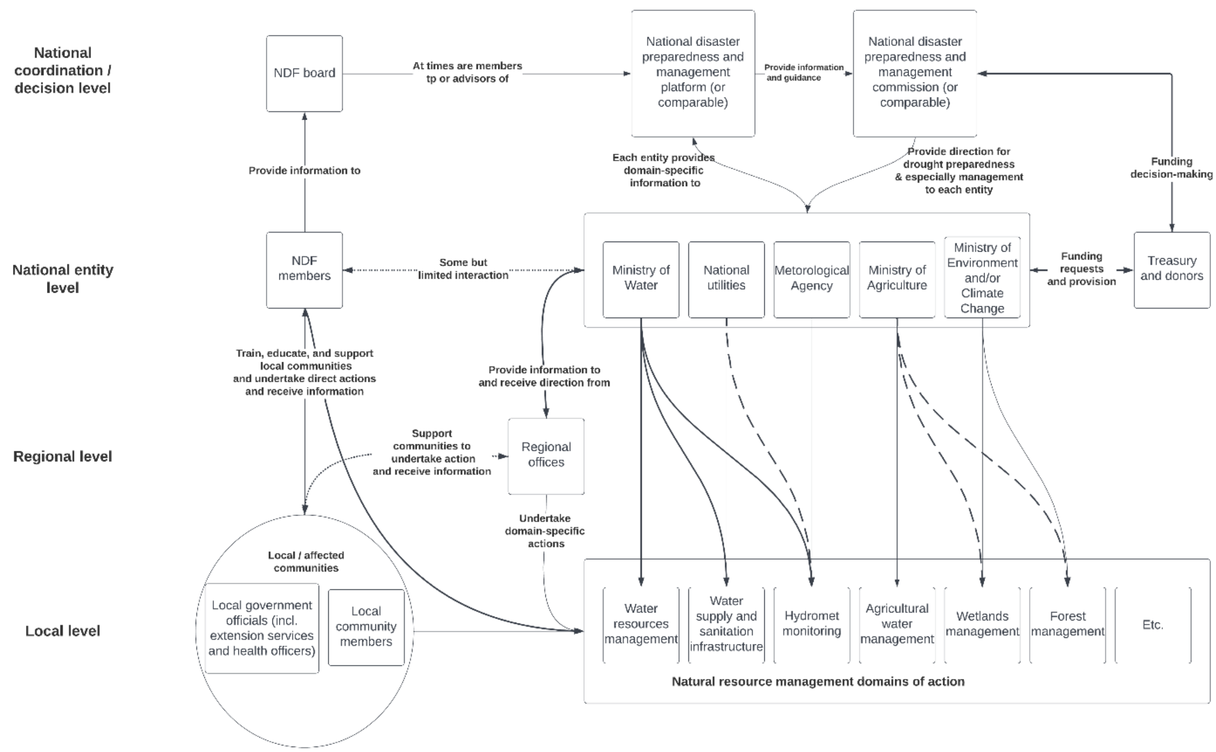

Figure 3: Levels of action and interaction, NBDF and national agencies (including NBI focal points). Note this is a generalization across the countries representative of typical relationships as described during the needs assessment.

3.2.1 Priority drought impacts for the Nile DEWS

Given the findings and consideration of the NBI Strategy, the Nile DEWS should focus on the following two priority drought impacts:

a. Macro-level hydrological drought and its impacts on national and transboundary water resources management and large-scale infrastructure operation; and

b. Meso- and micro-level impacts of hydrological drought on rural and agro-pastoral communities' water and food security.

Designing the future Nile DEWS to facilitate and support management of these drought impacts entails significant differences from the current NBI DEWS in:

- Intended users and uses of DEWS data and information;
- Early warning system modelling focus and therefore setup;
- Incorporation with decision-support systems and other generation of useable information;
- Data and information sharing; and
- User engagement.

In particular, current systems are designed primarily around macro-level hydrological drought impact and technical expert users. The implications of these differences are discussed further in Sections 5-7.

Further, this focus for Nile DEWS would make it complementary to, rather than duplicative of, existing and trusted regional drought monitoring and forecasting systems such as FEWSNet and ICPAC, which are discussed more in Section 3.4.1 and Section 4.

3.3 Intended users and uses of DEWS data and information

As described in the Inception report, participants from government and NBI focal points generally described themselves as the primary intended users of the Nile DEWS system in the immediate future, with a desire to expand users to wider publics over the medium to long term. However, NBDF members desired to be priority users from the outset.

Survey and workshop results also indicated that the organizations primarily receive drought related data rather than produce much of it. Therefore, they tend to think that drought monitoring is important for them primarily in relation to matters directly within their ministerial mandate, but that it is not core for them to conduct drought monitoring or drought management for all-of-government functions or policy responses.

Developing the Nile DEWS such that NBDF members are priority users from the beginning of Phase 2 of the DRM project would entail a different approach than if NBI focal points and NBI centers are the priority users. The differences are discussed in more detail in Sections 5.1 and 5.2.

It is important to note that the long-term objectives of participants from NBI centers, NBI focal points, and NBDF members did not differ substantially; rather, they had different views about the timing and staging of developments[7]. In both cases, participants state that intended uses include internal-to-government data and information purposes (e.g. policy advice and operational

[7] Note that at least one NBI focal point suggested delaying development of the DEWS until broader political agreement was reached on a Nile River Basin Commission.

management) as well as a more public alert and advisory system with associated information dissemination and feedback mechanisms.

3.4 DEWS output requirements

During the workshop, participants described DEWS output and analytical requirements. Stated requirements related to relevant indicators and datasets, the timestep of outputs, format of outputs, and characteristics of data accessibility.

3.4.1 Relevant indicators and datasets

As with intended users and uses, responses included a "wish list", a wide selection of indicators and data that are relevant to drought writ large. During DEWS development, there will have to be careful consideration of prioritization and staging. This section summarizes the common elements, and full results show the participants' breadth of thinking:

- **Common drought indicators/indices:** meteorological, agricultural, and hydrological drought indices such as SPI, NDVI, surface water supply index, soil moisture deficit, etc.;
- **Drought impact indicators** such as crop yield, community and livestock health, indicators based on indigenous knowledge, etc.;
- **Environmental monitoring data** such as monitored streamflow and groundwater levels, wetland and forest condition, etc.; and
- **Socio-economic data** including population and socio-economic indices, water demand, market prices, etc.

3.4.2 Timestep of outputs and timelines of production

By and large, respondents noted that the DEWS analytical components for monitoring and forecasting should be run fortnightly or monthly using input data with daily or near-daily time-steps. They recognise that drought impact indicators, environmental monitoring, and socio-economic data will not be available with the same frequency, but it depends on the specific data under consideration.

3.4.3 Format of outputs and information dissemination

Participants unanimously agree that DEWS data outputs should include gridded geospatial data and tabular data. They agree that information outputs should include spatially aggregated maps, summary statistics, and summary reports available online and appropriate for print production, and inclusive of summary report designed for mobile phones. They also agree that there must be feedback mechanisms for users of the system to provide data into the system (ie., impact data) as well as validation of system data and information.

There was consensus on the fact that the general website content and reports must be understandable to non-technical specialists and be usable by people at the community level from various sectors. At the same time, it must have functionality for at least NBI centers' staff to access and manipulate data.

Participants mentioned several ways to achieve these goals:

- Dynamic website with user friendly graphic interface including:
    - Zoom in and out;

    - "hover over" functionality;
    - Ability to create Areas of Interest (AOI) on the fly;
- Data displays showing timeseries, past droughts, and "red-flag" thresholds;
- Feedback for verification of products;
- Ability to input shapefiles to enable long-term system development;
- Mechanisms for GIS and CSV data download, importing and exporting functional extracts including for user-created AOIs, creation of reports via PDF; and
- Android application tool for outputs.

Also, participants think the geodatabase/metadatabase should incorporate hydrometeorological ground stations' locations and enable telemetry data pipelines to support long-term model development. However, they recognize this is a long-term ambition because it would require necessary cooperation arrangements for observation data that to date have been institutionally challenged to develop.

3.4.4 Data and information accessibility

There was no consensus on data and information accessibility, other than that staff from NBI centers *must* have access to the system output data and information. This issue will have to be considered thoroughly during the DEWS development process. Views ranged widely from some participants saying the entire data and information archive should be publicly accessible, to others saying that the output data and archives should be limited to registered users from government agencies.

3.4.5 DEWS modelling requirements

Participants were supplied with an example list of DEWS modelling "must-haves" with which they had no disagreement. They included the following[8]:

- Able to meet input data requirements through gridded regional / global products;
- Facility to introduce observation data (data assimilation);
- Possibility to calibrate with suitable tools;
- Outputs are gridded; and
- Validation of inputs and outputs.

Additionally noted must-haves included the following:

- DEWS should be open source as far as possible; otherwise use system for which NBI has license;
- Can be run on Windows platforms; and
- Avoid complexity.

[8] Note that they also stated that models must be at least partially physically-based, but there was no explanation or contextual information about this, and therefore it has not been included in this list.

Additional comments on must-haves stressed the need for verification and validation of model data as well as the long-term need for data assimilation. They also noted that physical models are resource-consuming, particularly when considering the strong need for observation data.

Participants noted desired components primarily in relation to related modelling tools. This included the potential for integration with existing hydrological models (including local empirical models), crop maps, and crop yield production models.

3.4 Pillar 1 themes – (drought early warning)

3.4.1 Sources of information about drought

Results from survey of NBI focal points, interviews with government officials, and workshop presentations

The majority (80%) of NBI focal point survey respondents (question 7) reported the NBI DEWS as a source of drought information they receive regularly, followed by information from international organizations (70%) and other central government organizations (50%). Likewise, 80% of respondents produce bulletins, 50% produce tabular data, 40% produce digital maps with GIS data, and 30% produce general public alerts (question 8).

All NBI focal points reported that they produce or receive information about meteorological drought (question 9), and 80% produce or receive specific information about hydrological drought.

FEWSNet, the WFP Seasonal Monitor, and ICPAC were the most commonly mentioned regional drought monitoring products accessed (question 13). When asked about trusted sources for drought monitoring and/or seasonal forecasting data (question 12), respondents noted meteorological agencies, NBI DEWS, FEWSNet, and ICPAC most frequently. No respondents stated that they had accessed the African Flood and Drought Monitor[9], and as noted in the inception report, it is unclear if it is still operational.

Governmental interviewees in Ethiopia and Uganda were far more likely to report reliance on the national meteorological agencies, and then ICPAC, and lastly a few mentioning FEWSNet. Beyond those who interact directly with the NBI, none had heard of the NBI DEWS.

Nakalembe et al (2021)[10] compare key characteristics of these regional systems (excluding the African Flood and Drought Monitor), and several others. They differ in elements such as particular satellite data inputs, use of ancillary data like land use layers, and extent of reporting networks. However, by and large they are comparable systems. National governments within the Nile Basin (at least Kenya, Tanzania, Ethiopia, Uganda, and Rwanda) have partnered with the organizations that produce these regional systems to create nation-specific monitoring systems focused primarily on agricultural drought based on the regional platform.

[9] http://hydrology.soton.ac.uk/apps/afdm/

[10] Nakalembe, C., et al. (2021) A review of satellite-based global agricultural monitoring systems available for Africa, Global Food Security, Vol 29, 100543. https://doi.org/10.1016/j.gfs.2021.100543

During the workshop, officials provided varying levels of detail related to hydro meteorological drought monitoring and forecasting, as well as impact monitoring that their governments undertake (see the regional workshop country presentations in the Annex). In sum, environmental data relevant for drought monitoring that agencies generate varies significantly, but in most cases, it is typically provided to disaster risk management commissions and combined with information from regional systems like ICPAC and FEWSNet for management purposes. Most NBI focal points do not undertake seasonal forecasting themselves, though a few noted they have begun or plan to begin in the near future, and most rely on meteorological institutes or regional systems for such information

Results from the NBDF needs assessment survey and interviews

NBDF members receive information about drought differently than government officials. Their sources of information are shown in the table below, and it is worth noting that "other" included ICPAC and national meteorological agencies, among others. NBDF interviewees were familiar with the NBI DEWS but none of the focus group participants were, and several interviewees also spontaneously mentioned familiarity with and reliance on ICPAC forecasts.

Table 5: NBDF members' sources of information about drought (survey question 13)

Source of information	Proportion
Police, civil defense, and/or military personnel	2.17%
Healthcare workers	6.52%
People from private companies	8.70%
Scientists from universities or research centres	17.39%
Other (please specify)	19.57%
Staff from international organisations	30.43%
Farmer extension service officers and/or veterinarians	34.78%
General members of the community	36.96%
Central or local government agencies or officials	45.65%
Journalists	50.00%
Staff of local or national non-governmental organisations	54.35%

Respondents listed a range of trusted sources of drought information with various media and community members being most frequently mentioned (question 15).

Further, the main "vehicles" for drought information they receive (question 14) are television (72% of respondents), radio (67% of respondents) and newspapers (61%), with more than half (59%) reporting internet search, and just over one third (35%) reporting alerts to email. When specifically asked (question 16), 28% reported being having seen NBI DEWS bulletins, which would make it the most well-known regional drought early warning system other than the World Food Programme Seasonal Monitor.

They report (question 15) that short bulletins available online (67%) and text message alerts (61%) are the most useful way for their organization to receive information, with only 41% stating that an interactive website or GIS data would be the most useful.

Synthesis

In short, government agencies primarily deal with one another in relation to drought information, as well as with regional systems including ICPAC for meteorological drought monitoring and forecasting, and FEWSNet for agricultural drought monitoring and forecasting, whereas NBDF members primarily receive information from media, government officials, and also local community members. NBDF members are likely only to see official reports about drought. which in many cases have "information loss"[11]. Given the relatively low confidence NBDF members have in reported seasonal forecasts (as reported in interviews and focus groups), this is understandable, but it does mean that NBDF members receive partial information when official sources provide only limited information publicly.

The results also highlight that:

- NBDF members have excellent on-the-ground networks from whom they source information about drought. This is a critical point related to DEWS validation and impact reporting;
- The Nile DEWS' value add is primarily related to hydrological drought so as to avoid duplication of regional modelling efforts focused on meteorological and agricultural drought that have been the focus of many years' effort from ICPAC and FEWSNet; and
- There are potential synergies for the NBI to partner with ICPAC, as described in Section 8.3, in relation to seasonal precipitation and temperature forecasting given their potential to improve the hydrological forecasting skill of the Nile DEWS.

3.4.2 Feedback about the NBI DEWS

Positive feedback in surveys

Overall feedback in surveys about the NBI DEWS bulletin was positive as shown in Figure 4 from government officials and Figure 5 from NBDF members. In particular, feedback indicates that respondents from both groups trust the information it shows. This likely reflects overall high trust of respondents in the NBI more than critical reflection about the data and information in and of themselves – literature shows that trust in information tends to stem as much (if not mostly) from trust in the developer and communicator of the information as trust in the ultimate source of the information itself[12].

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[11] To make information about monitoring and prediction more accurate, precision and specificity are often sacrificed; the prime example of this is probabilistic seasonal forecasting whereby precipitation volumes or specific days are not provided but rather general likelihood of above or below average or early and late.

[12] Turnhout, E. and T. Gieryn, 2019: Science, politics, and the public in knowledge controversies. In *Environmental Expertise: Connecting Science, Policy and Society. Edited by Esther Turtnhout, T. Willemijn, & W. Halffman. Cambridge University Press, Cambridge, United Kingdom*, 68-81.

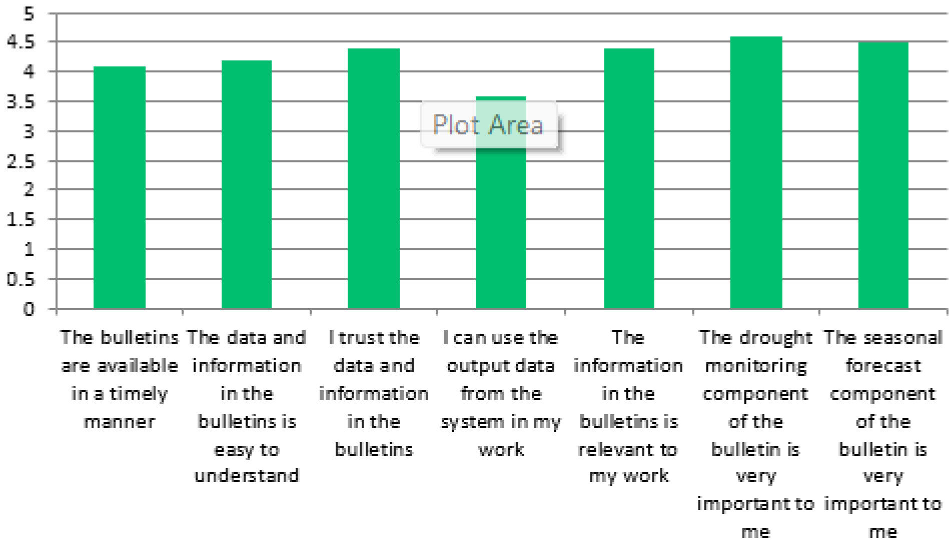


Figure 4: Responses (n=10) to question 14 in the Drought Early Warning Needs Assessment – NBI focal points survey "to what extent do you agree with the following statements about the NBI's monitoring and forecasting system"

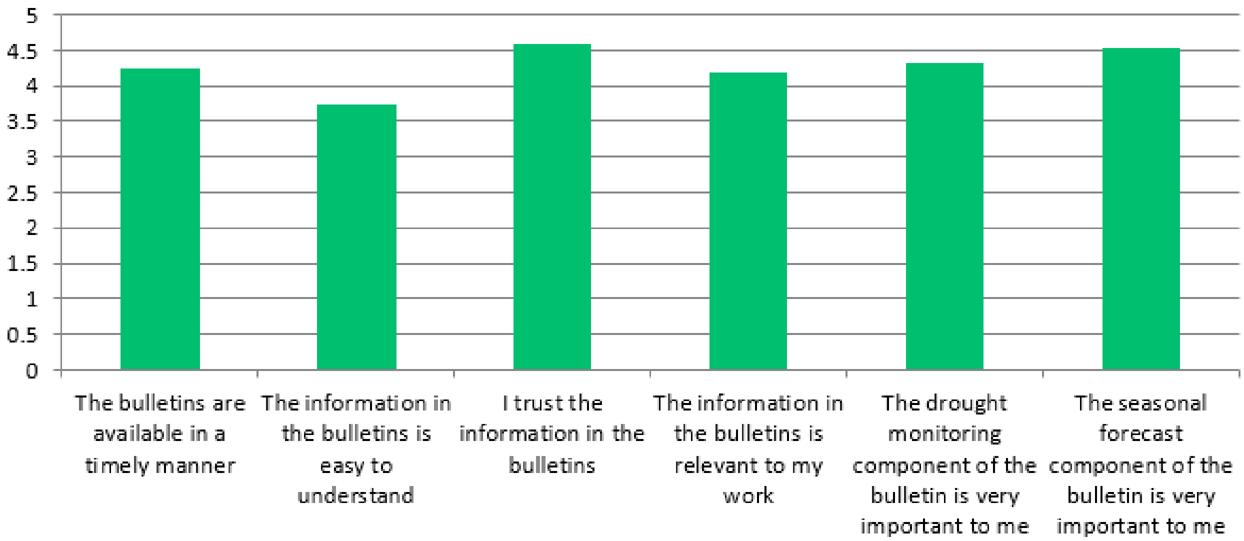


Figure 5: Responses (n=12) to question 14 in the needs assessment survey "to what extent do you agree with the following statements about the NBI's monitoring and forecasting system?"

Of note, government officials' lowest score was for the statement on ability to use output data from the system in their work, and NBDF members' lowest score was for the statement about ease of understanding the bulletin.

More negative feedback in interviews and focus groups

However, interviews and focus group discussions painted a different picture about the NBI DEWS and the bulletin. Firstly, they indicated lower familiarity with the bulletin and flood and drought portal than the surveys. Moreover, except for highly technical experts, participants described the bulletins and website (which fewer were familiar with than the bulletin itself) as difficult to understand and not particularly applicable to their work.

They considered it too technical and full of jargon, not tailored for their geographies, administrative, and cultural contexts, and that it lacks feedback mechanisms.

In this case, the interviews and focus groups provide more reliable information than the surveys. Neither set of information provided a representative sample, survey respondents have a tendency to positive bias about organisations with which they collaborate[13], and responses about shortcomings came through via probing questions during interviews and focus groups, such as when asking specific ways in which information can be used. The implications of these findings are discussed thoroughly in Section 5.1

Stated needs to improve the NBI DEWS bulletin

Survey respondents (question 16 in the NBI focal points survey and question 22 in the NBDF survey) provided several suggestions to improve the NBI DEWS bulletin.

Both governmental and NBDF stakeholders emphasized the following points as most important:

- Provision of the bulletin in local languages and not just English;
- Less technical language and jargon;
- More location-specific information; and
- Improve the accuracy of the information.

NBDF stakeholders had the following additional suggestions:

- Improve linkages with other media – radio, TV, and online social media;
- Promoting it more effectively with members of the NBDF network;
- Inclusion of guidance within or alongside the bulletin, not just information on hydrological and climatological conditions; and
- Incorporation of feedback mechanisms to producers of the NBI DEWS.

3.4.3 Other explicitly stated drought monitoring and forecasting needs

Participants described a wide range of drought monitoring and forecasting needs. Some of these focus on early warning in and of itself, but many relate to the ways in which early warning information interacts with drought management; in several cases it is relatively arbitrary whether stated needs are included here or in Section 3.5.3.

- Improve the hydrometeorological observation networks;
- Support drought data collection, quality assurance, and management procedures and systems including through development of information tools for this purpose;

[13] E.g. Furnham, Adrian (1986). "Response bias, social desirability and dissimulation". *Personality and Individual Differences*. 7(3), 385–400. doi:10.1016/0191-8869(86)90014-0

- Improve understanding of drought risks and hazard, including in relation to demographic and socio-economic data to facilitate their use for drought planning, mitigation, and response purposes;
- Seasonal forecasting information is most useful 1-3 months ahead;
- Seasonal forecasting is most useful in relation to onset of rainy season (date of arrival), end of rainy season, and anticipated volume and distribution of rainfall over the rainy season;
- Improve spatial precision of early warning in relation to geographic and administrative boundaries;
- Validate models more thoroughly (including development of information tools for this purpose);
- Establish early warning thresholds for action; and
- Capacity building for individual technical experts and institutions to produce and use monitoring and forecasting information.

The recommendations in Sections 6 and 7 reflect these explicitly stated needs as well as other needs deduced from the wider needs assessment findings.

3.5 Pillar 2 and 3 themes – impact and vulnerability assessment, and drought preparedness, mitigation, and response

3.5.1 Drought impacts and sources vulnerability

In Nile Basin countries, drought results in major society-wide impacts including famine and political instability. The purpose of this project was not to undertake a comprehensive assessment of drought impacts, vulnerabilities, and coping and adaptive capacity[14]; rather it was to incorporate consideration of those factors into recommendations on development of a DEWS and longer-term DRM project components.

This section catalogues the wide range of drought impacts and sources of vulnerability that participants noted[15]. This includes various categories with a few examples, and the survey, focus group, and interview materials provided in the Annex have more detail. Note that some of these impacts are "second order" effects in that they result from people's responses to primary impacts

[14] Coping capacity relates to near-term ability for people to "weather the storm" whereas adaptive capacity relates to their long-term ability to change practices so that the conditions do not affect them. More formally, coping capacity is the ability of communities, people, or systems to withstand drought without irreversible changes in state and functions, whereas adaptive capacity is the ability for systems, people, and communities to change form and function under new conditions.

[15] For more comprehensive reviews of drought history, impacts, vulnerability, and coping and adaptive capacity, see the "regional workshop country presentations" document in the Annex, the PCA report, which has spatial hazard exposure mapping for the Eastern Nile basin, and the following papers: Haile et al (2019); Ayugi et al (2022); Masih et al (2014); Naumann et al (2014)

– for example, human migration is primarily a follow-on effect from crop or livestock production decreases.

Impacts

Human health and wellbeing – famine, malnutrition, reduction in water quality (bacteria counts, agricultural inputs such as pesticides and nitrogen, turbidity, and salinity) and associated increase in water, sanitation, and hygiene (WASH) related disease burden, extreme heat, lung infections in cities due to heightened particulate matter, stress and mental health problems, gender- and family-based violence, removal of children from school, family breakup.

Human migration – movement from traditional cultivation or pastoral areas to others, out-migration from rural areas to cities, and emigration as low-skilled labor, especially to the Persian Gulf states.

Social conflict –access to water resources, grazing versus cultivation of lands, migration, impacts on incomes, political instability.

Ecosystem effects – deforestation (alternative livelihoods), forest fires, and forest degradation due to weather conditions as well as added grazing pressure; conversion of wetlands to cultivation areas, construction in wetlands; reduced pasture/rangelands biomass and vulnerability to long-term degradation and desertification; increased hunting of wildlife, and fisheries degradation.

Energy – reduction in hydropower generation, increase in energy demand for pumping.

Economic and livelihoods impacts – reduction of national GDP by several percentage points during drought years indicative of economic contraction that exacerbates poverty and slows the rate of poverty alleviation in future years, increase in food and water prices, shifts away from agriculture or animal husbandry.

Livestock – milk production, body weight, health status, sale prices.

Agriculture – crop yield and harvested area, pests, diseases, irrigation water supply.

Water resources – delays in rainy season onset, early finish of rainy season, reduction in rainy season volumes, reduction in streamflow, reduced water availability for people and livestock, micro- and small-scale water storage (e.g. household, village, and community-level reservoirs) is depleted before the end of the dry season, pump intakes left above water levels, high turbidity and siltation, groundwater table drops and shallow wells drying, springs drying.

Sources of vulnerability

Climate variability – high and increasing (due to climate change) intra- and inter-annual climate variability, which indicates high climatic hazard exposure, and increases in extreme heat[16].

Pre-eminence of rainfed agriculture – agriculture is the largest component of economy and labour market in most countries, and with the exception of Sudan, Egypt, and specific areas of the other countries, rainfed agriculture and pastoralism is predominant.

Demography – very young populations, in some countries reaching more than 50% of population under 18.

Poverty – leads to very low household level coping and adaptive capacity.

Water, energy, and communications and logistics infrastructure – low levels of water supply, treatment, and distribution infrastructure, rural electrification, and transport, logistics, and communications infrastructure.

Low water storage per capita – this is especially the case outside of major river basins, though it varied significantly between countries.

High exposure to currency and commodity price fluctuations – depreciation of local currencies against global benchmarks (especially USD in which most international energy trade is conducted) and base increases in food and agricultural input prices increases the costs of agricultural (and other) production and household expenditure.

Knowledge of underlying drought occurrence and spatial characteristics of impacts and vulnerability – this impedes preparedness, mitigation, and response investment and policy planning at the national and regional levels.

Knowledge of appropriate drought risk mitigation and management response practices – NBDF participants overwhelmingly stressed the need for community-level sensitization and training to adopt appropriate drought risk mitigation and management response practices; in some cases, this was linked to funding measures, but in many cases, it was related to education only.

Lack of access to finance and/or drought financial risk management mechanisms – this relates to both coping and adaptive capacity, and this source of vulnerability was particularly variable between countries.

3.5.2 Drought policy in Nile states

Nile Basin countries have advanced national drought policy and coordination mechanisms, most often as part of national offices responsible for wider disaster risk management. In relation to

[16] Note that in several workshop presentations, vulnerability studies were presented such that climatologically drier areas – absent other causal factors – were shown as having higher drought vulnerability. This is conceptually problematic: rather than lower precipitation being the climatic cause of drought vulnerability in and of itself, it is the *variability* of precipitation and accessibility of water resources (intra- and inter-annual) that causes vulnerability.

drought, they focus primarily on food security and basic water needs of people and livestock. They do not have components specific to hydrological drought, though many of the national platforms, commissions, or working groups include ministries of water, the representatives of which bring hydrological-related information to management considerations. Table 6 provides basic information on drought policy and governance.

Table 6: National drought policy, drought management lead, and integration of drought monitoring and forecasting into policy responses

Country	**Drought policy**	**Drought management lead**	**Drought monitoring and forecasting lead and integration into policy responses**
Burundi	National Drought Control Plan in Burundi (2020)	National Platform for Risk Prevention and Disaster Management	Various agencies including IGEBU; inputs coordinated through national platform according to drought control policy.
DRC	Disaster relief organisation plan (2012)	Recently announced (June 2021) creation of Agency for Prevention and Management of Natural Disasters. Ministry of Environment and Sustainable Development leads hydrological drought management operationally	No formal planning responses; Ministry of Environment and Sustainable Development undertakes monitoring for management purposes within its own remit
Egypt#	Water Resources and Irrigation Law, No. 147/(2021). Egyptian water law serves as its drought policy	Ministry of Water Resources and Irrigation (MWRI)	Nile Forecast Centre of MWRI
Ethiopia	National Policy and Strategy on Disaster Risk Management (2013); Disaster Risk Management Strategic Programme and Investment Framework (2014)	Disaster Risk Management Commission (Office of Prime Minister)	Information from various agencies (especially Ethiopian Meteorological Institute, Ministry of Agriculture, and Ministry of Water and Energy) and regional systems (especially

Country	Drought policy	Drought management lead	Drought monitoring and forecasting lead and integration into policy responses
			FEWSNet and ICPAC) inform planning; local-level impact surveys feed into national response
Kenya	National Drought Management Authority Act (2016) incorporating subsequent amendments	National Disaster Management Authority	Conducting drought risk surveillance once every three months; FEWSNet and ICPAC; forecasting using ECMWF and Integrated Forecast System (IFS) products, GEOGLAM crop monitors (Nakalambe et al 2021)
Rwanda*	Disaster Management Law (2016)	Ministry in charge of Emergency Management	As described in the National Contingency Matrix Plan (2016) – meteorological office, Ministry of Agriculture, Ministry of Environment, Environmental Management Agency, Water Resources Management Agency, contribute information alongside FEWSnet.
South Sudan	National Disaster Risk Management Policy (2022); working on National Disaster Risk Management Bill	Ministry of humanitarian affairs and disaster management; Disaster Risk Management Committees at local levels	National early warning technical working group and early warning platform for information dissemination. Members of working group include numerous agencies. National monitoring information also comes from the Meteorological Agency (in the Ministry of Transport), ICPAC, WFP/FAO, and FEWSNet as

Country	Drought policy	Drought management lead	Drought monitoring and forecasting lead and integration into policy responses
Sudan	National Drought Plan (2018) created under the auspices of the National Council for Combating Desertification	Relief and Rehabilitation Commission; National Drought Plan Task Force; Disaster Risk Management Strategy under the Civil Defense Department (Ministry of Interior)	early warning unit composed of Sudan Meteorology Authority, Remote Sensing Authority, rainfed and pastoralist associations, NGOs and CBOs, etc.
Tanzania*	Disaster Management Act (2015) and regulations (2017)	Disaster Management Department (DMD) within the Office of the Prime Minister; National Platform for DRR inclusive of government, civil society, and NGOs	Tanzania meteorological agency, ICPAC, national system based on GEOGLAM crop monitor (Nakalambe et al 2021) and local information via the National Platform for DRR
Uganda	National Policy for Disaster Preparedness (2010)	Ministry of Disaster Preparedness and Refugees; Disaster Preparedness and Management within the Office of the Prime Minister	Information from various sources including Ugandan meteorological authority and ICPAC for forecasting and ministries, including agriculture and water, as well as FEWSNet for monitoring purposes.

* Information comes primarily from interviews with the NBDF and literature review
# Information comes primarily from literature review, especially Bazza, Kay, and Knutson (2018)

Responses from all stakeholders indicated that they desire support to improve coordination between levels of governance (national, regional, local) including development of technical tools for this purpose. Also, many respondents, especially from NBDF, described current systems as focusing primarily on disaster response after impacts occur rather than preparedness and mitigation. The regional workshop results and NBDF survey results, and to a lesser extent interview findings (see Annex A) describe civil society organisations’ and government agencies’ current focus themes related to drought preparedness and mitigation.

3.5.3 Stated needs to improve drought management and associated institutional relationships

Actions stakeholders wish to undertake in the future to reduce drought impacts

NBI focal points and NBDF participants undertake a range of drought management-related actions, and they consider that improved early warning system information would enable them to do more types of actions, or do existing actions more effectively.

NBI focal points mentioned actions related to:

- Infrastructure creation for drought mitigation;
- Policy development related to drought preparedness, mitigation, and response;
- Drought monitoring and information-sharing;
- Natural resource management and governance;
- Training and capacity building at the national, regional, and local government level including for community development (e.g., supporting creation of water user associations); and
- Impact assessments to support intervention planning.

NBDF participants undertake a range of actions to reduce drought impacts (survey question 8; interviews, and they described a desire to do more in the future related to the following categories of actions:

- Communication, early alerts, and information-sharing;
- Education and training;
- Risk assessment;
- Humanitarian support;
- Livelihoods support and undertaking mitigation measures to reduce vulnerability to following drought (e.g. tree planting and support to develop irrigation networks); and
- Liaising with government and mobilizing resources for humanitarian (e.g. food provision) and livelihoods support (e.g. provision of seeds for planting in the next season).

Notably, for NBI focal points, only “natural resource management and governance” (e.g., dam operations), relates to *direct* responses to drought, whereas all the other categories of action relate to how others can and will manage drought impacts (and in many cases, also indirectly), or they relate to mitigation of future drought impacts. In contrast, NBDF members are more likely to engage in direct drought management, as well as indirect efforts that are still more closely connected to immediate and concrete drought management efforts. This has implications for Nile DEWS development as described in Section 5.1

Stated needs to improve drought risk management

Participants described a range of needs to improve drought risk management. Again, several of the themes described in relation to drought monitoring and forecasting needs (Section 3.4.3) could equally have been included here.

- Enable more rapid mobilization of resources for drought response;
- Improved utilization of existing local governance and civil society structures;
- Reduce mandate overlap;
- Strengthen transboundary drought management coordination.
- Improve coordination between governance and institutional levels – national, regional, and local; and
- Strengthen human, technological, and financial capacity of key actors to ensure better preparedness and effective interventions during drought;

The first two themes were particularly prominent for NBDF members, and last two themes were particularly prominent for NBI focal points and government officials.

Institutional relationships that can be leveraged to improve drought early warning systems and drought management responses

As shown in Figure 3, NBI focal points and NBDF members interact with fundamentally different institutions and groups of people in relation to drought monitoring and management: NBDF members are far more connected to local communities, local government officials, and other local community organizations (NBDF survey question 23), whereas NBI focal points are far more connected with central government agencies and international organizations, and to a lesser extent with local government (NBI focal points survey questions 18 and 19). This is reflected clearly in government officials' desire for improved coordination between governance levels as well as training and capacity building at sub-national (regional), and local government levels.

4. Results – Review of the existing NBI DEWS and piloted PCA system

This section provides new results from the technical review. Specific content from the Inception report's technical review is incorporated into Sections 5, 6 and 7 as appropriate, and Appendix C provides a description of the existing NBI DEWS.

4.1 NBI River Flow Forecasting System and piloted PCA system

The NBI DEWS includes a streamflow forecasting component (NBI River Flow Forecasting System, NBI-RFFS). The NBI RFFS is substantially different than the piloted PCA system as illustrated in Table 7:

Table 7: Comparison of the NBI RFFS and the piloted PCA system

Modelling characteristics	**NBI RFFS**	**Piloted PCA system**
Hydrological model used	NAM (embedded within Mike Hydro)	HBV and RAPID
Precipitation forecasting input	CFSv2 (Climate Forecasting System) for seasonal forecast (1-6 months) and GEFS for medium-range forecast (typically 3-10 days)	Purpose-developed ECMWF ensemble for seasonal forecast 1-6 months

Temporal forecast period	~3 days – 6 months	1 – 6 months
Infrastructure and water user operational rules	Yes, defined by NBI	Not able to be determined from available information (presume no)
Model run	Can be up to daily; currently run twice-monthly	Monthly (in line with ECMWF data publication)
Spatial scale of model outputs	137 branches, 738 river nodes, 203 catchments, and 206 specific forecast locations: 81 river nodes, 21 hydropower plants, 42 reservoirs, lakes, and swamps, and 62 "water users" (mainly irrigation sites)	69,744 reaches
Spatial coverage	All of Nile Basin included within the hydrological model, but lower reaches of White Nile, Machar Marshes, and predominantly arid catchments in Sudan and Egypt do not have rainfall runoff component	Eastern Nile (Abay-Blue Nile, Baro-Akobo,Sobat-White Nile, Tekeze-Setit-Atbara, Nile Mainstem)
Validation against observed streamflow	No formal evaluation against observed data; staff at NBI centers conducted informal evaluation, with results being reported as unreliable	Validation against 9 gauging stations with daily and monthly data available for varying periods. Correlations range from 0.4 to 0.83 at daily scale and 0.46 to 0.92 at monthly scale.
Integration with Nile Basin Decision Support System	Yes	Would need development of a "model adapter"

4.1.1 Nile DSS and integration with the NBI RFFS

The NBI RFFS model system is integrated with the Nile Basin Decision Support System[17] (Nile DSS), which is a powerful desktop-based data management and modelling software that enables complex water resources management analysis and planning.

NBI focal points are able to install and use the Nile DSS for various purposes. For example, the Nile DSS has modules for multi-criteria analysis, cost-benefit assessment, and scenario analyses, and the NBI has created training materials for it. It is a tool that officials use to consider national and transboundary infrastructure operation, investment options, and trade-offs related to various aspects of water management such as irrigation abstraction, water storage, and energy production among other themes.

[17] https://nbdss.nilebasin.org/support/home

As such, NBI RFFS integration with the Nile DSS provides immense opportunities to support water management. It enables technical experts to anticipate flow conditions and test the effects of responses to them; this functionality is incredibly important when linking drought early warning to response management. It greatly expands the ability of the NBI DEWS to "translate" scientific information into useable information that supports decision-making.

The Nile DSS is based on Mike Workbench, and NBI has numerous seats available for NBI focal points to install and use the system. The Nile DSS has "adaptors" that enable it to ingest data inputs from a range of hydrological models and, at least for some hydrological models, also to control scenario analyses for subsequent hydrological model runs[18].

4.1.2 Stakeholder considerations of the NBI RFFS

However, information produced by the NBI RFFS is not shared beyond NBI centers because NBI staff consider that it is not yet viable for operational forecasting due to the inaccuracy of results; this perception is based on limited analyses of NBI RFFS outputs compared to some gauge station data. NBI staff proposed several reasons for this model inaccuracy:

- No data assimilation from real-time observations;
- The hydrological model used had been developed with a focus on allocation and general water resources management and so was perhaps not particularly well parameterized for more general flow forecasting;
- The model is calibrated based on historical precipitation data (CRU) but uses different datasets for forecasting. For the forecast dataset (CEFSv2) that has bias-correction factors against CRU, the two products tend to have high differences (reported as 20-40% difference); GEFS and CRU do not have bias correction factors; and
- There is a very course assumption of PET.

4.2 Technical review synthesis

The Inception report concludes the following about the NBI DEWS and associated NBI RFFS, which still stand: it has severe weaknesses in technical components (especially related to precipitation inputs) and has not been validated in any robust manner. Further, it is now concluded that the NBI DEWS, inclusive of the Bulletin and Flood and Drought Portal, meets general information-sharing and dissemination needs as articulated by both governmental and NBDF stakeholders. However, the specific information content and ease of manipulation of available data – as well as inability to provide validation or feedback on specific outputs within the system – means that it does not meet users' needs for engagement, especially NBDF members.

Piloted PCA system

The piloted PCA system could become fit for purpose according to users' stated needs with improvements in some technical processes, expansion to the entire Nile Basin, additional

[18] At present, it has adaptors for EPANET, FEFLOW, GENERIC, GoldSim, HEC-RAS, MIKE 11, MIKE 21 FM, MIKE FLOOD, MIKE HYDRO Basin, MIKE HYDRO River, MIKE SHE, MIKE+, NWS, SWAT, WEAP.

development of information sharing mechanisms, and incorporation of data assimilation over time. It is a purpose-built hydrological drought monitoring and forecasting system, but it seems to lack core elements that will improve its performance related to infrastructure operation, and it does not have critical linkages to purpose-built decision-support systems such as integration with the Nile DSS.

Synthesis

Overall, the NBI RFFS seems to be a hydrological forecasting component added to the Nile DSS rather than a purpose-designed hydrological drought monitoring and forecasting system.

The hydrological drought monitoring and forecasting function seems to be an afterthought; the NBI RFFS is not particularly well-suited for it in its current form, primarily due to its weak setup for core meteorological and hydrological drought modelling functions. For example, streamflow forecasting run on a weekly or bi-weekly basis and forced using medium-range (3-10 days ahead) forecasts is largely irrelevant for hydrological drought monitoring and management because hydrological systems do not change drastically on a week-to-week basis, especially in the large catchments modelled by the NBI RFFS.

These issues could potentially be overcome depending on the specific drought impacts of relevance and concerted effort to focus the modelling for desired purposes.

5. Conclusions

This report builds on the core conclusions from the Inception report: it adds depth to some, modifies others, leaves some unchanged, and there are new conclusions. This section provides broad conclusions from the needs assessment – as well as more detailed conclusions about priority impacts, users, and uses of the DEWS – that are then addressed in the Recommendations sections.

5.1 Overview

Table 8 below shows DEWS aspects (organized according to categories in Figure 1 and accompanying text in Section 1.2), key conclusions from the Inception report, states what has changed in this report, and identifies the recommendations sections that reflect the conclusion.

Table D1 then describes the present ability of the NBI DEWS / NBI RFFS and PCA system to meet these needs, and what would be required to meet them more fully. The summary conclusion from the analysis presented in Table 1 is that:

- both the NBI DEWS, inclusive of the NBI RFFS, and the PCA system are primarily designed around NBI centers' and NBI focal points' needs related to priority users and uses of information;
- the NBI DEWS and PCA system are designed around different priority impacts and have different capabilities regarding the generation of usable information, primarily due to the:
    - integration of the NBI RFFS with the Nile DSS;

    - spatial scale and incorporation of infrastructure operation rules within the hydrological modelling; and
- Both systems would require modifications around information generation, sharing, and user engagement to meet the needs related to all priority impacts, and intended uses and users.

Table 8 –Progression from Inception report conclusions

DEWS aspect	Inception Report conclusion	Change	Where reflected in this report?
Priority stakeholders	ENTRO's key constituencies (priority stakeholders) are 1.) basin countries' ministries of water and 2.) civil society organisations (especially NBDF members) in basin countries	Add that NBDF members' own key constituencies include 1.) their own internal boards, 2.) communities with whom and where they work, and 3.) their funders	Section 1.2 and 6.1.1
Intended users and uses	Participants consider that [the DEWS] should focus first on [NBI focal points and centers] as the primary intended users, and the primary intended use is to support their policy advice to Ministers, collaboration with other governmental agencies, and operational functions	NBDF members unanimously desire the tool to be immediately useful to them, and local government officials, to support their interactions with affected communities related to drought impact management and mitigation actions	Sections 3.3, 6.1.1, and 7.2
	Tentatively conclude that most participants consider that the DEWS should have wider public goods functions in the medium- to long-term and therefore service wider publics over time	In line with above – increase the strength and "urgency" of this conclusion and now make recommendations to address it more fully in the short-term rather than leave it to the medium- to long-term	As above
Priority impacts	The greatest "value proposition" for the Nile DEWS is to focus primarily on seasonal precipitation forecasting and hydrological drought monitoring and forecasting	Additional specification of macro-, meso- and micro-level hydrological drought impacts focus; addition of remote sensing tools for water body identification and change detection.	Sections 3.2.1,5.2, and 6.1.1-6.1.3
Technical work of DEWS	The underlying data inputs and analytical/modelling processes [in the DEWS] could be improved substantially	No change	Sections 4.1, 4.2, and 6.3
	Validation of the DEWS outputs and drought impact assessments can be considered jointly, and undertaking them at least partially through participatory processes provides a significant opportunity to support regional information sharing, engagement, and collaboration	No change	Sections 6.2.1, 7.1, and 7.2

	There are opportunities to develop new drought monitoring tools incorporating remote sensing analysis workflows; some of these opportunities, especially in connection with the Surface water and Ocean Topography (SWOT) satellite mission, are particularly suitable for potential partnerships with donors and applied research institutes rather than contractual processes.	Increase prominence of water body identification and change detection within recommendations	Sections 6.1.4, 7.3, and 7.4
Scientific to usable information and information dissemination	The existing Nile DEWS is strong in terms of accessibility and simplicity of use and understanding	Qualification of existing Nile DEWS as a technical, expert-focused tool	Sections 5.2 and 6.1.1
Information dissemination and user engagement	The information dissemination [from the DEWS] could be strengthened significantly through training and relationship building	No change	Sections 5.2, 6.1.1, and 7.2
User engagement	NBI focal points strongly desire capability building for the DEWS related to scientific / technical elements, operational and policy decision-support, and stakeholder feedback components	Addition of NBDF members strongly desiring capability building so that they can understand, engage with, and use the system in their day-to-day interactions with local communities and government officials	Section 6.1.5
User engagement and long-term work program	Given stakeholders' ambitious and wide-ranging objectives for the DEWS, governance aspects, connections to operational planning and policy-making, and other institutional features are core considerations for its development and operation;	No change	Section 7.5

Additionally, it is now concluded that NBI focal points primarily undertake direct drought management in relation to water infrastructure operations, which represent macro- and, in some cases, meso-level hydrological drought impacts, whereas NBDF members directly deal with meso- and micro-level drought impact management. Therefore, any future DEWS development must consider how the Nile DSS can be incorporated given its primary importance to the remit of NBI focal points.

5.2 Nile DEWS as a tool for technical experts to address macro-level hydrological drought impacts

At present, the NBI RFFS and its primary integration with the Nile DSS reflect the following strategic approach, whether that was made by an explicit choice or not:

1. Information produced primarily for technical experts to support analysis and advice on decision-making related to macro-scale hydrological impacts, especially large infrastructure operation;
2. Tools that are only useful for technical experts:
    a. The DSS requires deep expertise in physical science domains of relevance, such as water resources modelling, as well as significant training in use of the software itself. While many scenario analysis components are automated, it is very much an expert-driven tool;
    b. The Nile DEWS and the associated flood and drought portal is useful for policy staff who are deeply familiar with water resource management and associated natural hazards; and
3. Tools that are inaccessible to, and information that is not immediately useful for, people who have the primary responsibility for on-the-ground drought interventions and management: local government officials, members of rural communities, and non-governmental mediators with rural communities (ie., NBDF members in each country).

This statement is not a criticism of the existing Nile DEWS and Nile DSS. Given NBI's historical predominant focus on transboundary water management issues, it is understandable that it has primarily focused on central government technical experts when considering development of such tools.

In relation to NBI strategic Goals 1, 2, and 6, focusing the DEWS primarily on macro-level hydrological drought impacts is critical and preferable. However, DEWS contributions to achieving NBI strategic objectives, particularly Goals 3-5 (and most especially Goal 5) would require more focus on affected communities.

5.2.1 Strategic choices – development of technical expert tool or tool more immediately useful for communities

ENTRO and the NBI more widely thus have strategic choices in the future (short, medium, and long terms) about development of the DEWS: resource prioritization and focus differ depending on whether ENTRO and NBI want tools to be used by technical experts or tools to be immediately useful for those who interact directly with communities. In all likelihood, the answer will be "some of both".

If ENTRO and the NBI more widely wish to shift the focus to, or at least increase the focus on, more immediate impact with on-the-ground stakeholders and affected communities – rather than working predominantly with central government and the implicit assumption that providing them with useful tools and information, in and of itself, will accomplish that objective – then it will need to expand the focus of the Nile DEWS and change the way it engages and interacts with both central government and the NBDF.

In short, the findings of the needs assessment (in particular, see Figure 3) indicate that if ENTRO desires to emphasize impact at the local level, it must pursue two parallel institutional relationship tracks:

1. Top down governmental:

    1a. NBI focal points, and via them

    1b. NBI focal points' own agencies' local networks, and also the relevant disaster risk management commission (or comparable national level entity), and via the disaster risk management commission (or comparable entity),

    1c. wider central government, but most especially local government networks;

2. Civil society:

    2a. NBD, and via it

    2b. NBD boards, and via them

    2c. NBDF members, and via them

    2d. Local communities and also local government networks.

Past DEWS engagement seems to have focused on 1a and 2a only. Results of the needs assessment indicate that deepening engagement (ie., focusing on 1b and 1c as well as 2a-2d) will require a moderately significant shift in 1.) ways of working and 2.) the prioritization of institutional focus and resources.

In short, it will require more attention and resourcing on stakeholder outreach, engagement, coordination, and training, and the development of DEWS information tools to support that engagement. However, before agreeing with this conclusion, the NBI should consider it in light of information coming from engagements with national counterparts and NBDF members through other projects.

If ENTRO wants to shift focus as outlined above, the budget and expectations for Phases 2 and 3 of the DEWS development (per the Concept Note) will enable it to start in this direction and lay the foundations for longer-term changes, but not make significant progress in and of itself.

This strategic choice will have implications for the importance of the Nile DSS. If focus shifts to the meso- and micro-level impacts, integration with the Nile DSS becomes less important. Further, if focus and emphasis shift to development of more widely usable tools rather than technical expert tools, that will also imply the need to develop other platforms to share information and engage DEWS users beyond the Nile DSS.

6 Recommendations – near-term approach for the DEWS

Here are recommendations that will meet all stakeholders' stated needs. There is no consideration of strategic prioritization of those needs in relation to available budget and resourcing. Development of the DRM TOR will proceed on the basis of accepted and rejected recommendations.

6.1 Overview

6.1.1 Recommended priority drought impacts for the Nile DEWS and associated DEWS composition

1. The Nile DEWS should focus on the following priority drought impacts:

    a. Macro-level hydrological drought and its impacts on national and transboundary water resources management and large-scale infrastructure operation; and

    b. The meso- and micro-level impacts of hydrological drought on rural and agro-pastoral communities' water and food security.

2. The immediate priority for DEWS development is on meso- and micro-level impacts of hydrological drought. This is due to pre-existing investment and capability in monitoring and forecasting macro-level drought impacts. Still, new investment should seek to improve DEWS related to both priority impacts.

3. The Nile DEWS should consist of 3 primary components:

    a. Hydrological modelling (monitoring and forecasting) related to macro- and meso-level impacts;

    b. Meteorological and agricultural drought analytical workflows (monitoring and forecasting) related to meso- and micro-level impacts; and

    c. Remote sensing-based tools for drought monitoring and impact assessment related to micro-and meso-level impacts.

6.1.2 Hydrological modelling recommendations

4. Nile DEWS hydrological model outputs should be based on catchment units smaller than 500km^2 (or river reaches associated with comparable maximum sized catchment areas) and generally aligned with the existing 203 catchments within the DSS.

5. Nile DEWS hydrological streamflow forecasts should focus 1 to 3 months in the future, but it should also 4-6 months in the future.

6. The Nile DEWS hydrological model will ideally produce data that can be integrated into the DSS, but this is not a requirement, especially if other information generation requirements are met (see Recommendations 10-11)

6.1.3 Recommended focus for meteorological and agricultural drought analytical workflow improvements

7.Nile DEWS improvements on meteorological and agricultural drought analytical workflows should focus on:

    a. Seasonal forecast skills for both precipitation and temperature;

    b. Observed precipitation bias correction; and

    c. Satellite data pre-processing for precipitation, temperature, evapotranspiration or proxies for it, and vegetation indices.

6.1.4 Recommended tool for small surface water body identification and change

8. The Nile DEWS should include a remote-sensing based tool to identify and assess changes in small surface water bodies (expected minimum threshold size 50-100m2), which are sources of community-level irrigation, household, and/or livestock water supply.

6.1.5 Generation of usable information for different intended users

9. The Nile DEWS should produce data and information that is usable to support decision-making on interventions related to the targeted priority drought impacts. Therefore, it must be accessible and meaningful to both technical experts as well as:

a. Policy advisors and/or decision-makers; and

b. People who immediately undertake drought management and interact with affected communities such as national NBDF members and local government officials (community liaisons).

10. Nile DEWS developers should therefore engage with different intended users during the DEWS development process to design specific the tools (ie., website, software, bulletins, etc.) to meet their needs.

11. The Nile DEWS must also have engagement mechanisms built into it, especially validation and/or impact reporting functionality.

12. As the Nile DEWS is implemented, intended users will need training on how to interpret the information generated, how to provide validation feedback, and how to use the information to support their decision-making on drought management interventions.

6.2 Detail on hydrological component of the Nile DEWS

6.2.1 Hydrological model validation and associated considerations for access to streamflow data

ENTRO, and to a lesser extent the consultant, must work closely and creatively with national agencies to secure their agreement for protocols regarding observed streamflow data. These protocols should be based on the following principles:

- Streamflow observation data is sovereign;
- Model validation requires analysis that uses streamflow data, but the conditions of access to or use of that data rest with national agencies; and
- Improving NBI's hydrological drought monitoring capability is in the interest of all NBI participants.

Based on these principles, following the acceptance of this report, ENTRO should begin discussions with national agencies to enable analysis that uses historical streamflow data through one or more of the following approaches:

- Contractual data privacy controls – for example, the consultant is contractually precluded from sharing any data provided by national agencies and required to destroy the data upon completion of the project;
- Database controls ie., a 3rd party database is established such that the consultant may only see metadata associated with the provided data;
- Consultant or NBI staff may do the analysis on local government servers and computers and only use the results of the analysis;

- The consultant may write the code necessary to analyse the streamflow data and staff from the national agency undertake the analysis and provide necessary results;
- Comparison to national model outputs that have been calibrated and validated using observation data; and
- In relation to all of the above, results of analysis can be reported in such a way that streamflow cannot be "back-calculated" from those results – usage of deviation or percentile ranking could be particularly effective for this purpose.

Further, if ENTRO are able to provide the PCA-produced historical streamflow timeseries, the consultant can compare that to the historical MIKEHydro time series from the Nile-DSS.

Beyond assessing the Nile DEWS hydrological model outputs against observed and modelled streamflow data, they should be assessed against drought impacts of relevance to communities and the economy. Given past challenges in accessing or using observational streamflow data and the impossibility of assuring that it will occur for Phase 2 development of the DEWS, and the wider necessity of impact assessment, validation should include "triangulation" approaches whereby model outputs are assessed in relation to impact proxies. This could include assessment of the relationship between drought monitoring and forecasting outputs and agricultural, municipal water, hydropower production, human health, or effects on other social-ecological systems. This is a form of model validation as well as impact assessment.

6.2.2 Integration of the Nile DEWS and the Nile DSS

Whatever specific model is used for the Nile DEWS in the future, in order for it to provide maximum value to the NBI, it should ideally produce data that is directly "ingestable" by the DSS. If integration of the Nile DEWS and the Nile DSS is not possible, then the Nile DEWS system should enable (in a user-friendly format) comparable basic analytical functionality in relation to scenario analyses focused on streamflow infrastructure operational rules.

Whether integration between the Nile DEWS and the DSS is immediately possible or requires additional "back-end" work on the DSS itself depends on the specific hydrological model used (see Footnote 11 for the list of models for which the DSS has "adaptors" for data integration).

In other words, the Nile DEWS and its constituent online user interface will ideally enable users to assess the effect of different infrastructure operation scenarios – such as variable dam release timings and volumes, location, volume, and timing of irrigation abstraction, etc. – on downstream flows. Ideally it would be possible to undertake these scenario analyses at the same locations as done by the RFFS currently (see Figure 3.2 from the RFFS report and note that while location should be the same, not all specific analyses at all points must be the same).

Given these recommendations, Appendix E includes suggested criteria for evaluation of hydrological modelling component of TOR proposals.

6.3 Detail on meteorological and agricultural drought analytical workflows

6.3.1 Monitoring - precipitation

Comparison and validation of operational satellite precipitation data products per country, agro-ecological zone, or other climate region is key, as is the usage of bias-correction factors. The DRM TOR should include a literature review comparing product accuracy in countries of the basin, and if lit review is inconclusive, it should include validation against available station data or reconstructions such as the MSWEP product used in the PCA study as well as development of precipitation bias correction factors.

It is possible that different satellite products will perform better in certain areas; the DEWS coding framework may need to be able to ingest more than one precipitation data product to account for this.

CHIRPS' final product comes significantly later than IMERG each month and therefore has disadvantages in terms of operational latency. However, in the case that CHIRPS' final product has higher accuracy in some or all locations, it may be possible use CHIRPS' interim products, and their historical relationship with CHIRPS' final product, to derive "modelled" CHIRPS final products. This could use regionalization and convolutional neural network (CNN) techniques to fit the operational satellite products to past meteorological observations or other data mining and bias correction techniques.

In terms of data post-processing, the DEWS should use sliding window techniques on the precipitation and SPI data to improve percentile ranking processes.

6.3.2 Monitoring – NDVI

NDVI inputs should have the following data pre-processing improvements:

1. Developing and implementing cloud / anomaly detection coding procedures for the "raw" satellite data used (e.g., Savitzky Golay filters); and
2. Developing and implementing routines to replace cloud-affected NDVI pixels using statistical approaches.

Like for the precipitation data, sliding window techniques should be used on the new pre-processed NDVI anomaly data to improve percentile ranking.

6.3.3 Monitoring – land surface temperature flux anomaly, a proxy for evapotranspiration

Satellite data on land surface temperature, one of the primary determinants of evapotranspiration, is prone to cloud contamination effects. It is possible to use a proxy for evapotranspiration anomalies – day-night land surface temperature flux (LST flux) – to evaluate this component of drought. Further, temperature data used for this procedure should include the following pre-processing:

1. Development and implementation of cloud and anomaly detection coding procedures for the "raw" satellite temperature data used;
2. Develop and implement a process, potentially including bias correction and/or "anomaly matching" like for LST flux implemented in MENAdrought to replace the cloud-affected pixel with one or more of the following:
    a. Temperature anomaly data from a different satellite product; and
    b. Temperature anomaly data from a publicly available regional or global land surface modelling product.

Again, a sliding window technique should be used for the new pre-processed LST flux anomaly data to improve percentile ranking.

6.3.4 Monitoring – soil moisture

Soil moisture data produced by satellites and regional modelling products have the highest uncertainty and least potential for observation-based validation; given the paucity of regional soil moisture observation data, the PCA report assessed HBV model-produced soil moisture data outputs against other satellite and/or model-derived soil moisture data. Senior decisionmakers all over the world tend to be highly skeptical of environmental modelling data that cannot be validated except through comparison to other model data, and they view information derived from this data as less legitimate[19]. Whether or not this is logical or pragmatic, it is highly relevant for the Nile DSS.

Given these considerations, if ENTRO desires to publish soil moisture data from the Nile DEWS, as opposed to it being an unreported intermediate data product for hydrological modelling, there should be validation and impact assessment of the relationship between temporally (growing season) aggregated soil moisture anomalies from the hydrological modelling product and agricultural impacts.

For areas where correlation is not robust, the DEWS *should not* report soil moisture anomalies by themselves or use them in a weighted index as described below. For areas where correlation is robust, *consider* reporting soil moisture anomalies by themselves and/or incorporating the anomaly into a weighted index as described below.

6.3.5 Monitoring – create and validate a composite drought index

Around the world, national governments and regional institutions are promoting the development of composite drought indices (CDIs). These integrate various indicators that have divergent driving factors; for example, precipitation deficit is only one factor that might lead to low NDVI, and likewise, precipitation deficit is generally unrelated to heat stress. Therefore, these weighted indices are able to capture multiple aspects of drought that combine to cause impacts on socio-environmental systems of interest.

Therefore, the Nile DEWS should incorporate a weighted CDI that includes at least SPI, NDVI, and a temperature-driven index such as LST flux or a hybrid index such as SPEI. Soil moisture may or may not be appropriate per the discussion above. Weighting could be determined through validation assessments that compare the CDI to impacts of interest such as streamflow observations, water body change detection, crop production or yield, or reservoir storage.

6.3.6 Seasonal forecasting – precipitation and temperature

Working to improve basin-wide seasonal precipitation and temperature forecasting should be a primary objective for the Nile DEWS. The focus to improve forecasts should be 1-3 months, and the system should also produce forecasts up to 6 months. The system should not include short- and medium-range (up to 15 days) forecasts for drought purposes.

I recommend that efforts on seasonal precipitation forecasting focus on the following elements given the rapid and major improvements in forecasting skill obtained with this approach in the

[19] Interestingly, though, optical indicators such as NDVI are less prone to this scepticism.

MENAdrought project[20] in Morocco and Jordan, other work including East Africa[21], and their potential applicability in the Nile Basin:

1. Climate regionalization at one or more of the following levels:
   - the entire Nile Basin;
   - the major sub-basins;
   - per aggregated koppen classification zone; and
2. Develop convolutional neural network models at one or more of the above-mentioned "levels" using as initial predictors the ensemble model proposed by PCA from the ECMWF and also North American Multi-Model Ensemble (NMME), which is available within a week of the month's end (as opposed to two weeks for the ECMWF) and therefore operationally preferable.

In addition, given the long-term application and regional experience in relevant methods, the DEWS should also incorporate statistical seasonal precipitation prediction at least in relation to the June-September rainy period.

6.4 Detail on remote sensing based tool for surface water body monitoring

The Inception report recommends that ENTRO pilot and then, if successful, deploy remote sensing analytical tools to identify and monitor micro-, small-, and potentially also medium-sized surface water storage bodies. This would form an integral part of the DEWS given its ability to monitor micro-level hydrological drought impacts of relevance for rural food and water security. Government officials and NBDF members interviewed consider that this would be a very useful product.

It is possible this could be built using existing platforms including the JRC's global surface water explorer[22] or Digital Earth Africa[23]. In some cases, government agencies hold location data for micro-, small, and medium-scale surface water storage infrastructure, although accessing this data, or its format, may pose challenges.

Below is an example specification for a geospatial data product resulting from this type of workflow:

1.) Location (geospatial) and identification (unique identifier) of water bodies that meet a specific threshold size (potentially 50-100m^2) in pilot sub-basins in different NBI countries;
2.) Shows change in area of each waterbody since last analysis (monthly, quarterly, or seasonal);

[20] Bergaoui, K., Belhaj, F., **Fragaszy, S.**, et al. MENAdrought synthesis report on operational drought monitoring and forecasting systems in the MENA region. IWMI technical report. Forthcoming

[21] E.g., Satti, S., Zaitchik, B. F., Badr, H. S., & Tadesse, T. (2017). Enhancing Dynamical Seasonal Predictions through Objective Regionalization, *Journal of Applied Meteorology and Climatology*, *56*(5), 1431-1442. Retrieved Sep 11, 2022, from https://journals.ametsoc.org/view/journals/apme/56/5/jamc-d-16-0192.1.xml

[22] https://global-surface-water.appspot.com/download

[23] https://www.digitalearthafrica.org/

3.) Compares current waterbody size to historical maximum and minimum in same period; (data to be populated over time);
4.) Shows number and area of waterbodies per sub-basin unit;
5.) Shows change in current number and area of waterbodies per sub-basin unit since last analysis; and
6.) Compares current number and area of waterbodies to historical maximum and minimum in same period per sub-basin unit.

6.5 Detail on generation of usable information for policy advisors and/or community liaisons

To ensure information generated by the DEWS is useful for intended users, they must be involved in its development from the outset. This is especially relevant for community liaisons.

Further, the Nile DEWS must include ongoing coordination and feedback mechanisms so that users are able to provide inputs and/or feedback about the DEWS information. One focus group participant described this as mechanisms to "push information down" rather than allowing it to "trickle down" haphazardly. This can usefully be accomplished through an impact reporting network as described in Section 7.1. User involvement in DEWS development from beginning.

As a starting point, stakeholders had the following recommendations related to bulletins:

- It must be in local languages. The following are appropriate to include initially based on use by communities across the Nile Basin: English, French, Arabic, Swahili, and Amharic;
- It should be less technical and full of jargon; these explanations should be available, but they should not be the primary presented information;
- Annexes should show national maps with relevant regional and local administrative units within the country and/or watersheds; and
- Incorporate guidance with the bulletin.

7 Recommendations – Medium- to long-term developments for the DEWS

Further, to achieve NBI Strategic Goals and meet stakeholders' stated needs, it is recommended to develop a medium- (2-5 years) to long-term (5-10 years) phase of work that builds on the near-term DRM project that includes the following components, in no particular order of importance[24].

7.1 Develop a drought impact reporting network in each country to support DEWS improvement over time

This impact reporting network must cover drought, and ENTRO should consider combining flood and drought impact reporting networks *if* the stakeholders involved (whether institutions or individuals) are likely to be the same for both themes. In either case, it would play several functions:

[24] The suggested components are relevant regardless of whether NBI wants to shift focus to community-level stakeholders, but they are written based on the presumption that NBI at least wants to increase focus on them. If not, the scope (and likely priority as assessed by NBI) would change.

- Support information dissemination to and engagement of local communities;
- Enable validation of DEWS outputs with local communities;
- Potentially provide inputs to the DEWS products; and
- Support for ongoing development of the DEWS over time.

As appropriate, this should "piggyback" on existing institutional structures and/or expert and community networks in each country. The following are key stakeholders to engage with and determine the best approach for development of such impact reporting networks:

a. Ministries of water, agriculture, meteorology, and/or disaster risk management commissions where they exist – they have extensive regional (and in some cases local) networks of officers, or they collect and collate information from others in relation to relevant hydrological drought impact themes;

b. The NBD in each country given their members' strong linkages with rural communities and local government officials in rural communities; and

c. FEWSNet and ICPAC given their existing regional network that regularly provides feedback on drought monitoring and forecasting products.

Why this recommendation?

Both national government officials and NBDF members emphasized the necessity of ongoing engagement to ensure use of the DEWS over time. Also, international examples from the US, Mexico, Brazil, and the MENA region highlight the importance of impact reporting networks in improving DEWSs over time and maintaining policy-makers' interest and focus on drought preparedness and mitigation even during wet years. Interviews and the focus group discussions indicate that NBDF members strongly desire this type of engagement and would gladly undertake this work if provided the necessary training and resourcing.

7.2 Additional DEWS validation through drought impact assessment and subsequent refinement of the DEWS if warranted

Additional DEWS validation through drought impact assessment and subsequent refinement of the DEWS. Ideally this will be conducted through a joint partnership (and potentially donor arrangement) with:

a. USAID, which produces the FEWSNet monitoring and forecasting products focused on agricultural drought, and

b. The WMO and IGAD, which produces the ICPAC monitoring and forecasting products focused on meteorological drought, and which has received substantial funding from the UK's FCDO in recent years.

Why this recommendation?

Impact assessment provides model validation in a way that is meaningful and useful to a wider range of stakeholders than a narrow validation focused on direct indicators only. Further, it is critical for the development of policy-relevant "trigger thresholds" for drought management responses, and it also provides useful information on underlying drought vulnerabilities.

For example, if relatively mild hydrological drought results in relatively severe impacts on irrigated agricultural production, that could indicate other aspects of sensitivity to drought impacts such as poor infrastructure or weak institutional arrangements. Likewise, if relatively severe hydrological drought results in relatively modest production declines, that indicates high coping capacity and/or low crop sensitivity to reduced water inputs. It helps to determine the severity of drought at which coping capacity begins to fail and drought impacts materialize more quickly and severely. Lastly, the review highlights a gap in knowledge about hydrological drought impacts in Basin countries except in relation to rainfed agriculture (soil moisture) as well as household and municipal water supply, which is a function of hydrological drought as it interacts with water management infrastructure and institutions.

7.3 Development of operational (repeated regularly and easily) remote sensing analytical tools

This may be through bespoke tool creation – or integration of such information produced regularly by other institutions – and it should incorporate some co-development with, or at least early feedback from, intended users (central government experts and, if NBI wishes to shift focus to immediate impact with local stakeholders, local area experts and/or community members). This also includes the following associated components:

a. Data architecture for the relevant database, hosting, and data access and information-dissemination mechanisms. This includes for output validation (quantitative, qualitative, and spatial) by national experts, and if NBI wishes to shift focus to immediate impact with local stakeholders, also local area experts and/or community member.

b. Training for national agency staff in use and interpretation of the tools

c. If NBI wishes to shift focus to immediate impact with local stakeholders, training for local area experts, potentially including community members, in interpretation of the information and validation procedures.

These tools would complement both flood and drought monitoring and forecasting. From the needs assessment, the most immediately-relevant tools (in order of importance according to the needs assessment) include the following:

a. Small surface water body identification and change detection (if not progressed through the upcoming TOR)

b. Crop type mapping

c. Irrigation area mapping

d. Deforestation mapping

e. Wetland change detection

Why this recommendation?

Production of these datasets in and of themselves would contribute to the NBI achieving Strategic Goals 3-5. In combination with drought monitoring and seasonal forecasting, they provide a powerful set of information on which to base drought preparedness and mitigation planning, as well as target response actions. They will indicate areas that are most vulnerable to various drought impacts and the areas where infrastructure or restoration investment would be most impactful.

7.4 Pursuit of a strategic partnership in relation to the SWOT satellite mission

Beyond the World Bank, it would most likely be appropriate to approach USAID, AFD, and/or CIDA to explore such a partnership based on the satellite mission developers. There is more detail on this recommendation, and the rationale for it, in the Inception Report.

7.5 Undertake drought vulnerability assessments and support policy planning processes

This recommendation is to:

1. Undertake spatial and quantitative hydrological drought vulnerability analyses (at national, sub-basin, and/or Nile Basin-wide level) using the DEWS and available demographic, ecological, socio-economic, agricultural, and other datasets;
2. Support NBI focal points in a policy process that incorporates the DEWS (or locally modified versions of it) into their national drought management policies – especially related to hydrological drought impacts, and inclusive of "trigger thresholds for action" linked to the DEWS – or strategies, and plans, Note that this could relate to any or all of macro-, meso-, or micro-level impacts; and
3. Establish appropriate procedural mechanisms and policy framework[25], and then develop a basin-wide drought preparedness, mitigation, and/or response policy that incorporates information generated by the Nile DEWS. Note that this could only relate to macro- and meso-level drought impacts.

The policy would incorporate:

1. Specific priority impacts that are the focus for the given policy;
2. Preparedness and mitigation actions associated with priority impacts developed through a structured options development and assessment process;
3. A governance framework that links the drought early warning and policy implementation functions to hierarchies of decision-making;
4. Drought definitions based on Nile DEWS outputs including:
    a. tiered Drought Classes that are based on expected return periods;
    b. Triggers that reflect severity, longevity, and extent of drought, and tie drought early warning system outputs to Response Levels;
    c. Response levels that reflect the resource intensity and robustness of government responses; and
5. Drought management response actions that escalate according to response levels; and
6. Impact monitoring as well as policy effectiveness monitoring, evaluation, and learning.

Both vulnerability mapping and policy planning must take a "working with the grain" approach and be tailored to each country. For example, vulnerability assessments must focus on specific aspects of drought impacts, and national stakeholders can direct that as most relevant for policy development needs. Likewise, policy planning must take into consideration the existing legal and regulatory framework, institutional relationships, and political economy needs of each country. These represent Pillars 2 and 3 in the Integrated Drought Management Program's approach.

Why this recommendation?

For a DEWS to be sustainable long-term, it must be useful for, and feed into specific decision-making processes. Vulnerability assessments help target investment and drought policy planning to the most relevant areas, communities, and/or environments. In particular, it would provide

[25] This could be within the mandate of a Nile River Basin Commission if there is a political accord of this type.

robust information on which to base investment decisions and policy planning for the most cost-effective way to reduce vulnerability to drought impacts.

Undertaking this work will contribute to NBI Strategic Goal 6 and it can include both national, sub-basin, and/or Nile Basin-wide approaches to vulnerability assessment and planning. The survey of NBI focal points (question 31) show that respondents were generally supportive of the Nile DEWS linking with national and basin-wide policy measures.

8 Options to consider medium- to long-term

8.1 Integration of flood and drought monitoring and forecasting staff into a functional unit across the NBI

In terms of medium- to long-term development, it is suggested that as Nile-SEC, ENTRO, and NELSAP develop basin-wide flood, flash-flood, and drought monitoring and forecasting tools as well as human resource capability, and they seek to expand their use of these tools to basin-wide applications, that they consider developing a combined functional unit (though the staff may be geographically dispersed) through personnel and resource-sharing arrangements. This functional unit should include at least the following capability:

1. Hydrologist (hydrological processes focus) OR water resources engineer (infrastructure focus) with large catchment modelling expertise;
2. Remote sensing applications expert;
3. IT and data infrastructure expert;
4. Social scientist / disaster risk management expert (e.g., human and physical geography, or sociology background) to focus on impact and vulnerability assessments as well as supporting scenario analyses; and
5. Communications, outreach, training, and engagement expert.

This unit should at least have *access to* the following sets of expertise:

6. Either hydrology or water resources engineering, depending on which expertise is within the unit;
7. Agronomy;
8. Meteorology; and
9. Policy development (government experience in development and implementation of laws, regulations, and policies).

8.2 Explore integrated modelling framework and data architecture for flood, flash flood, and hydrological drought monitoring and forecasting

In the medium-term (within 5 years), it may be useful to explore the potential to use an integrated modelling framework and data architecture for flood, flash flood, and hydrological drought monitoring and forecasting. This would enable resource efficiencies within NBI, provide synergies with national NBI focal points, and ease engagement and interaction with NBDF and through them local communities around flood and drought issues. Most of the NBI countries consider flood and drought within a common policy framework, have a formal disaster management commission that deals with both issues, and several have a combined flood and drought monitoring unit within the Ministry of Water (or equivalent).

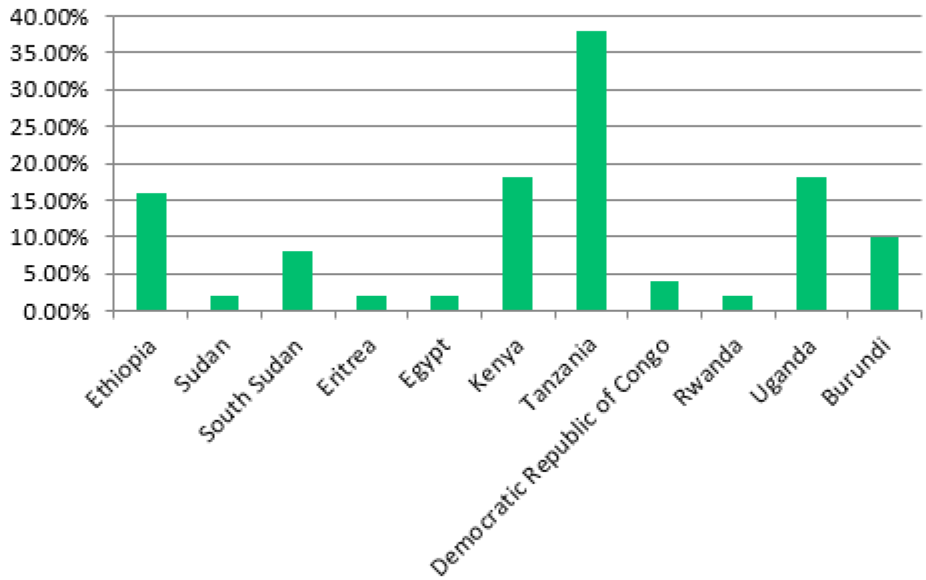
8.3 Explore strategic partnership with ICPAC in relation to precipitation and temperature forecasting

In the medium- to long-term, it is worth considering a strategic partnership with ICPAC focused on forecasting of precipitation and also temperature. As a regional meteorological center, it has worked extensively on precipitation forecasting (short- and medium-range, as well as seasonal) and has well-developed networks with national meteorological agencies. Further, its outputs are trusted and used by NBI stakeholders.

Appendix A – Additional detail on NBDF survey responses and respondents

The NBDF survey received 47 complete responses and 3 partial-completes.

Participants worked in the following countries (question 5; some respondents chose more than one country). Note that Tanzania had an outsized number of responses (19) compared to others and Egypt, Eritrea, Rwanda, and Sudan all had only one respondent each.



Respondents worked more in rural areas than urban, though it was mixed (question 6).

Cities and towns	2.00%	1
Rural areas	36.00%	18
Both	62.00%	31

Respondents predominantly worked in community support or development organizations (question 7, note that respondents could select more than one option). "Other" responses included Advocacy and budget tracking, policy research and advocacy, network organizations, and local government.

Professional association - members share a specific profession	8.16%
Community support or development organisation - the organisation aims to support development of people in specific areas and with certain types of communities and livelihoods	87.76%
Private sector business - any privately-owned company other than a cooperative	4.08%
Cooperative business - a business that is co-owned by its employees	0.00%
Research organisation - a university, research institute, or any other organisation that undertakes research studies	8.16%
Humanitarian organisation - an organisation that provides aid during and after disasters	22.45%
Trade union - members are all employees in a specific industry or trade (e.g. farmers' unions or dockworkers' union)	0.00%
Trade association - an organisation that aims to support businesses in a specific economic sector	0.00%

Other (please specify)	14.29%

Respondents listed a wide range of actions they undertake during droughts (question 8), with a high proportion related to:

- Communication, early alerts, and information-sharing;
- Education and training;
- Risk assessment;
- Humanitarian support;
- Livelihoods support and undertaking mitigation measures to reduce vulnerability to following drought (e.g. tree planting and support to develop irrigation networks); and
- Liaising with government and mobilizing resources for humanitarian (e.g. food provision) and livelihoods support (e.g. provision of seeds for planting in the next season).

In line with this, the primary drought impact themes they work to address include the following (question 9)

Electricity and/or energy-related issues	12.77%	6
Decline in freshwater fisheries	19.15%	9
Human migration	21.28%	10
Forest fires	23.40%	11
Livestock disease and/or mortality	23.40%	11
Food and/or water price increases	25.53%	12
Reduced water availability for people in towns and cities	25.53%	12
Human health problems caused or made worse by drought	27.66%	13
Social conflict related to water access	34.04%	16
Water quality problems (for example, salinity or pollution)	34.04%	16
Reduced incomes for farmers or herders	42.55%	20
Reduced water availability for people and/or livestock in rural areas	53.19%	25
Hunger	57.45%	27
Agricultural water management (irrigation or water conservation practices)	63.83%	30
Ecosystem degradation (wetlands, grasslands, forests, etc.)	63.83%	30

Appendix B – Uganda NBDF focus group summary

Picture of focus group 1 participants

What organizations do – monitoring:

- Organizations do not undertake drought monitoring per se – rather, in their role as liaisons between rural communities and local, regional, and central government, they convey information up the administrative chain

What organizations do – preparedness and mitigation:

Range of activities with primary focus areas including:

1.) access to finance for agricultural investment, particularly in micro-solar and irrigation projects, agricultural inputs, and mechanization;

2.) Support communities in water resource protection and rainwater harvesting;

3.) training and education in rural communities for local government and households on:

a.) improved agricultural techniques;

b.) rainwater harvesting and water resource protection and associated hygiene and sanitation issues;

c.) financial and business skills;

d.) environmental matters, particularly related to deforestation/afforestation, establishment of nursery beds;

e.) climate change adaptation more widely;

4.) Development of digital platforms for connecting communities, especially youth and women;

5.) Communication between local, regional, and national levels about issues of importance;

6.) Involvement with central government on disaster response planning;

7.) Provision of improved seeds and inputs (e.g. for drought-resistant pasture species), and specialized training for specific agricultural types;

8.) Support communities to have alternative food production methods (e.g. aquaculture); and

9.) support local community groups to become registered and legal entities.

Drought impacts and vulnerabilities

- Rainy season is becoming erratic, irregular due to climate change. This has been noticed over last 5 years, and especially last 2 years;
- Karamoja drought impacts noted particularly severe;
- Agriculture production losses – crops, reduced livestock productivity, low food storage
- Wetlands degradation (people move in for farming – sometimes they drain it, sometimes they leave after the rains return; construction in wetlands during droughts);
- Health impacts stemming from a.) water quality degradation and people getting water from unprotected/contaminated sources, b.) poor hygiene associated with low water availability or significant increase in water prices, c.) Health impacts in cities because of higher particulate matter;
- Drought leads to increased mental health stress, and an associated increase in gender-based violence and youth violence. This leads to family breakup and children out of school;
- People who can't afford irrigation are shifting away from farming and changing their sources of livelihoods. This results in:
    - More precarious livelihoods;
    - Increase in fishing and forest clearances; and
    - Rural out-migration to cities, and emigration as low-skilled labour, especially to the Persian Gulf states.

Comments on drought monitoring and forecasting (existing and needs)

- Minimal trust in seasonal forecast products because of several bad experiences in the past (comments focused on flood warning);

- Generally skeptical of ability for remote sensing / modelling outputs to be accurate and precise, again based on experience of products aggregating very large areas;

- Only 2 had heard of and/or seen ICPAC or FEWSNet, and no one had heard of or seen

NBI DEWS. All had seen the met agency forecast, but few voiced confidence in it;

  - Note that participants did not differentiate between near-term forecast (up to 10-days) and seasonal forecasting and so there will need to be sensitization on the differences;

- Perceived need assessment of historical drought impacts and hazard mapping;

- For a drought monitoring tool to be used and useful by mediators between the central and local level (like themselves), there has to be interaction, engagement, and feed-in to the system from the bottom-up. It cannot be a top-down tool and actually reach the community level;

- Onset of rainy season (date of arrival) is a key need, as well as anticipated volume of rain over the rainy season, and its expected length. 3 months outlook most important;

- Desire for inclusion of traditional knowledge – components mentioned included wind patterns, animal (especially bird) presence and behaviour;

- it needs to be available always. If I work with a CBO, I want to be able to bring that information to my groups when I work with them;

- Producing information isn't enough – there needs to be effective interaction and communication in place. If NBI can facilitate this type of coordination, it will be better. Already structures exist – don't recreate the wheel; and

- Use available social* and mainstream media. Popularize and ensure on-movement.

"We still lack reliable [forecasting] information, so when we interact with communities, we don't bring specifics. When we talk to farmers, we don't provide specific forecasts because of trust issues people have. They don't take forecasts seriously. They only trust their own local methods and they rely on that. But the problem is, with climate change, you can't use previous knowledge in the same way because the climate has shifted."

<u>How to improve the bulletin so that they, as mediators with the local community can use it effectively:</u>

1. It needs to be in local languages – broad agreement on Luganda and Swahili, mixed views on other languages.

2. It is overly technical and full of jargon. Don't write it for a technical expert (as is) but an ordinary person who works with village residents.

3. Tailor it for each country – Uganda is shown within the entire basin

4. Perhaps have 2 bulletins – one for technical experts, one for everyday people

5. Show national, regional, and local administrative units within the country (not just watersheds/catchments)

"I need the national picture as I visit local communities to understand likely allocation of resources and food supply/demand, and I need the local information to know how the specific place I'm working in will fit in that bigger picture."

6. Ability to incorporate traditional knowledge and other local content into it in some way – this requires a network of people being involved.

7. Provide guidance associated with the information; some if that guidance should be pictorial/visual.

How to improve the website:

Largely as above, and also:

1. Provision for NBDF users to ask their specific questions. FAQs and user community, especially at the regional level; and
2. Have the website "target" or "funnel" displays of content based on users' responses to specific questions.

What organizations do – drought emergency management:

1.) Communication between local, regional, and national levels, particularly to help government target initiatives (geographically and thematically); and

2.) Advocacy.

Drought management needs

- Training and sensitization for local government officials - every village has a secretary of environment and production, but most don't know what to do – there's no training for them. If they are empowered, they can be champions at the village level; and

- Can only have successful drought management if youth (under 30) are involved and there is employment. So there's a skillset and opportunities shortage.

Additional comments on drought management:

Different NGOs have different interventions in relation to emergency management; some do relief work – provide food, water. If NGOs were there on the ground, and they had accurate predictions, maybe the local NGOs would have been able to step in early. What they're doing now it's really emergency response – giving people handouts.

Some NGOs get resources from donors, but they're especially involved in terms of mobilizing existing resources and social support. They also do distribution of resources/emergency aid.

We expect them to work within the governance framework. They have to sign their MOU with local government – with the NGO act, you need to have your activities signed off at the district level. There's a monitoring committee (heads of departments at local level and also some of the NGOs) that helps support this.

That's where the NBD comes in – we're meant to work with central and local government and NBI to ensure the civil society is properly coordinated and there's less duplication. In some of these emergency responses, municipalities don't know what to do. So we train them on courses – how different communities do various things. Local government need to participate fully, but they also need to have full information and skills.

Synthesis and/or direct recommendations from groups to NBI from groups (ie., people said, "NBI should do X" related to the development and ongoing operation of the DEWS and other topics):

- If you want to "sell it to the people down there" you need to work with CBOs; if you make something you feel involved in it, and if you don't, you feel no ownership and won't use it. Put resources through NBD to get community inputs to DEWS and ongoing interaction - quarterly, or monthly. Devolve some aspect to the community.

"We want, for example, every national office to have a follow-up activity for this system. NBDF should have a specific workplan related to this each year. We need to connect better to NBI so that information reaches us, and then we reach down. The structure is there for CBOs, and we know and work with the local government structure. Make use of it. Make sure you use this in your planning. That is a long-term investment in resourcing, and it will ensure the tools is not an 'artificial' thing and has impact on communities"

- Link the DEWS to key economic and cc plans – have the DEWS support their implementation. For example, have some focus on agro-forestry given existing government business planning and the sub-sector's general ability to provide climate change mitigation and adaptation benefits
    - Note direct government investment strategies, and private sector enablement strategies in relation agro-forestry, and the potential for 4 regional pilot areas as endorsed by government of Uganda.

- Needs regional managers within NBI. Each country has an NBI office in the ministry, so why not to the NBDF.

- NBI are doing all these projects in countries, but they're not working closely with the communities who could support them. NBDF could be community liaisons to help them implement projects more effectively, but NBI go direct without us, which is a problem. For example, the Aswa river project.

Other:

Interesting exchange on weather stations – some said they were needed because of poor data, and others relayed stories of how they used to be ubiquitous but are no longer functional because of vandalism, and a third person said the fact that they were vandalized indicates that people in communities perceive the stations as not for "them", that there's not community understanding and ownership and therefore it's not useful. Likewise, some described a flood early warning system that was too loud and so villagers dismantled it. The point understood from all of this is that the system design needs consideration of locals' viewpoints and ongoing feed-in or they will ignore it.

Appendix C – Components of NBI DEWS and piloted PCA system

Bulletins of the operational NBI DEWS (Bulletin of the Drought Monitoring and Forecasting Component of the Nile Basin River Flow Forecasting System
(NB-RFFS)) include the following components:

- Precipitation monitoring based on IMERG data:
  - Historical precipitation volume between the 25th and 75th percentiles (aspatial)
  - Volumetric deviation from long-term mean (spatial, past month)
  - 3-month SPI (spatial, past month)
- Vegetation condition monitoring based on MODIS data[26]:
  - NDVI deviation (spatial, 16-day period)
  - Vegetation Health Index, which combines vegetation condition and temperature indices (spatial, 16-day period)
- Soil moisture monitoring based on ASCAT SSM and Global Hydrological Model[27] data:
  - The soil water index (most recent 10-day period, spatial) derived from ASCAT SSM satellite data that is resampled to higher spatial resolution; and
  - Root zone soil moisture deviation (most recent 10-day period, spatial) derived from DHI's Global Hydrological Model data.
- Seasonal precipitation volume forecast (9 months) between the 25th and 75th percentiles (aspatial but disaggregated for Main Nile, Blue Nile, White Nile, and Tkeze-Atbara

[26] As of the March 2022 drought bulletin; note that MODIS is going offline from October 2022 and so DHI will likely switch from MODIS to VIIRS data for vegetation condition monitoring.
[27] https://www.dhigroup.com/data-portals/global-hydrological-model

basins) derived from Climate Forecast System and downscaled using monthly bias-correction factors derived from 2000-2019 satellite precipitation data from TRMM.

- Soil moisture deviation seasonal forecast (9 months, aspatial but disaggregated for Main Nile, Blue Nile, White Nile, and Tkeze-Atbara basins) between the 25th and 75th percentiles based on DHI's Global Hydrological Model.
- As noted in Section 4, the NBI-RFFS data is not included in the bulletins or otherwise disseminated.

The piloted PCA system includes the following forecasting components, all of which are spatial and include forecast up to 6 months. These are based on downscaled ECMWF multi-model ensemble outputs with monthly bias-correction for temperature (monthly scaling) and precipitation (use of cumulative distribution functions) inputs, parameterized HBV hydrological model, and RAPID model for river routing:

- Volumetric precipitation forecast
- Precipitation deviation forecast using 1, 3, 6, and 12-month SPI
- Temperature minimum and maximum anomalies forecast
- Soil moisture forecasting using percentiles and threshold values
- Streamflow forecasting using percentiles and threshold values

The piloted PCA system did not explicitly include operational monitoring of drought. However, it would be possible to produce the same output for monitoring purposes as are produced for forecasting purposes by using global precipitation observation data inputs such as CHIRPS or IMERG rather than ECMWF forecast data.

Appendix D – Current ability of the NBI DEWS/NBI RFFS and piloted PCA system to meet identified needs, and what would be required to meet needs fully

Table D1 - Current ability of the NBI DEWS/NBI RFFS and piloted PCA system to meet identified needs, and what would be required to meet needs fully

DEWS need as indicated in Table 8	NBI DEWS/NBI RFFS	How to meet additional needs	PCA	How to meet additional needs
Priority stakeholders	Suited for NBI centers and NBI focal points only, and not NBDF members.	1. Address different priority impacts (meso-level hydrological impacts); 2. Design information generation, sharing, and engagement around different intended users and intended uses for the information	Same as for NBI DEWS/NBI RFFS	1. Address different priority impacts (macro-level hydrological impacts); 2. Design information generation, sharing, and engagement around different intended users and intended uses for the information; 3. Integrate with Nile DSS or otherwise add functionality related to infrastructure decision support
Priority impacts	1. NBI RFFS generally suited well for macro-level hydrological drought impacts (especially given integration with Nile DSS);	1. Do hydrological modelling at finer spatial resolution to address meso-level impacts; 2. Improve technical aspects of the NBI DEWS and NBI RFFS	1. Suitable for meso-level hydrological drought impacts and generally relevant for macro-level hydrological drought impacts;	1. Integrate with the Nile DSS (or develop other user functionality) for it to become suitable for macro-level hydrological drought impacts

DEWS need as indicated in Table 8	NBI DEWS/NBI RFFS	How to meet additional needs	PCA	How to meet additional needs
	2. NBI DEWS relevant for meso- and micro-level agricultural drought impacts, but existing regional systems (FEWSNet and ICPAC) are much better positioned for this purpose	3. Improve information-generation, sharing, and engagement around intended users and uses	2. Does not explicitly incorporate agricultural drought-related components	2 and 3 are same as for NBI DEWS/NBI RFFS 4. Produce soil moisture anomalies so as to increase relevance for agricultural drought.
Priority users and uses	Suitable for technical experts (not NBDF members or local government) to support analysis and decision-making on macro-level hydrological drought impact management	1. Generate information of more relevance for community liaisons; 2. Engage with users to determine information of relevance and feedback mechanisms	Suitable for technical experts (not NBDF members or local government) to support analysis and decision-making on meso-level hydrological drought impacts	1. Same as for NBI DEWS / NBI RFFS and also 2. Develop comparable flow and infrastructure operational scenario analysis functionality
Technical work	Significant weaknesses as described in detail in Section 4 in relation to the NBI RFFS and Inception report in relation to the NBI DEWS	Address recommendations in 6.1.2, 6.2, and 6.3	Weaknesses as described in the Inception report	as described in the Inception report, Section 6.1.2, 6.3
Scientific to usable information	1. For macro-level drought priority impacts, excellent capability due to integration with the Nile DSS but currently not used due to the poor	1. Additional technical improvements and validation; 2. Modelling undertaken at finer spatial resolution	1. Suited for meso-level impacts but less for macro-level, especially due to lack of integration with Nile DSS	1. Additional technical improvements and validation; 2. Creation of a bulletin with user inputs;

DEWS need as indicated in Table 8	NBI DEWS/NBI RFFS	How to meet additional needs	PCA	How to meet additional needs
	hydrological modelling results (see above); 2. Unable to meet meso-level impact early warning needs due to spatial scale of modelling.	3. Changes in bulletin; 4. Creation of impact reporting network or other user engagement mechanism	2. uncertain about utility of website platform	3. Testing and potential modification of website with user inputs; 4. Creation of impact reporting network or other user engagement mechanism;
Data and information sharing and dissemination and user engagement	Same as for priority stakeholders and priority users and uses	Same as for priority stakeholders and priority users and uses	Same as for priority stakeholders and priority users and uses	Same as for priority stakeholders and priority users and uses

Appendix E – suggested criteria for evaluation of hydrological modelling component of TOR proposals

1. To what extent (high, medium, low, none) does the proposed model output relate to
    a. Macro-level drought impacts
    b. Meso- and micro-level drought impacts
2. Can the model outputs integrate with the DSS?
    a. Yes, completely with no additional work
    b. Yes, partially with no additional work (please describe limitations of integration)
    c. Yes, completely with additional work (scoped as below)
    d. Yes, partially with additional work (as scoped below; please describe limitations of integration)
    e. No, not possible
    f. Unable to determine based on proposal description
3. To what extent (high, medium, low, none) do you consider it likely that the consultant will be able to access the data necessary to undertake the proposed validation efforts?
4. How robust do you consider the proposed validation efforts
5. To what extent (high, medium, low) do you consider the consultant to understand the following, based on the proposal:
    a. Stakeholder needs from the DEWS
    b. NBI context, operating environment, and constraints
6. What hydrological model output analytics can be undertaken through the user interface?
7. To what extent will the user interface enable scenario analyses related to infrastructure operation
8. What types of data can be exported through the user interface, and how will that be accomplished?

Annex

- Inception report including its annex

FINAL - ENTRO inception report_23

- NBDF survey excel sheets (summary and individual, both cleaned for privacy)

Summary responses for NDF survey - PRI

Individual responses - NDF drc

- Interviews (Uganda government, Nile-sec, and NBDF interviews, all cleaned for privacy)

Nilesec interviews.docx

Uganda government intervie

NBD interviews.docx

- Regional workshop excel sheet

Regional workshop country presentatio