FINAL REPORT: FLOOD FORECASTING AND EARLY WARNING SYSTEM (FFEW) ASSESSMENT FOR SUDAN

FLOOD FORECASTING AND EARLY WARNING ENHANCEMENT PROJECT

Submitted by

RedwanAbdelrhman Mohammed Ahmed

March 16, 2020

ENTRO
NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

P.O.Box 27173/1000

Addis Ababa

Ethiopia

Telephone: +251 (11) 646 1130/646 1132

Fax: +251 (11) 645 9407

Email: ENTRO@NILEBASIN.ORG

WEB SITE: WWW.NILEBASIN.ORG/ENTRO

ENTRO is an organ established to implement the Eastern Nile Subsidiary Action Program within the framework of Nile Basin Initiative

Egypt, Ethiopia, South Sudan, Sudan

Executive Summary

The rationale and objectives of this consultancy work is to conduct country level survey for in-depth understanding of stakeholders, vulnerable communities in flood prone areas in the basin. This will contribute toenhanced ENTRO FEWS and to ensure continued forecast communication and dissemination is easily accessible to rural communities and also support other studies under FFEW that contribute in addressing flash flood.This surveyidentified vulnerable household levels that are most affected by floods including urban areas; it also identified coping mechanisms employed by the households during floods and strengthen positive coping strategies and identify needs of stakeholders;the scope of the work was stakeholder mapping, vulnerability mapping and household survey that addresses community based flood warning system.

The methodology for stakeholders mappingused in this survey was focused onindividual interviews,aimed at finding their specificmandate related to floods and gaps on it.Methodology for vulnerability survey was of two types, first is survey based on GIS maps overlay and buffering the river to find the location of villages on flood prone areas. Second was assessment of urban and rural vulnerability to floods using an indicator-based approach through sampling from Households and using face-to-face interviews, group discussion and questionnaires.

The results indicate that at regional level ENTRO was found to be the core forecast providers and disseminatorfor EWs to most of organizations, but ENTRO FFEWs does not cover Atbara River, Dinder and Rahad and it does not also addressflash flood in the Blue Nile basin and Gash river. The ENTRO FEWS suffers from an inadequate of observation data system, adequate data sharing, and lack of updated information and modern communication systems.

There are several users of ENTRO FFEWs products such as Civil Defence, Sudanese Red Crescent Society, Humanitarian Aid Commission,Ministry of Agriculture and Forestry,Ministry of Livestock and Fisheries, Ministry of Roads and Transport, Ministry of Environment, Natural Resources and Urban Development, and Ministry of Information and Communication, inaddition, communities at risk and vulnerability settlement on flood prone areas.

The survey found 2,900 villages living in flood prone areas, these population and pastoral villages are distributed among the basins of the Blue Nile, Dinder, Al-Rahad, Al-gash and Tekeze - Atbara- Setit inside Sudan. Thehouseholds live in floodplains that are more susceptible to high flood impacts as well as highlyvulnerable to economic, physical/ infrastructural and attitudinal dimensions. These communities have the ability to avoid floods if they warn at least 3 days before the flood occurred, and this is evident from the floods of 2018 and 2019. The study also found out that the frequency of flash floods that occurred in the past ten years was more than riverine flood.

As a recommendation, Ministry of Water Resources, Irrigation and Electricity/Eastern Nile countries, need to upgrade existing manual records stations to make them automatic and ENTRO need to established/enhance models system in trans-boundary river basins. It also need more capacity building tousers,responders and communitiesthus regular feedbacksfrom stakeholders to ENTRO is important to improve ENTRO FFEWs.

Ministry of Water Resources, Irrigation and Electricity needs tobuild confidence between local government units and community, and launch awareness campaigns and design risk communication strategies to enhance the flood risk perceptions of the communities and engage the local institutions with the communities to implement disaster risk reduction plan effectively.

ACRONYMS

BAS:	Baro Akobo Sobat
BN:	Blue Nile Sub-basin
CMORPH:	CPC MORPHing
DRM:	Disaster Risk Management
EMMP:	Eastern Nile Flood Mitigation and Management Program
ENPM:	Eastern Nile Planning Model project
ENTRO:	Eastern Nile Technical Regional Office
EWHIC:	Early Warning and Humanitarian Emergency Information Center
EWS:	Early Warning System
FEWS:	Flood Early Warning System
FFWC:	Flood Forecasting and Warning Centre (Bangladesh)
FPEW:	Flood Preparedness and Early Warning
HAC:	Humnatiarian Aid Commission (Sudan)
HEC-HMS:	Hydrologic Engineering Center Hydrologic Modeling System, US Army Corps of Engineers
HEC-RAS:	Hydrologic Engineering Center River Analysis System, US Army Corps of Engineers
ICPAC:	IGAD Climate Prediction and Applications Centre
IDEN:	Integrated Development of the Eastern Nile
ISDR:	International Strategy for Disaster Reduction
IVR:	Interactive Voice Response
MAF:	Ministry of Agriculture and Forestry
MENRU:	Ministry of Environment, Natural Resources and Urban Development
MLF:	Ministry of Livestock and Fisheries
MoIC:	Ministry of Information and Communication
MoIWRE:	Ministry of Water Resources; Irrigation and Electricity
MRC:	Mekong River Commission
MRT:	Ministry of Roads and Transport

NCCD:	National Council for Civil Defense
NCORE:	Nile Cooperation for Result project
NFC:	National Forecasting Centre
NGOs:	Non Governmental Organizations
NOAA:	National Oceanic and Atmospheric Administration
RFE:	Rainfall Estimates
RFMMC:	Regional Flood Management and Mitigation Center
SRCS:	Sudanese Red Crescent Society
TRMM:	Tropical Rainfall Measuring Mission
TSA:	Tekeze-Setite-Atbara Sub-basin
UNISDR:	United Nations Office for Disaster Risk Reduction
USGS:	United States Geological Survey
WRF:	Weather Research and Forecasting

TABLE OF CONTENTS

Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

The EN Flood Protection and Early Warning Project (FPEW) has been one of the earliest successful IDEN Projects. The Project aims to reduce human suffering caused by frequent flooding, while preserving the environmental benefits of floods. The project emphasis on enhancing regional collaboration and national capacity in flood risk management, including flood mitigation, forecasting, early warning systems, emergency preparedness, and response. The FPEW project that ran until 2010 operated in Egypt, Ethiopia, and Sudan.

After the completion of FPEW project ENTRO initiated with Eastern Nile countries and created a regional Flood Forecast and Early Warning (FFEW) system under the Eastern Nile Planning Model project (ENPM) and the FFEW activity continued under the current Nile Cooperation for Result project (NCORE).

Currently, ENTRO is implementing its second, 2014-2019, Strategic Plan. The Strategic Plan, which is oriented in four strategic directions (i.e. Facilitating Cooperation, Promoting Water Resources Management and Planning, promoting Water Resources Development and Power Trade, and Institution Building), strives to position ENTRO for effective pursuance of its focus on Investment.

Rationales of the Consultancy work and the Project

The rationale of this consultancy work is at country level surveyor to conduct areport for further in-depth understanding of stakeholders.Vulnerable communities and flood prone areas in the basin, tocontribute in enhancedFFEW systemand toensure continued relevance of this vital program, forecast communication and dissemination need to be more easily accessible to rural communities and other important stakeholders.

The current FFEWS has gaps on coverage of all flood prone areas in the basin, robustness of the system and model, limited capacity in enhancing the system to up-to-date forecast standard. The current FFEW system use different models for the different flood pro ne areas in the basin, which makes it, time consuming and hard to update whenever there is a new version of model is available. Thus, there is a need to have a single robust unified flood forecasting and early warning system for the entire EN basin that include some parts of the basin were no prior work is done like flood prone areas of Tekeze-SetiteAtbara (TSA)sub-basin.

Objectives of the Project

The objective of this project is:

To ensure a robust forecasting, issuing and warning system that effectively minimize loss of life and damage by enhancing, expanding and developing a unified Flood Forecast and Early Warning (FFEW) system for EN basin.

To support other studies under FFEW that contribute in addressing flash flood, stakeholder analysis and flood related DSS development.

To assess the vulnerability of households for flood prone areas and stakeholder with need for warning level and danger level that address community based flood warning system design

The Study Sub-basins

The Eastern Nile Basin can be dived into four major sub basins, the Abbay-Blue Nile Sub-basin (B.N.) including Lake TanaSub-basin, the Tekeze-Setite-Atbara (TSA) Sub-basin, the Baro-Akobo-Sobat (BAS)-White Nile Sub-basin and the Main Nile Sub-basin (Table 1).

Table 1: Total Area of the Sub-basins

Sub-basin	Area (Square kilometers)	Mean Annual Inflow (billion cubic meters)	Proportion of Nile inflow at Aswan Dam (%)
Abbay-Blue Nile Sub-basin including Lake Tana Sub-basin	313.657	51	57
Tekeze-Setite-Atbara Sub-basin	219.570	12	14
Baro-Akobo-Sobat-White Nile	425.511	26	29
Main Nile Sub-basin	654.600		

The Abbay-Blue Nile (B.N.) Sub-basin

The Blue Nile (or Abbay as it is known in Ethiopia), with an area of over 310,000 km2,

Originate in the highlands of the Ethiopian plateau. It begins its long journey to the Main Nilefrom Laka Tana and through a deep gorge dropping from about 4000 masl to 400 masl on its journey to Khartoum.

The Blue Nile (Abbay) contributes most of the Eastern Nile waters. The Blue Nile with several major tributaries such as the Didessa, Dabus, Guder, Anger, and Beles yield about 54 Bm^3 total when the river flows into Sudan to augment the 3.5 Bm^3 that leaves Lake Tana at the headwaters of the Blue Nile. The climate of the Abay-Blue Nile basin varies from humid to semiarid. Most precipitation occurs in the wet season (June through September), and the remaining precipitation occurs in the dry season (October through January or February) and in

the midseason (February or March through May). Mean annual evaporation ranges from about1, 500mm (Fiche station (2,300 masl)) in the highlands of the sub-basin to more than 6,800mmaround Khartoum, the mouth of the sub-basin. Flooding is a serious problem at the mouth of thebasin such as Khartoum as well as in the upper course of the sub-basin.

The Tekeze-Setit-Atbara (TSA) Sub-basin

The TSA sub-basin (covering about 230,000 km2) consists of the Tekeze river (known as theSetit in Sudan), and its tributaries, the Goang (Atbara in Sudan) and Angereb, all of whichoriginate in the north central highland plateau of Ethiopia. As the river makes its 1325 kmjourney, it falls from a height of about 3000 masl near its origin to about 500 masl when it joinsthe main Nile in Sudan, about 285 km downstream of Khartoum.

Water availability in the Tekeze-Setit-Atbara is erratic. The rainfall varies from 1000 mmnear the source of the river to about 40 mm near its junction with the Main Nile. The flows arehighly variable (compared to the Blue Nile and Baro-Akobo-Sobat sub-basins) especially in thecrucial low flow months. The main system of the sub basin at El-Girba station (about 156,000 km2) observed to have mean annualinflow of 11.45 Bm^3 (1980-2000).

The Baro-Akobo-Sobat (BAS) and White Nile Sub-basin

The BAS Sub Basin,(covering about 180,000 km2) consists of the Baro river (and its tributaries such as the Birbir) and the Akobo river (with its main tributary, the Pibor). After the confluence of the Baro and Akobo, the river is called Sobat in Sudan. The river makes its way from an altitude of over 3000 masl in the Ethiopian hills to about 400 masl when the Sobatcrosses into Sudan on the way to its junction with the outflow from the Sudd wetlands thatbuffer the outflows from the Nile Equatorial Region. The resulting White Nile (with its basincovering about 280,000 km2) flows north to Khartoum where it joins the Blue Nile.

Water availability in the BAS:TheBaro-Sobat-White Nile sub-basin within Ethiopia is wellwatered.However, spatial variation of the mean annual rainfall is considerable due to the greatrange in elevation across the basin. Average annual precipitation ranges between 600 mm in thelowlands (less than 500 masl) and 3,000 mm in the highlands (over 2,000 masl). Averagerainfall of about 100 mm occurs from May to October. The highest rainfall occurs in June-September (ENTRO, 2006c).

An overview of Eastern Nile (EN) Seasonal Flood Forecast and Early Warning

The FFEW, since its establishment, has been an important part of ENTRO's activity that continuously been conducted for the last six year flood season (June – September). The FFEW has helped the Eastern Nile countries in reducing the loss of life and money by preparing flood

forecast bulletins for the Lake Tana (Blue Nile -Ethiopia), the Blue Nile-Main Nile (Sudan) and Baro-Akobo-Sobat(BAS) sub-basins flood prone areas. The FFEW activity have strengthened national offices in terms of capacity and overall reduced the risk of flood devastation for 2.2million people in the region.

Methodology

The methodology of the stakeholder mapping, vulnerability mapping and household survey has been designed based on the scope of work, objectives, criteria and deliverables of the Study.

Stakeholder consultations conducted with key agencies related to FFEW including government, non-government, and civilsociety,regional and international organizations. The checklist questioner was used to guide the interviews with organizations provided.

The methodology includes:

Key stakeholders interview

The Key stakeholders' interview conducted among the selected relevant stakeholders. The interviews captured the qualitative progress of flood early warning system products and intervention including sustainability of the understanding project activities and the tasks of the consultancy as stipulated in TOR.

Discussion meetings

Discussion meetings was held with the National flood forecast and early warning center's staffs and primary data producers, who are feed the real-time data to the regional Flood Forecast and Early Warning (EWS), to gather the implementation mechanism of data communication and dissemination need to be more easily accessible to rural communities and other important stakeholders.

Groupdiscussion on significant evidence

The focus group discussions was conducted with the targeted communities and relevant stakeholders, which captured the information in regards to the existing flood-forecasting early warning system; forecast communication and dissemination need to be more easily accessible to them and other important stakeholders. Thus, aiding further in-depth understanding of most vulnerable communities, their socio-economic characteristics understood for fit-for-purpose response and preparedness mechanisms.

Individualinterviews (Face to Face)

The consultant divided the stakeholders, into two groups based on their function, androleas following:

Data providers,those have a high-level data, and could explain the phenomena of floods. This group includes experts from:

Regional and National concerned Ministries (information of flood forecast producers);

Academic sector

United Nation organizations with non-governmental organizations and communities-based agencies.

Independent experts in flood risk management.

Data Users: a group of users whom can provide exploratory data about the events of floods occurred in the study area and their impacts. This group includes users from:

O Regional and National concerned Ministries (information of flood forecast users);

Agriculture sector

Community leaders

Local communities and others

Vulnerability mapping

A survey has been made of the buffering the river at a distance of 2, 5 and 15 from the riverbank by the GIS using data obtained from the offices of the Ministry of Infrastructure and Urban Planning and the Population Statistics Authority.

Study sample was selected from Household population of 2900 villages, so primary data was took from selected sample (n=50), done on August-September, 2019 extreme flood, through conducted face-to-face interviews, group discussion and questionnaires, open discussion, with household representatives during the evacuation period.

MAPPING OF STAKEHOLDERS IN FLOOD EARLY WARNING SYSTEM

Flood Early warning systems require contributions from a wide range of actors and institutions, including localcommunities, national governments, regional organizations, NGOs, the private sector, and the science community(UN 2006; IPCC 2012).

Twenty-four institutions involved in different aspects of disaster risk reduction in Sudan were consult about the status and effectiveness of existing flood forecast and early warning systems (Policies and institutions) and their proposal in future, the informant interviews in the respective organizations, focus on those more actives in fields of data providers and dater user's organizations.

Interviews conducted mainly with

Regional partner representatives

Government officials (Ministries)

NGOs' representatives and community leaders

2.1 Data and Forecast providers

Eastern Nile Technical Regional Office (ENTRO)

ENTRO in addition to weekly, monthly and seasonalalyissued reports also conducts daily monitoring with three-day lead-times to produce forecasts of rainfall and hydrological data used to model and predict flooding with greater accuracy. The information generated is sent to ministries of water resources and universities collaborating with ENTROin Ethiopia, South Sudan and Sudan.

In Ethiopia, the forecasts used by the Ministry of Water, Irrigation and Energy to provide early warning information to local government (woreda) authorities to aid in flood preparation and response.

In Sudan, the information forwarded to the national flood committee, which uses it to enrich its own analysis and alerts. In addition, Sudan's National flood center / Nile Water Directorate receive a daily bulletin during the flood period, which they have increasingly used to avert destruction from flood events.

ENTRO developed flood early warning models for South Sudan, which are also now included in its bulletins. The system continually evolving, and feedback on how it is working is integrated by ENTRO to ensure the system becomes increasingly effective.

Local communities, relief organizations, use warnings and alerts and governments, 350,000 people across the region receive early warning messages during flood season and daily alerts in flood prone areas, 1.7 million more people across the region benefit indirectly from these alerts and messages, and are better able to reduce their risk of flood devastation.

Ministries of Water Resources; Irrigation and Electricity (MoWRIE)

MoWRIE works simultaneously as data user of ENTRO's FFEW models products and data provider to national stakeholders.

The ministry provides policy support, coordination, and technical assistance related to flood disaster risk management in Sudan.

The ministry shared (works) on the four components of early warning systems

Risk knowledge (know the vulnerable of flood prone areas along river Nile).

Risk monitoring (has 29 stations. Hydrometric Network most read manually by an observer uses low frequency radio and cell phones to permit remote site staff to communicate by voice to report manually observed data to Khartoum).

Communication/dissemination (e.g. disseminate FEW via Broadcast);

Response is limited to partially closing JabelAulia Dam located atWhite Nile, 40 kilometer upstream to Khartoum, and Rosaries Dam located at Blue Nile, 620 Kilometer upstream Khartoum.Sowhen flood crosses the danger limit (discharge at Eddiem Station more than 610 million cubic meters per day), ministry take action by partially close Rosaries Dam to regulate Blue Nile flow. The same case applied for Jabel Aulia Dam to control flood peak by adjusting the inflow and outflow at Khartoum around 700 million cubic meters per day, flood hazard problems addressed at the design stage of dams that only to break the peak of floods and not store water at time of flood. The conclusion from above is close Rosaries Dam to protect downstream from the high wave of floods.

The response taken by MOIWRE also reduce the irrigation canals discharges (e.g., close Gazira and Managil canals) to protects farms and livestock and fisheries at flood plain areas (e.g. to give time for evacuate animals).

Sudan Meteorological Authority (SMA)

Sudan Meteorological Authority (SMA) is the provision of Meteorological information and services for the safety of life, protection of property and conservation of the natural environment.

SMA conduct short range forecast of weather warning on daily bases up to five days lead-time.

SMA does not warn for floods or flash floods, but it alerts for heavy precipitation and indicateit might lead to flooding.

IGAD Climate Prediction and Applications Centre (ICPAC)

ICPAC is a specialized Institution of IGAD with the strategic objective to contribute towards enhancing the livelihoods of the people of the Greater Horn of Africa region to mitigate climate-related risks and disasters.

ICPAC's activities focus mainly on climate information, prediction and early warning applications in support of environmental management, disaster risk reduction for sustainable development in the region.

ICPAC plays an important role in providing the IGAD sub-region with weather and climate advisories and more importantly, timely early warnings on possible extreme weather and climate events.

ICPACcontribution is through countries share the document of Seasonal Climate Outlook Forum, which brought together climate information providers and users from key socio-economic sectors, governmental and non-governmental organizations, decision-makers, climate scientists, and civil society stakeholders among others.

ICPAC does not analyse the potential impacts of the hazards, it indicates seasonal rainfall outlook and on daily alerts for heavy precipitation and indicates whether it might lead to flooding.

ICPAC disseminates information and early alerts to the public via Webpage and Portal.

SMA and HAC used the products of ICPAC to enhance quality of their own analysis and alerts and forecast.

2.2 Forecast Warning Users

Humanitarian Aid Commission (HAC)

The Flood Task Force, led by Government's Humanitarian Aid Commission (HAC), is coordinating and facilitating flood preparedness and response efforts.

The Task Force has been working to identify response gaps and ensure they addressed in a timely manner and remained active until the end of such rainy season.

Early Warning Center for Multi-Hazard in HAC has Flood Watch bulletin through this Bulletin give more explanation and clarification of image downloads from ICPAC–IRI to the areas of the flood risk situation in the upcoming 3 days, spatially for those including heavy rainfall, also include the levels of river Nile and tributaries copied from ENTRO bulletin.

The Early Warning Center for Multi-Hazard not produces EW but make use of it easy.

The Early Warning Center for Multi-Hazard, disseminate the bulletin to the HAC centers at states and localities level also to the NGOs.

National Council for Civil Defense (NCCD):

NCCD dealing with alltypeofdisasters risks in Sudan.

Civil Defense (CD) more active memberof NCCD in field of logistic response.

NCCD for first time discussing the flood forecast day by dayin 2019flood, the information provided by MOIWR and SMA members (of NCCD) after meeting the CD take action directly to

guard vulnerable places on river bank, and send the message to CD stations at states to take action.

CD with HAC and SRC are members of NCCD, their mandate response/evacuation people foremergency cases.

Sudanese Red CrescentSociety (SRCS):

The SRCS is a member of various emergency working groups (e.g. Task Force) at the state level.

The SRCS headquarters is coordinating the response at the national level; implementation in Khartoum is largely taking place through Khartoum State branch and its extensive network of volunteers.

SRCS to do its duty (response) receivedthe forecast information from MOIWR and SMA, and take appropriate action also forward the information to its branches at states where risk expected, for to take action.

Federal Governance Ministries(Flood-sensitive economic sectors)

Flood-sensitive economic sectors thoseare received from MOWRIE monthly, seasonal hydrological outlooks reports for planning, as well as short- and medium-range forecasts and warnings for daily operations. However, hear the interviewee's replies focus on daily operations.

Ministry of Agriculture and Forestry (MAF)

The main mandate of the Ministry of Agriculture and Forestry is increase food security, improve agricultural production and productivity and formulate agricultural development policies and to advise the government on such policies relating to its administration and the management of the agricultural sector and forest of the Sudan's economy.,

Specific Flood related mandate is to protect and monitor productivity of the scheme irrigation and rain-fed farms at depression and floodplains land areas adjacent to rivers and streams that are subject to recurring inundation.

Upon receiving flood early warning information from or issued by MoWRIE, the action taken as following :

The actions taken by farmers include:

- Quick move and transfer of machineries and pesticides to high lands
- Open stockades door for animals to escape
- Move equipment to high lands and/or dry places
- Put power supply off in the flooded areas
- Lock sewage irrigation, fuel depots and pesticides stores

Ministry of Livestock and Fisheries (MLF)

The Mandate of the Ministry of Livestock and Fisheries is anchored on Government functions include:

Animal Health

Fisheries and Aquaculture Research

Livestock and Veterinary Research

Veterinary and Fisheries training

Fisheries and Livestock Extension

Livestock Identification and Traceability

Dairy Industry Development

Fisheries and Management Development

Livestock Development

Specific Flood related mandate is to protect and increase product and productivity of the animals and fish.

The actions taken upon MOWRIEreleased FEW massages the ministry ordersthe farmers/pastoralists move their animals and cattle to high places, other people plugging sewage feeding fishponds.

Ministry of Roads andTransport (MRT).

The mission of MRT, is to have a sustainable, efficient, safe and internationally comparable quality of road infrastructure in general and National Highways infrastructure in particular to achieve enhanced connectivity, quick mobility to a level which accelerates socio-economic development.

Specific Flood related mandate isto provide effective flood alleviation and mitigation solutions (drainage).

The actions taken by Ministryof Roads and Transport, once received the massage from MOWRI, it to be ready for closing drainages discharge water back from river and prepare pump for uplift water to the river in case water from rainfall comes sidelong.

Ministry of Environment, Natural Resources and Urban Development (MENRU)

The MENRU mandate is, achieving balanced development while preserving the natural environment biodiversity in accordance with the purposes of the nation's international and regional obligations in the country, in order to bequeath future generations a clean environment.

Specific Flood related mandate is conducting Hydro-meteorological hazard process and disseminating information about it, more especially for urban areas.

The actions taken by Ministry upon receive the massage of FEW from MoWRIE it start to prepare and identify safety roads and safety places for evacuation if such flood occurred.

Ministry of Information and Communication (MoIC)

The ministry's work focuses on developing communication policies and strategies. The ministry coordinates the public service advertisements of the government.

Specific Flood related mandate iseach type of media (print, FM radio, and television) receives a package of public service advertisements from the government.

The action taken by this Ministry, MoWRIE send daily flood statement situation to the broadcast, Flood/disaster issues addressed through the advertisements.

Communities at risk

Communities at risk including community-based organizations and civil society action groups

Communities at risk received the information of flood early warning from MOWRIE and SMA, the action taken by communities saving lives and protecting livelihood assets by moving to upland

Six communities were used as pilot riverine flood prone areas namely:

Um Benein village located on the western bank of the Blue Nile within Singa locality with an estimated population of 10,000 persons, most of them from Kenana tribe;

El Sabonabi village is located on the western bank of the Blue Nile within Singalocality. The village established since 1700 it is a big village compared with that selected villages by more than 1.5 times in term of population. The total population of about 15,000 persons (750 families), 45% of the population is male and 55% were females predominantly from the Mahas, Galiyin, Bargo, Hawsa and Kawahla tribes;

Tuti island villagelaid in the heart of Khartoum state at the junction of the Blue and White Niles, at latitude 13 o 15' N. and longitude 30o E. Its total area is about 8 square kilometers and altitude is 1,260 feet above sea level. The total number of houses in the island is 1,820, 1% built of concrete, 96.3% of red bricks and 2.7% of mud. The total population is about 20000.

Wawisi village is located east of the River Nile, about 100 km north of Khartoum, within of Sharq Al Nil locality, Khartoum state. The total population is about 6,000 (about 800 families) mainly from Mahas tribe.

Wad Ramly consist of five villages is located east of the River Nile, about 102kms north of Khartoum, within of Sharq Al Nil locality, Khartoum state. The total population is about 40,000 (about 14000 families) mainly from different tribes.

Sidon city belong to Sidon administrative unit, Lamar locality, River Nile State.It is located 60 Km from Lamar, at the eastern bank of Atbara River.Number of inhabitants is 700 families.

Alabka village belong to Sidon administrative unit, Damar locality, River Nile State. It is located 60 Km from Damar, at the western bank of Atbara River. Number of inhabitant households is 460 families. The cultivated land is about 950 acre.It is considered as flood affected area.

2.3 Vulnerability mapping for settlement on flood prone areas

The major flood prone zones not covered by the current ENTRO FFEWs in Sudan are:

Riverine flood areas along Atbara River and Setit, Dinder and Rahad Basins

Flash flood areas on the Blue Nile River from Sudan borders with Ethiopia to junction at Khartoum, including Khartoum town.

Main settlement areas at Blue Nile are Hasehisa city, Wad Medan city, Singa City and Roseires city. Areas along main Nile include Shandi city and Atbara town.

Others for mostly torrential and flash flood is gash river and settlement area Kassala city. (Plate 1)

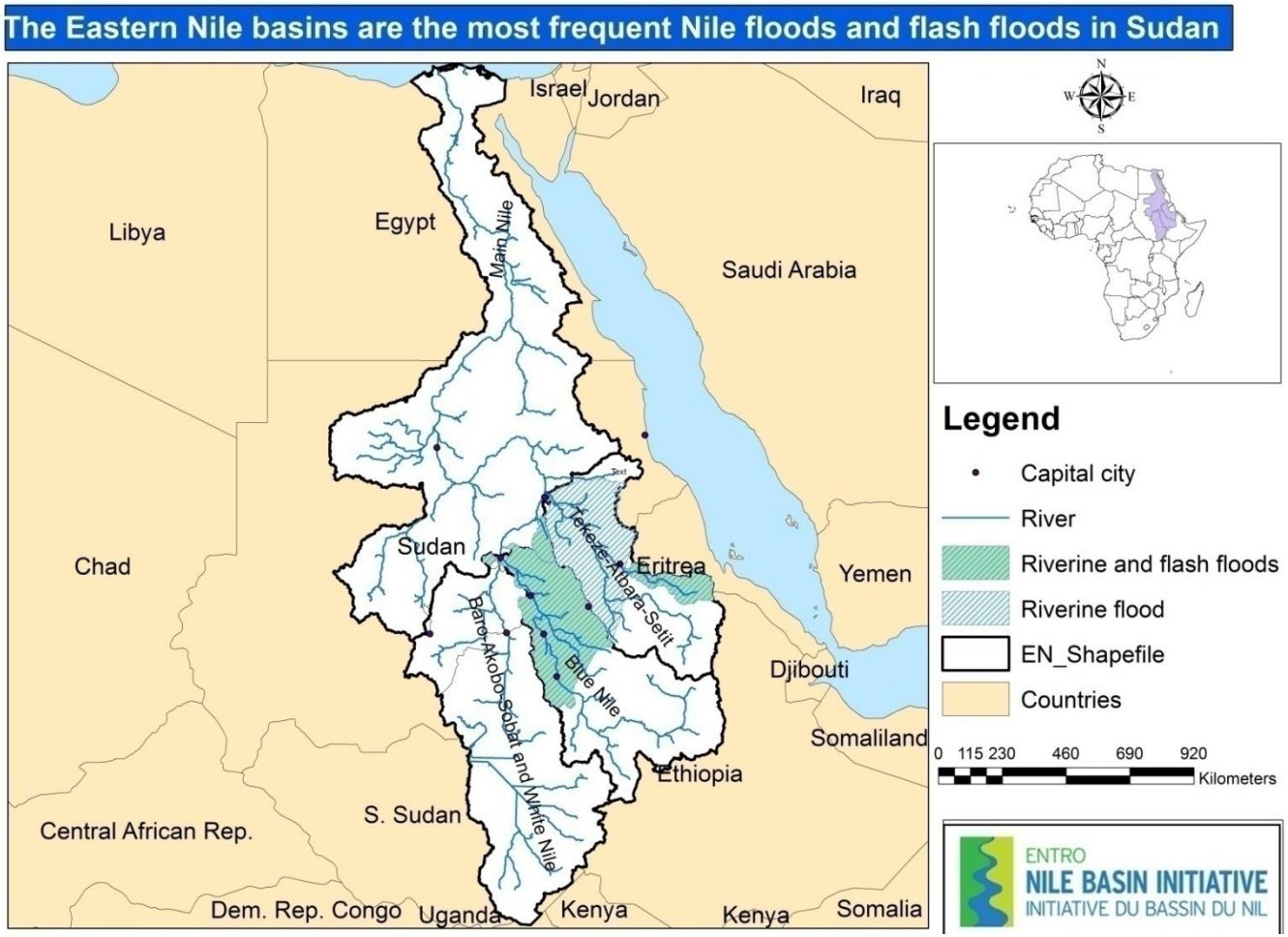


Plate 1:Catchments riverine and flash flood in Sudan

3.1 Forecast movement and use

The interviews and questioners consulted 24 organizations involved in different aspects of flood disaster reduction in Sudan, as part of this survey, including government organizations, non-government organizations (NGOs).

Table 2 describe forecast information movement and use (information from whom it is received and who is the end user).

Organizations received the forecast information either from main provider (producer, or secondary provider (forecast disseminator) and users (responder).

Summary of the finding of study in Table 2:

Three types of forecast early warning issued either riverine or rainfall forecast indicating likelihood of causing flash flood or both riverine and rainfall.

ENTRO was found the core of forecast FEW for both (river and rainfall) providerand disseminator to most of organizationsdirect and indirect.

MoWRIE is second order provider (used flood early warning information from ENTRO), disseminate to national stakeholders.

SMA is not hydrological information provider it is a rainfall information provider,disseminate to national stakeholders.

HAC is not hydrological and not rainfall provider (used the information from ENTRO, MoWRIE and SMA),and further disseminated to NGOs, for make iteasy to use.

The other organizations are users (e.g. HAC, CD, SRCS, MAF, UNDP ...act.)

Table 2 Providers and users of forecasting and early warning information

SN	Organization	information from whom it is received and who is the end user			
		Type of information	Main FEW provider	secondary provider	user
	Government organizations				
1	Ministry of Water Resources;Irrigation and Electricity	river and rainfall	ENTRO	Yes	Yes
2	Ministry of Interior/CD	river and rainfall	MOERIE		Yes
3	Ministry of Humanitarian Affairs/HAC& SRC	river and rainfall	ENTRO/ICPAC	MOWR	Yes
4	Ministry of Agriculture and Forests	river and rainfall	MOWRIE/SMA		Yes
5	Ministry of Livestock and Fisheries	river and rainfall	MOWRIE/SMA		Yes
6	Ministry of Roads and Transport	river and rainfall	MOWRIE/SMA		Yes
7	Ministry of Environment, Natural Resources and Urban Development	river and rainfall	MOWRIE/SMA		Yes
8	Ministry of Information and Communication	river and rainfall	MOWRIE/SMA		
9	Sudan Meteorological Authority (SMA)	Rainfall	Yes		
State-owned organizations enterprises/corporations					
10	Khartoum state	river and rainfall	MOWRIE/SMA		Yes
11	Sinnar State	river and rainfall	MOWRIE/SMA		Yes
Intergovernmental partnership					
12	ENTRO	river and rainfall	Yes		
13	ICPAC	Rainfall	Yes		
National and International NGOs					
14	Sudanese Red Crescent (SRC)	river and rainfall	MOWRIE/SMA		Yes

15	Youth organization	river and rainfall	MOWRIE/SMA		
16	FAO	river and rainfall	MOWRIE/SMA		Yes
17	UNDP	river and rainfall	MOWRIE/SMA		Yes
18	UNICEF	river and rainfall	MOWRIE/SMA		Yes
Community representatives					
19	UmAshira; Tuti; Wawoossivillages	river and rainfall	MOWRIE/SMA		Yes
20	Saboonabi&Banain Villages	river and rainfall	MOWRIE/SMA		Yes
21	Azhur Ext.&Ammara villages	river and rainfall	MOWRIE/SMA		Yes
22	Sedon& El Abka villages	river and rainfall	MOWRIE/SMA		Yes
Academics and individual experts					
23	University of Khartoum	river and rainfall	ENTRO		Yes
24	Rabaat University	river and rainfall	MOWRIE/SMA		Yes

3.2 Data and Forecast provider's gaps

Eastern Nile Technical Regional Office (ENTRO)

ENTRO have developed a hydrologic model (using HEC-HMS) for the entire Blue Nile basin, including the portions of the basin in Ethiopia, and a hydraulic model (using HEC-RAS) for the Blue Nile from border to Khartoum. With assistance from ENTRO, Sudan was restoring and upgrading its previously implemented hydrologic forecast system, which was provide a new user interface and integrate the hydrologic and hydraulic models. The models are running simultaneously in National flood forecast center and regionally at ENTRO office, every morning during flood period. ENTRO also publishes a flood bulletin covering Ethiopia, South Sudan and Sudan, which includes rainfall indicators of potential flash flooding conditions based on daily rain forecast.

The interviewees mentioned that there some gaps in ENTRO FEWs as following:

ENTRO FEWs does not cover Atbra River, Dinder and Rahad also areas of flash flood and torrential in the basin which inhabited by about more than 5 million residents (Urban, Semi-urban and Rural) with flood risk in the downstream river extend from Eddeim stations at Sudan border with Ethiopia to Atbara town at main Nile.

Use of Stage-discharge data at Eddeim station; the stage data has effect on the shape of the hydrograph due to storage and/or backwater of Roseires dam.

ENTRO's flood forecast has only forecast products one cycle (e.g. accumulated precipitation for 24 h, should be breaking into at least 3 hours depending on the criticality of situation).

ENTRO Flood early warning does not issue flood risk, hazard and vulnerability mapping derived from rainfall extremes.(The flood risk map developed by ENTRO maximum risk probability is 100-year return period flow magnitudes at Eddiem station, such that the peak of the hydrographs matched the peak of river flow magnitude of the flood frequency events), but this extreme stream flow is not combined with rainfall intensity duration curve andoverland flow.Forexample,for a12-hour duration 100-year rainfall intensity (Plate 2) if the two cases happen in the same time results for both extreme precipitation and extreme stream flow not issued by existing ENTRO FEWS, moreover ENTRO FEWS not addressing extreme events beyond 100-year return period.

Outputs of forecasting system or hydrological model does not covered all inundation areas for Example River Atbara, Dinder and Rahad, and Flood Hazard Maps not available in all areas of risk at Blue Nile (Plate 3) only the red circles. The existing one not update since 2012.

Return periods of the floods for which the flood hazard maps were developed is only for 100-years.

ENTRO is not engaged in seasonal flood forecast with the lead-time of 1-3 months.

The flood forecast of ENTRO's flood forecast communicated to MWRIE (decision maker) is too late during the day (e.g. after 12pm).

Language utilized in warning bulletins is in English and highly technical and poorly understood by local communities.

ENTRO's data sharing and collaboration with other institutions is not satisfactory. The gaps in flood forecasting in trans-boundary river basins include low capacity in flood monitoring systems, limited data exchange and technical cooperation and inadequate institutional and capacity development.

Lack of early warning indicators: Products of ENTRO's FEWS require practitioner's assessment indicators that are regionally agreed and locally referenced to measure success and failure of early warning systems and thus improve the basis for collecting and analyzing risk data.

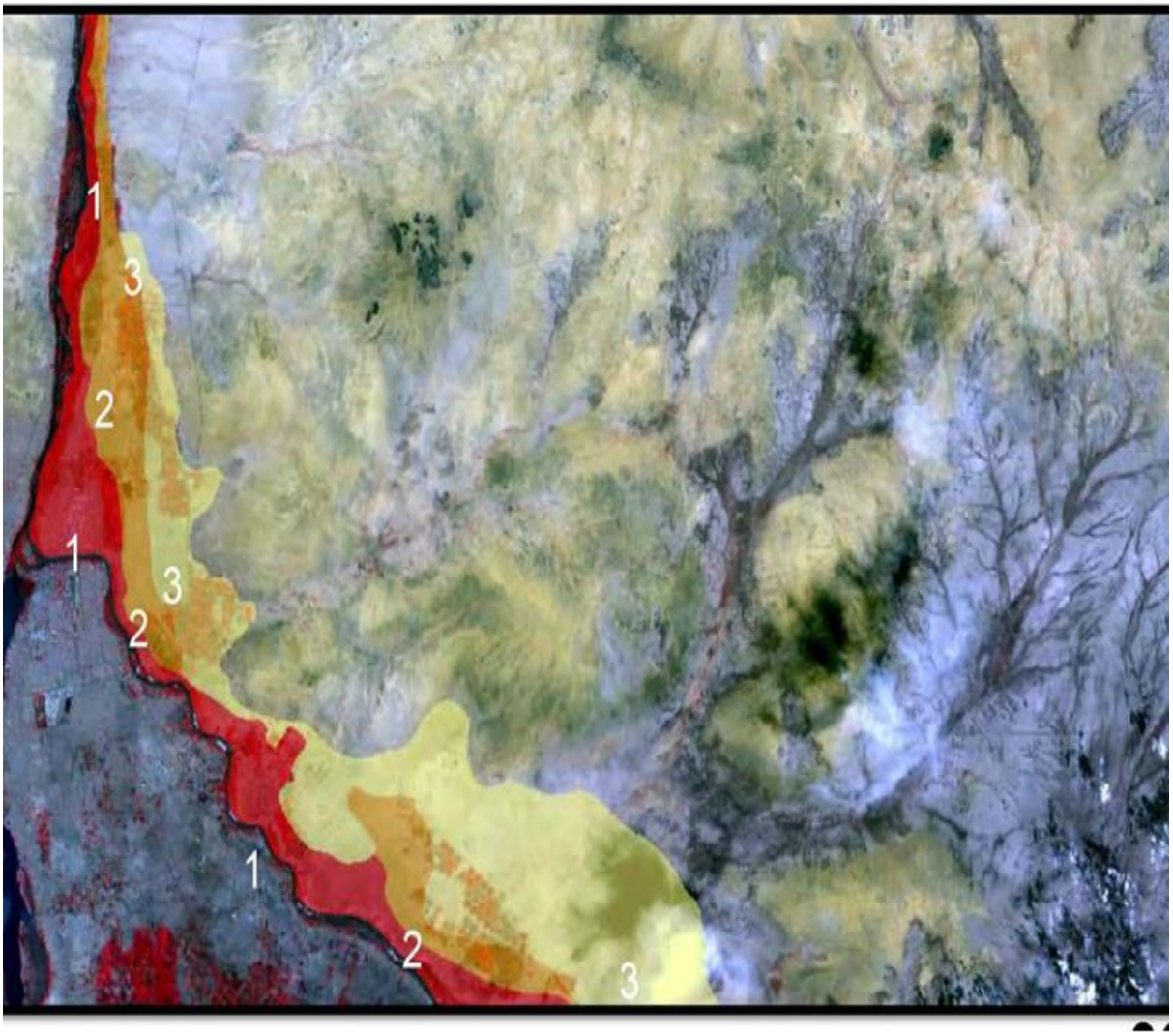


Plate 2: Flood zone levels and the related to risk (ASTER 13/8/2013)

Key:

1 -Level of high risk, mainly from the river Nile

2 - Level of high risk, mainly from the Valleys and

3 - Level rarely it affected by the Valleys.

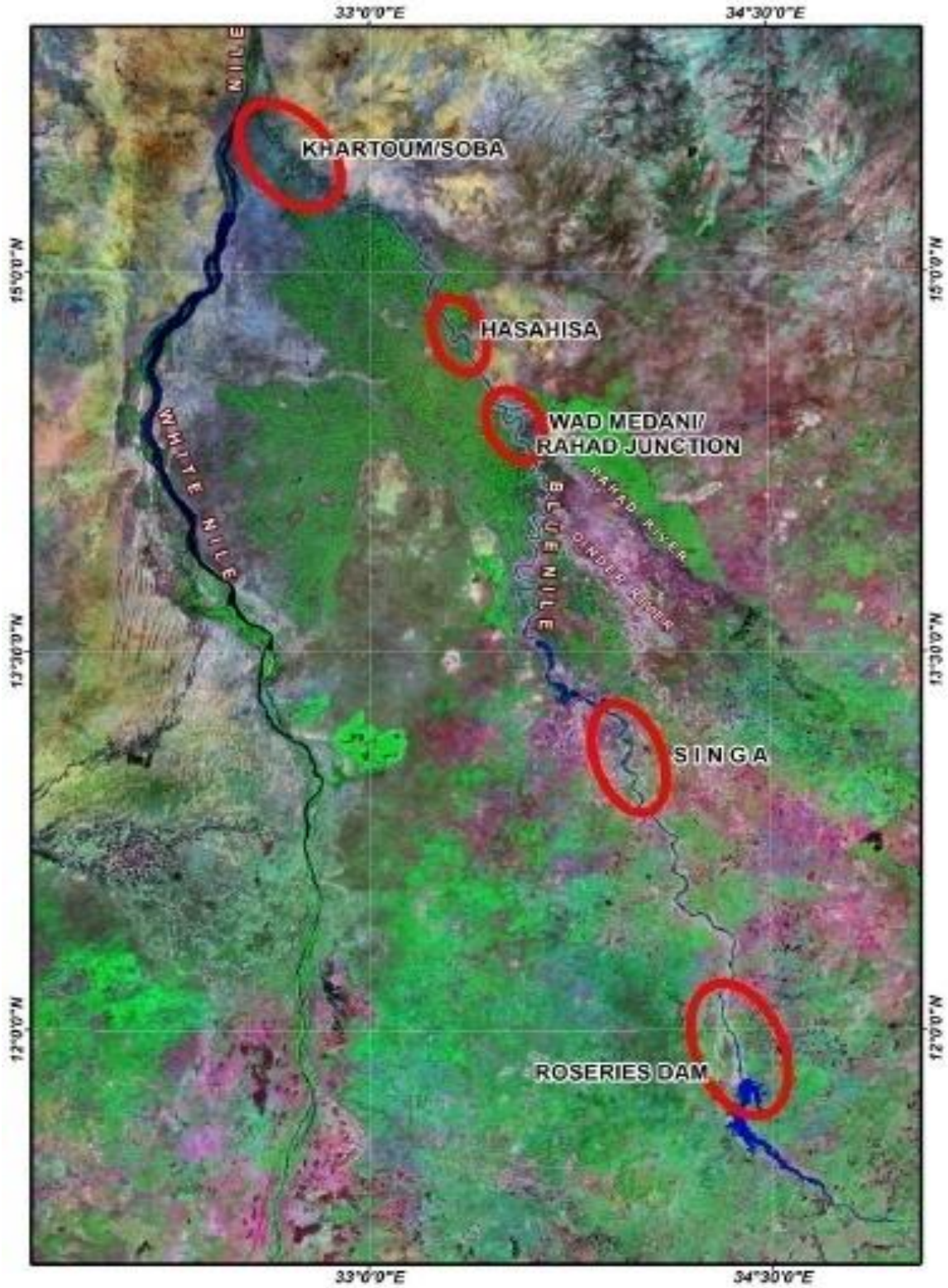


Plate 3: Pilot flood prone areas studied by FPEW I

Ministries of Water Resources; Irrigation and Electricity (MoWRIE)

Most important gaps are:

Inadequate of observation, monitoring and forecasting systems, based on n eeds and capacities of MWRIE, establishing appropriate observation systems in highly vulnerable/risky areas, developing multi-hazard impact-based forecasting models, upgrading forecasting procedures to ensure effective use of local and regional products, and systematizing forecast verification, recording, and publication are priority areas.

Data collection and transferring are manual.Both the data collected and data recorded are manual (e.g., Person in the upstream manually read the data with an instrument and provides the data to the Ministry of Water Resource; Irrigation and Electricity).

Real-time data are not available from river and rainfall gauges (automatic stations), however there is inadequate capacity for modeling-based forecasting.

Limitation of data available and past experiences warnings to the most of target community (flash floods and torrential)

Inadequatefrequencyoutputs of forecasting system or hydrological model (one per day)

MoWRIE relies on ENTRO EW uses the forecasts that received from ENTRO to enrich and fill the gap of rainfall forecastedto three days ahead which not covered by the Ministry.

Sudan Meteorological Authority (SMA)

Lack of cooperation and data sharing activities between institutions and regional

Inadequate coverage and sustainability of observing systems for monitoring of hydro-meteorological hazards and hydro-meteorological-observation units installed in the river basin.

Lack of systems for many hazards, such as dust and sandstorms, severe storms, flash flood s and storm surges, particularly for people at-risk and vulnerable.

Lack of upgrading of information, communication, and IT systems as applicable to SMAneeds and requirements of resource and capacity for maintenance.

Need for enhancement of central database for collection, processing, and archiving of historical climate data, forecasts, projections, and guidelines.

3.2.4 IGAD Climate Prediction and Applications Centre (ICPAC)

There were a level of uncertainty within the observed data and seasonal outlook t hat demonstrated (e.g. flood 2019 dry in blue catchment).

Climate outlook it's not good indicators for rainfall distribution for both temporal and spatial.

3.3 Forecast Warning Users gaps

Humanitarian Aid Commission (HAC)

The Early Warning Center for Multi-Hazard bulletin depends onENTRO, MoWRIE, SMA and ICPAC information.

The information in the bulletin written in way that more specific to HAC partners

Low level of coordinate and fully utilizing received EW/forecasts of ENTRO EW

National Council for Civil Defense (NCCD)

Weakness of coordination between early warnings related institutions in the areas of DRR and users.

Absence of attention to exchange of experience and sharing of techniques

Low spirit of cooperationbetween members

Sudanese Red Crescent Society (SRCS)

No sustainable staff depends on Volunteer.

Inadequate coordination and collaboration with other institutions

Ministries (Flood-sensitive economic sectors)

Ministry of Agriculture and Forestry

No local hydrologic model with more spatial detail concern farms on flood prone areas.

No flood hazards maps in detail for most area of agriculture and forestry.

Ministry of Livestock and Fisheries

Inadequate lead-time to provide information of flood risk and warning to the pastoralists at remote areas

Lack of trust on early warning information by end-user pastoralistcommunities.

Ministry of Roads and Transport (MRT)

Warnings given only to communities on/near embankments

MRT not authorized to give information to the media

Unofficial mobile communication is used to communicate with communities

Ministry of Environment, Natural Resources and Urban Development

No flood risk map at areasof urban development

Low controls and regulations to grant licenses to companies working in the field of environment and urban development

Ministry of Information and Communication (MoIC)

Weakness in to cover all Sudan with information, and providing citizens with information

Weakness provide information for researchers interested in Sudanese affairs and field of media in particular

Communities at risk

The eight pilot communitiesassessedthrough the interviews agree upon common state (regarding the flood risk map they have since 2010) as following:

Absence of regular monitoring, maintenance and scientific research (risk map since 2010 no update), in other words river surveyed was limited to specific pilot reaches of the Blue Nile.

Floodplain areas were characterized used a 90-meter DEM which low elevation resolution, now there is resolution up to 10-meter DEM which is very high accuracy to generate an inundation extent grid, 2D models, the flood extent, depth, and velocity can be visualized directly in the model output

The river is subjected to continuous changes in channel geometry due to its high sediment load, need of modern river cross-sectionsurvey.(The points above factors governed the model accuracy, high accuracy give more confidence in early warning, subsequently more action/response by communities)

Lack of support from government to ENTRO project for long-term master plan (Strategic planning)with respect to communities needs(This mean no government's program for periodic surveying of river channels to capture morphologic changes and update the terrain model accordingly, for the communities' pilot areas).

Inadequate training initiatives, especially the volunteers, as appropriate, to enhance local capacities to mitigate and cope with seasonal floods

No enough time to implement an evacuation if needed

No reliable forecast or measurements, clear threshold for warning and alert; sometimes alerts comes from different channels this make some confusion

3.4 Household Survey of Flood Prone Areas

Generally, the land adjacent to a Nile river, the lower ground around riverbanks more likely to experience floods. With the very steep topography of east of Khartoum region it is likely that flowing water moves from higher places to lower places which experience flash floods sometimes as result of human intervention (e.g. build a roads across a valley).

Vulnerability mapping for flood prone areas

The major flood prone zones not covered by ENTRO FFEWs in Sudan are:

Riverine flood areas along Atbara River and Setit.

Flash flood areas on the Blue Nile River Dinder and Rahad Basins from Sudan borders with Ethiopia to junction at Khartoum, including Khartoum City.

Main settlement areas at Blue Nile are Hasehisa city, Wad Medan city, Singa City and Ed Damazin city.

Areas along main Nile include from khartoumto Shandi city and Atbara town.

Others for mostly torrential and flash flood are gash river and settlement area Kassala city,Plate 1and States most vulnerable to floods and torrential disasters,Plate 5.

Household surveys

General spooking about residential land,people live near major rivers and small rivers due to the availability of water, agricultural lands and fodder for animals, so found2900 villages living in flood prone areas, is an important factor for vulnerable area to flood,2 to 5 km distance from rivers bank were categorized as high risk areas, 5 to15 km as medium risk areas and areas located at over 15 km to the river channels were described as low risk areas this guidance from statistical flood return period of 25, 50 and 100 year of pilot areas, Plate 6. Because this area not only subjected to riverine, flood but also flash flood.

Geographic Vulnerability of villages in sub-basins (GIS-based map)

Geographic vulnerability caused due to the specific location of a household where hazard strikes first, giving minimum time to react and move away to save life and assets. one of the indicators namely distance from the river 2, 5 and 15 kilometer more or less it look like 25, 50 and 100 year return period. Distance analysis shows that total of 4262 villages withintwo sub-basin in Sudan, 791villages (19%) laid in high risk level category, 801 households (19%) laid in moderate level category, 2900 villages (31%) laid in low level category and the remaining 1354 (31%) laid in very low risk level category, Table 3 and Plate 4.

Table 3 Number of villages located within 15 Kilometers extends to the riverbanks

Level of Risk	Distance from bank in each side in km(flood risk zones)	Number of villages		Total
		Abbay-Blue Nile Sub-basin including Dinder and Rahad	Tekeze-Setit-Atbara Sub-basin including Kassala	
High	0 - 2	485	306	791
Moderate	2 - 5	416	386	802
Low	5 - 15	700	607	1,307

Total		1,601	1,299	2,900

Sample of Study area (Wad Ramly five villages, 2019 flood)

Study Area Selection

The reason why Wad Ramli villages chosen as a place to study,is because they were devastated by floods in 2019, and this has not happened before in history, also combined riverine and flash flood with torrents, moreoverWad Ramli villages laid within the high-risk zone of floods (e.g. 2 kilometer from riverbank). Many of the houses in terminal residential neighborhoods in Khartoum built from brick, cement block and mud, these building materials are not strong enough to withstand an extreme flash flood and more of the surveyed houses severely damaged by the 2018 flood (Table 3). In 2019 flood, the water level of the Nile gradually increased over a period of two weeks. People not anticipated a higher level for longer duration of the flood than usual. Several houses were inundate for two weeks in Wad Ramly as result riverine flood in 2019 (Figure 2) however the event of death was less compared by flood 2018 because they received flood-warning massage from MOWR at time. In response, some people decided short-term preventive measures to reduce damage they moved to safe places.

Study sample from HouseholdSelection

The community from Wad Ramly was chosen forin-depth study based on a face-to-face interviews, group discussion and questionnaireswere conducted for households, and identified based on proximity to floodhazard sources, frequent severe flooding, and past heavy flood damages, 14,000 households lived in the Wad Ramly villagestook 50 households as a sample. Using 17 questionnaires concerning five main dimensional vulnerabilities donein the field, in August - September 2019.Thisstudy tries to quantify dimensional vulnerability usingsocial, economic, physical/infrastructural, institutional, andattitudinal dimensions.

This multidimensional vulnerabilityassessment would greatly help in identifying a relevantcourse of action for disaster risk reduction in exposedcommunities.

Formulation of a Multidimensional Vulnerability Index

The index-based approach ofthis study developed for assessing five dimensions ofvulnerabilitysocial, economic, physical/infrastructural,institutional, and attitudinal vulnerability.Four indicators each was used for social, economic, physical/infrastructural andattitudinal vulnerability,five indicators for institutional vulnerability;the original primary datasets were standardized usingrespective weights for the computation of the compositeindex.Thisstudy also uses a subjective weighting technique to allocatevalues to classes of phenomena for each indicator andformulates indices based on Eq. 1. (Annex 3).

Results and Discussionof studysample

Indices for each dimension calculated using the methodology described in the previous section. Statistical tests performed to understand the level of difference in each dimension.

Social Vulnerability

The socialsurvey shows that households in Wad Ramly villages community,most of them wereextended families (68%),About 14% of households includedmembers who were suffering from a chronic illness or aphysical/mental disability, or were pregnant.Long pastexperiences of householdsattributed toreduce floods disaster in Wad Ramly community, and because mostfamilies in village had relatively dealing with each other's like one family during the floods disaster, however with respect to social vulnerability, around 8% of the surveyed householdsclassified as highly vulnerable. Table A2-1,thesocial vulnerability index of households variedfrom 0.05 to 1, average 0.4 inWad Ramlycommunity, Table A3-6.

Economic Vulnerability

The dependency ratio (dependents to total household size)was relatively high in the Wad Ramlycommunity(30%) in the range of 75-100% members of family depended on Household head, most of the households living in the floodproneareas were low income,working as famers, due to fact that people inherited agricultural lands from their ancestors, agricultural lands became narrow and did not fulfill the individual's need, so some of them working as governmentemployees, traders, or daily wage earners, or they migrated temporarily to the locations of the gold mines,making those households

highly vulnerable.Significantly, 30% ofthe households had no other asset (land/house outsideflood-prone area), making them economically challenged. Table A3-2,the economic vulnerability index of households variedfrom 0.1to 1average 0.45 in Wad Ramlycommunity, Table A3-6.

Physical/Infrastructural Vulnerability

Almost all of the surveyed households lived in highlyvulnerable floodplains, and some had even built houses betweenlevees (trench) and embankments (68%). These houses were builtillegally (nature of villages in Sudan you can build without return to urban planning regulations and laws local name Ashwaei) when the floods comes last time not find drainage to Nile, closed by building. Generally, most of the houses wereGalosse (constructed from mud, 48%), and built almost 20 years ago (44%), Table A3-3.Only a few households were living in adobe housesGreat beam (Brick, Cement) (20%). The physical vulnerability index of households variedfrom 0.05 to 1 with average 0.4, Table A3-6.

Institutional Vulnerability

Institutional vulnerability included reach and efficiency ofearly warning systems, risk information communication, and emergencyplanning by institutions.More than a quarterof thehouseholds (28%) in the study areas did not receive anykind of warning in the initial of 2019 flood.This inefficiency can be attributed to the lack existence of locality management authority,

and no local agency (SRCS) was officially delegated with this responsibility.Around 20% and 15% (Table A3-4) of the households were unaware of the location ofemergency shelters and evacuation routes during floods started, respectively.

Around 30% of the households did not have access toemergency plans, increasing their vulnerability.10% of the household members had never attended anykind of awareness program to cope withflooding. Households asserted that local administrationshad not helped them prepare for flood hazards andmitigation.The institutional vulnerability index of households variedfrom 0.04 to 1 and average 0.34, Table A3-6.

Attitudinal Vulnerability

Around 14% of the households had poor approached localinstitutions to seek help or advice regarding flood preparedness.Respondents indicated that they distrusted thelocal institutions, perhaps because the government, according to its strategies, wants to deport them to high places, or may be lack of communicationbetween exposed households and local institutions.Around 14% in of the households did not believe in communitycooperation when floods strike,respondents were of the opinionthat everyone looks after himself or herself, and no one paysmuch attention to the people around them in disaster settings.

The attitudinal vulnerability index value of householdsvaried from 0.05 to 1, average 0.4

Table A3-5, Table A3-6.

Multidimensional Vulnerability

The results in the previous sections highlight the fivedimensions of vulnerability and emphasize the major factors that affect these dimensions.

Different dynamicsinfluence of the flood vulnerability in theWad Ramlycommunity, are riverine floods, flash flood and torrent, a markeddifference in flood hazard sources (e.g.,flash flood and torrent was more destructive).

Figure 1 reveals interesting insights into each dimensionof vulnerability, through average index values. Figure 1,show no-big variations observed in social, economic, and physical/infrastructural vulnerability among the very high vulnerability scale.Overall, the average multidimensional vulnerability is 0.4 (Table A3-6), was more or less the same for all five dimensionvulnerability. These findings show that there is a need to launch awareness campaigns and design riskcommunication strategies to enhance the flood risk perceptionsof the communities and engage the local institutionswith the communities to implement disaster riskreduction plan effectively.

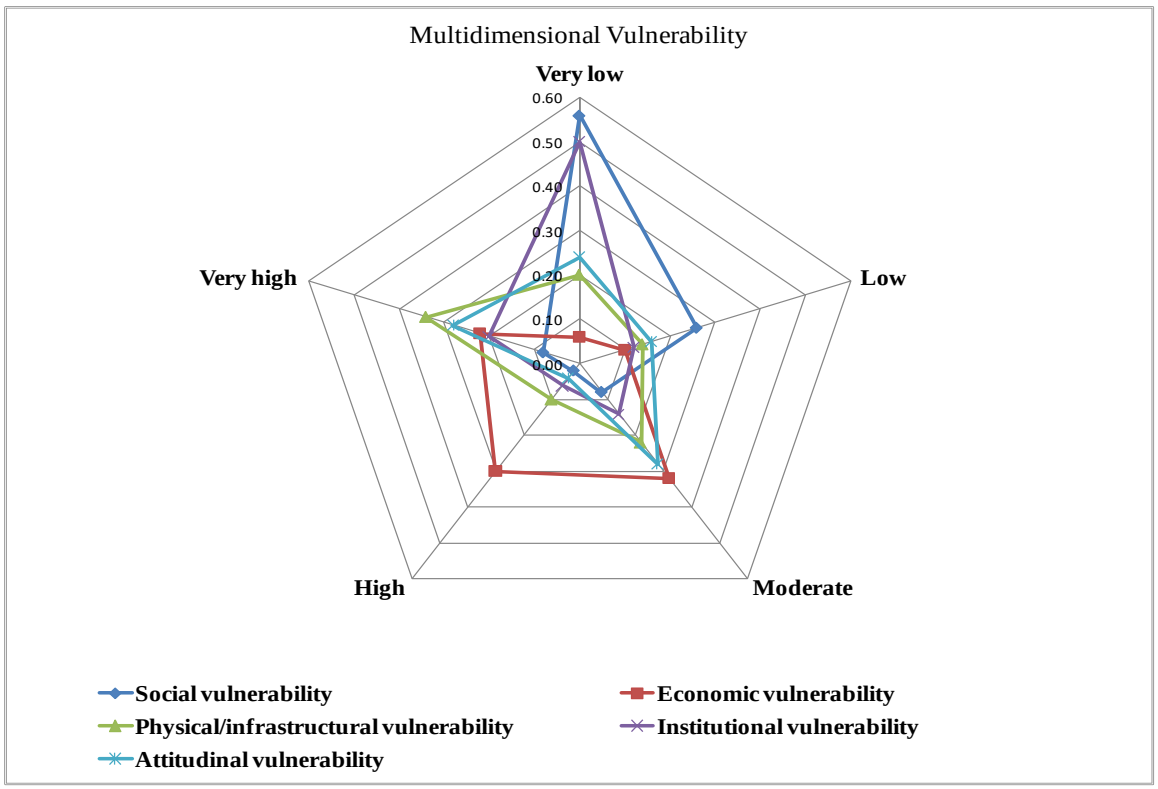


Figure 1 Multidimensional vulnerability to Floods prone area in Wad Ramly community

3.5 Communities, which have experienced floods

Specifically the study was considered some villages as pilot riverine flood prone areas, the basis for selection was the communities frequently suffer impact of the flood, communities who are residing on or near to floodplains, people living in a community lacking provision for flood protection in both rural and urban, people more affected by and less able to cope with floods.

Um Benein village located on the western bank of the Blue Nile within Singa locality with an estimated population of 10,000 persons, most of them from Kenana tribe;

El Sabonabi village is located on the western bank of the Blue Nile within Singa locality. The village established since 1700 it is a big village compared with that selected villages by more than 1.5 times in term of population. The total population of about 15,000 persons (750 families), 45% of the population is male and 55% were females predominantly from the Mahas, Galiyin, Bargo, Hawsa and Kawahla tribes;

Tuti island village laid in the heart of Khartoum state at the junction of the Blue and White Niles, at latitude 13 o 15' N. and longitude 30o E. Its total area is about 8 square kilometers and altitude is 1,260 feet above sea level. The total number of houses in the island is 1,820, 1% built of concrete, 96.3% of red bricks and 2.7% of mud. The total population is about 20000.

Wawisi village is located east of the River Nile, about 100 km north of Khartoum, within of Sharq Al Nil locality, Khartoum state. The total population is about 6,000 (about 800 families) mainly from Mahas tribe.

Wad Ramly consist of five villages is located east of the River Nile, about 102kms north of Khartoum, within of Sharq Al Nil locality, Khartoum state. The total population is about 40,000 (about 14000 families) mainly from different tribes.

Sidon city belong to Sidon administrative unit, Damar locality, River Nile State. It is located 60 Km from Damar, at the eastern bank of Atbara River. Number of inhabitants is 700 families.

Alabka village belong to Sidon administrative unit, Damar locality, River Nile State. It is located 60 Km from Damer, at the western bank of Atbara River. Number of inhabitant households is 460 families. The cultivated land is about 950 acre. its considered as flood affected area.

3.6 Infrastructure and properties on flood prone areas

The interviewees stated that flash floods had devastating consequences and had effects on the economy, the built environment, properties, infrastructure and the people. During 2018 floods, especially flash floods destroyed roads, bridges, farms and houses.

As examples:

National road northern state

Kosti- Al obeid

Sinnar - Madani

Wad Banda-Kordfan north

Al fao -Al mafaza

In Khartoum, 2013 flash floods at eastern Nile locality, the interviewees mentioned that, many factors that causes high flash flood risk. Some factors are natural while other factors are due urban growth allows for buildings or infrastructure to be constructed that actually obstruct natural drainage channels, that can be seen from satellite images perspective the flood-prone areas are formed by the three-major valley Deltas in the locality, namely, Green valley, Soba valley and Haseeb valley, Plate 7. Most of the valleys end-up to Deltas (Flood prone area), no water courses reach the Nile.

The second factor causing by human intervention like lack of proper land use planning; 80% of the urban and agricultural schemes are within the flood-prone zone; and road construction intersecting valleys without proper drainage system very narrow culverts.

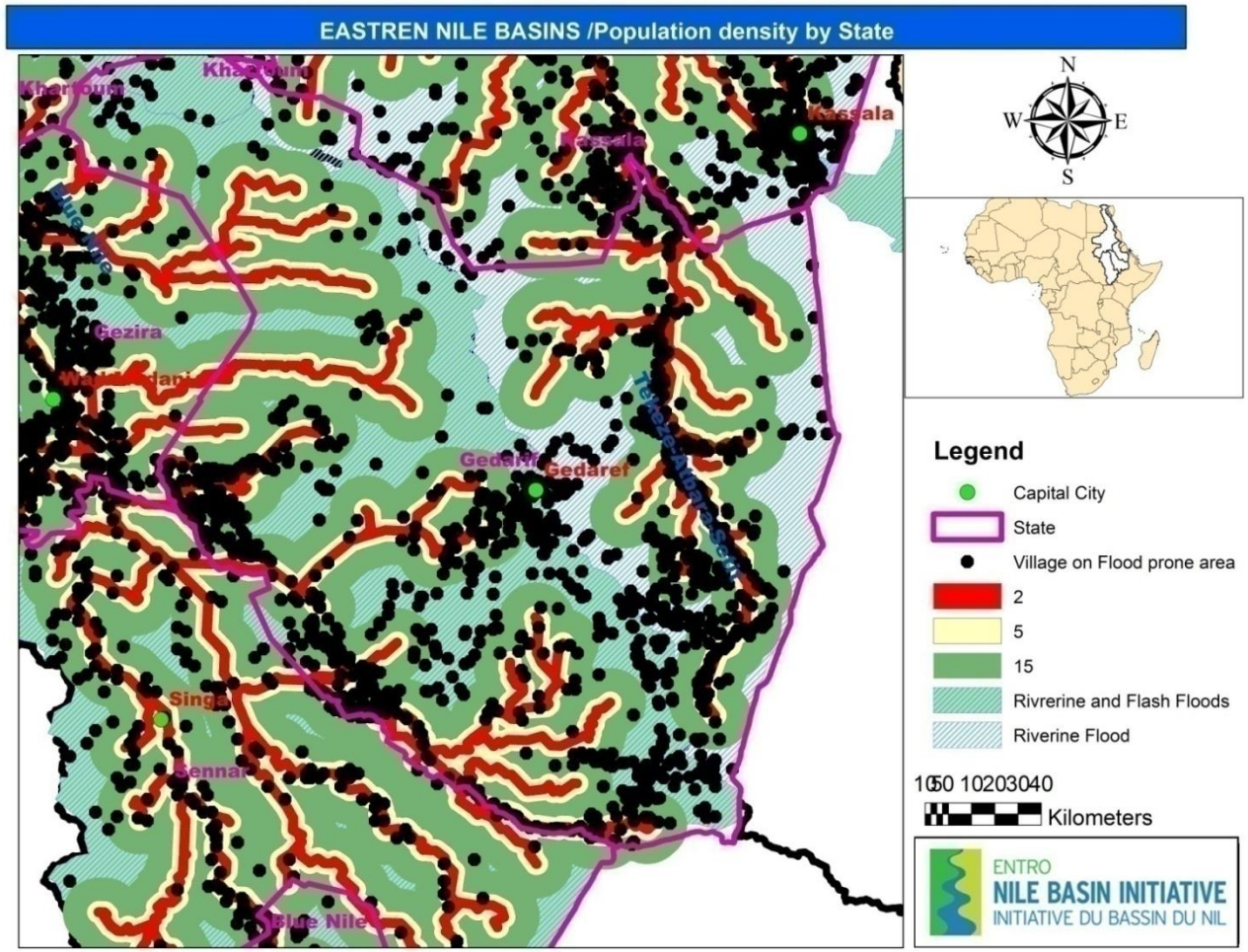


Plate 4: Population density by State on flood prone areas

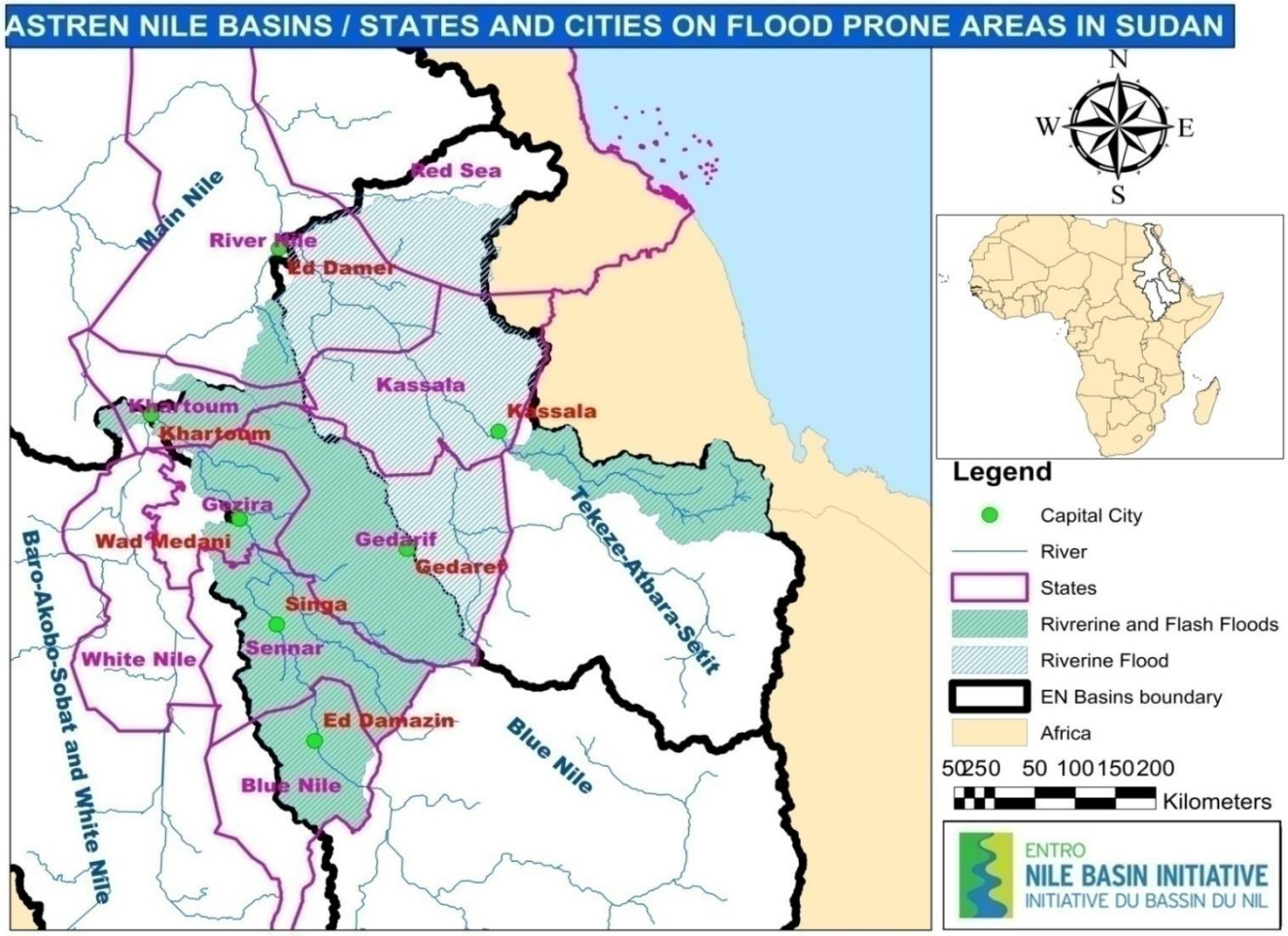

ASTREN NILE BASINS / STATES AND CITIES ON FLOOD PRONE AREAS IN SUDAN
Red Sea
Main Nile
River Nile
Ed Damer
Kassala
Khartoum
Khartoum
Kassala
Gezira
Wad Medani
Gedarif
Gedaref
Singa
Sennar
White Nile
Ed Damazin
Blue Nile
Blue Nile
Baro-Akobo-Sobat and White Nile
Tekeze-Atbara-Setit
N
W
E
S
Legend
Capital City
River
States
Rivrerine and Flash Floods
Riverine Flood
EN Basins boundary
Africa
50250 50 100150200
Kilometers
ENTRO
NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

Plate 5 : States most vulnerable to floods and torrential disasters

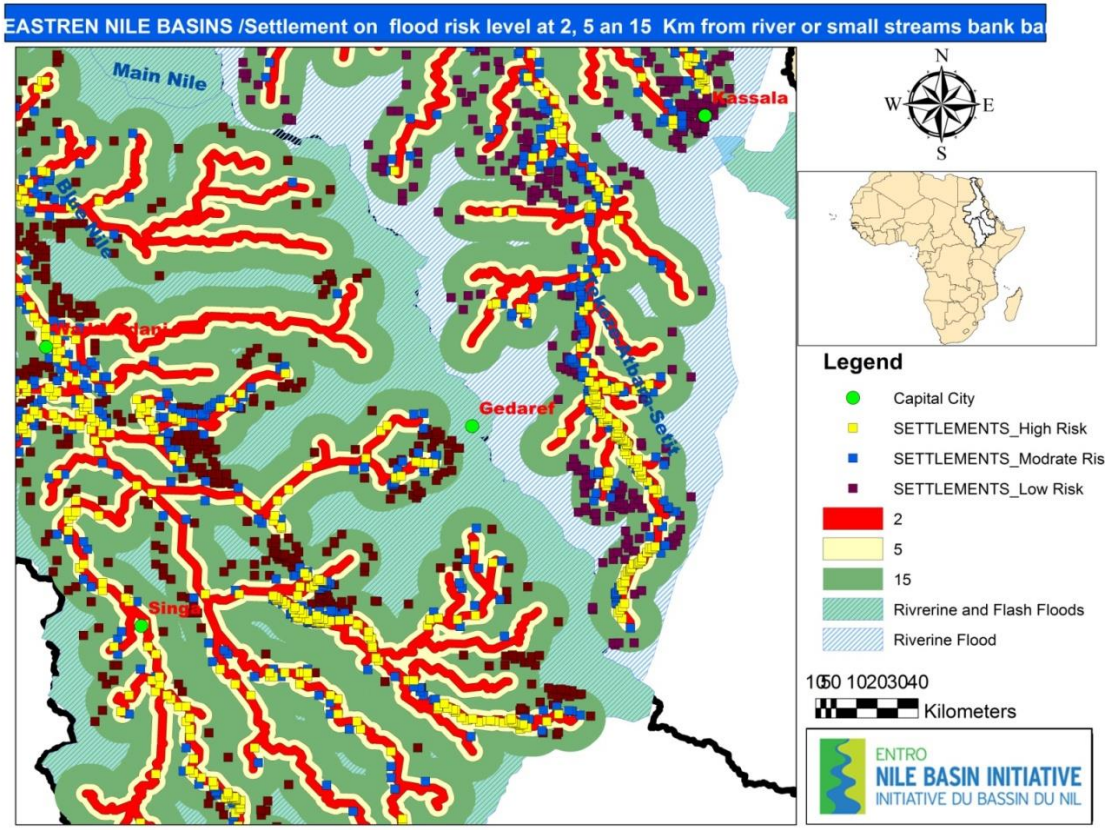


Plate 6: Proximity of settlements to rivers and drainage

Table 4 : The impact of the 2018 and 2019 extreme floods

State	Year	People		Houses damage		Services	Shops and stores	Agriculture sector(Acre)	Animal death	
		death	injured	Total	partial				cattle	Poultry
Khartoum	2018	30	24	62	81	3	1		10	
	2019	16	19	34	96	46				
Gazira	2018	8	3	156	271	37				
	2019	19	33	1709	2276	55	4	900	495	
Sinnar	2018	3		699	2265		1		273	
	2019	6	29	4000	3972	6	1		12	
White Nile	2018	4	5	1162	502	56				
	2019	5	5	6302	7845	109	10	114170		
Gadaref	2018	3	1	5583	4207	13		200040	5	
	2019	1	1	1196	1774	87	14	71000	36	
Kassla	2018	5	1	1500	2087	9				
	2019	14		2702	2675	1			175	

Red Sea	2018	11	11	474	1796	23	249	456	276	21000
	2019	3	1	575	2114	10	137	8	1877	
River Nile	2018	14	2	60	474	8	2			
	2019	14	7	3496	1896	55	4	900		

Source: CD, secondary data, household survey, 2018 and2019

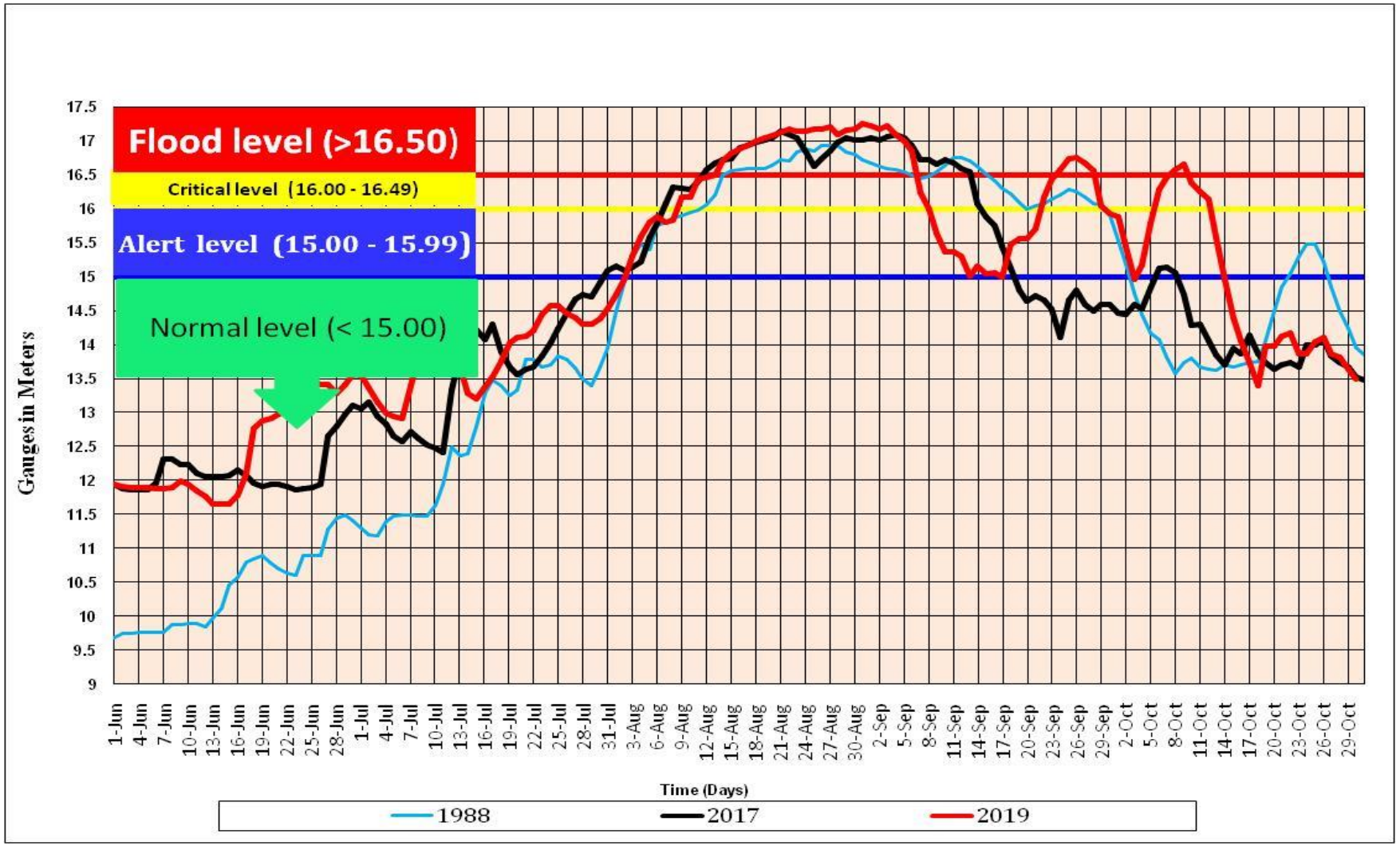


Figure 2: Water level at Khartoum station

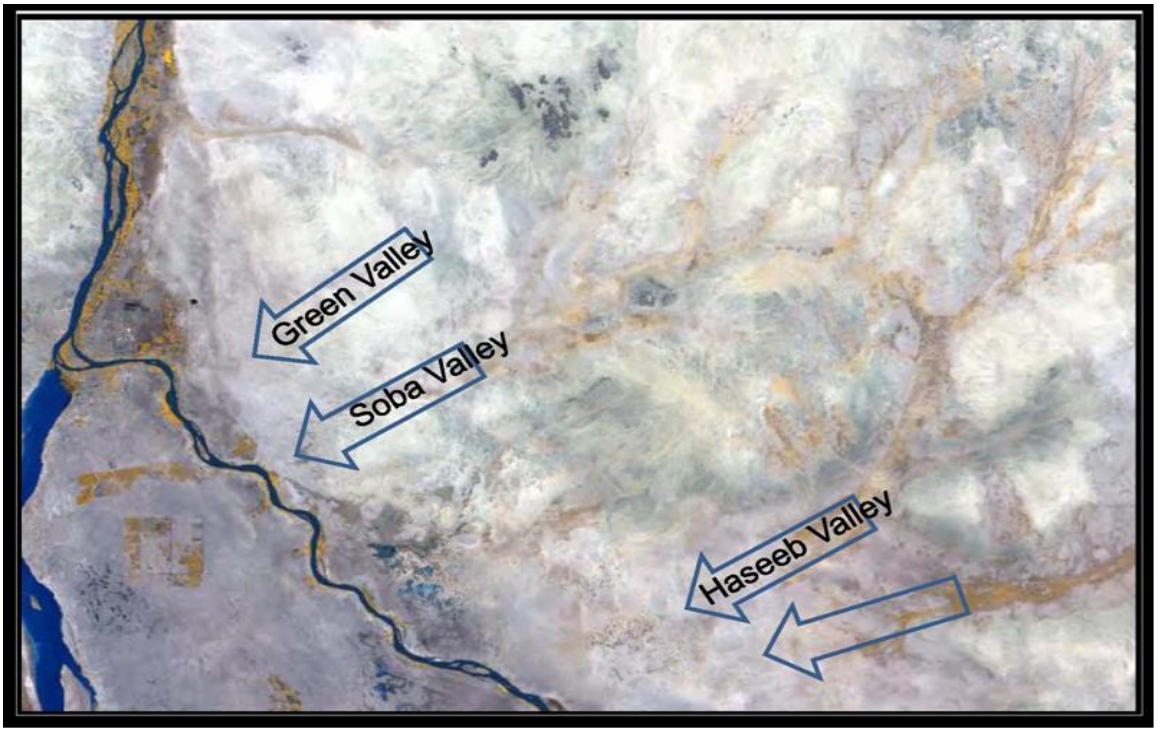


Plate 7: Valleys where floods in eastern Khartoum

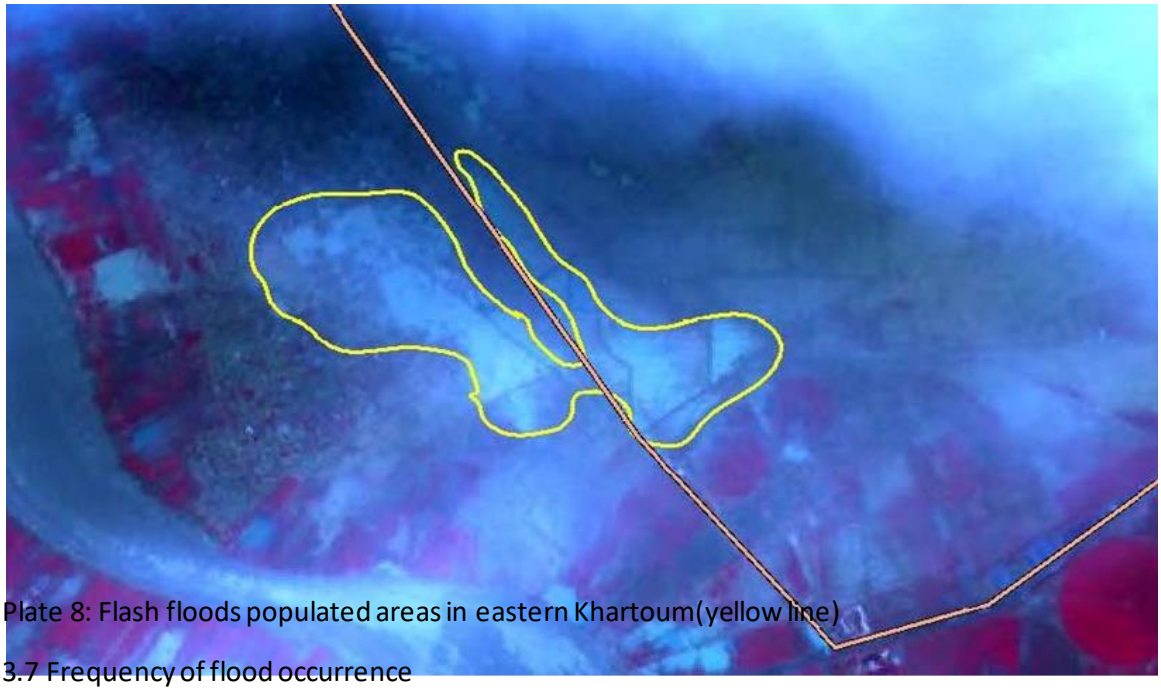


Plate 8: Flash floods populated areas in eastern Khartoum(yellow line)

3.7 Frequency of flood occurrence

After reviewing all interviewee's replies about flash floods events, it was found that in Sudan flash flood events was more periodic occurred in recent years than before Table 5.

Some of these events happened when the season was at its peak (during August), at night period of the day, which cause significant impacts at the local communities and agricultures sector, it leaves economic impacts. The occurrence of these events has left many damages in private and public properties besides the death of many people.

Table 5: Type of flood events and its time in Sudan

N	Year	Riverine	Year	Flash	Most affected cities
1	1988	√	1988	√	Khartoum, Damazin and Madani
2	1998	√	2000	√	Khartoum, Singa, Kassala
3	2006	√	2006	√	Madani, Singa, Damazin
4	2011	√	2013	√	Khartoum, Singa and Kassala
5	2012	√	2012	√	Sinnar, Singa and El girba
6	2016	√	2018	√	Khartoum, Sinnar, Singa and Kassala
7	2019	√	2019	√	Khartoum, Sinnar, Singa and Kassala

3. 8 Needs of stakeholders from flood warning

Lead time

Lead-time provided by flood warning has to be sufficiently long to allow response action to take place. Forecasts with short lead-time are useful for saving lives, but not adequate for making decisions to reduce flood risks to livelihood systems. Community level surveys in Sudan (Table 6) revealed that at least 7 days lead time is required to save livelihood assets from flood disaster, however long lead time the less accurate.

Table 6: Forecast lead-time required for community-level decisions

Target group	Decision	Lead time requirement	Current estimated time from historical analysis (short-lead time)	
			Riverine flood Plate 1	Flash food mentioned in Para 2.1
Households	Excavating drainage canals for torrential and flash floods; and evacuation people on threatened flood prone zones.	7-14 days	From Eddiem to Ed Damazin 1 day ---------- From Ed Damazin to Singa 1.5 day ---------- From Singa to Madani 1day ---------- From Madani to Khartom 2 days ---------- From Khartoum to Ed Damer 2 days	Dinder and Rahad up to Singa and Madani 5-7 hours …….. Flash flood around Khartoum 2-3 hours …….. Kassala 3-5 hours
Farmers	delayed sowing cotton at Gezira Scheme, Sorghum at Gedarefand Selling or move poultry	10-15 days		
Pastoralists	Move cattle, goats, and camels from drainage and flood prone areas	1-2 days		

Warning level and danger level

Flood threshold levels, such as warning level and flood level, are important references for the issue of flood warning. Flood warning thresholds define the meteorological and river, conditions at which decisions taken to issue flood warnings. Flood level thresholds are the values at which flooding occurs. Normally, a flood-warning threshold is set to achieve an acceptable lead-time before the flood level threshold reached (Figure 2). If proper flood warning threshold levels identified for the areas of interest, an automatic alert system based on real-time monitoring could also developed. Rainfall thresholds could provide additional lead-time, and could be useful in mobilizing personnel to increase the frequency of monitoring.

Threshold for riverine flood key stations

The flood-forecasting departmentof the MOIWR has defined the warning level as the flood flow that just passes over the riverbank (Critical), but does not affect the nearby settlements. It is the level of flow at bank full stage of a river. The Danger level is that level of flow at which the floodwater rises above the mainstream channel and enters the settlements affecting people and their properties (flooding).

Because of this work, the warning levels and danger levels have identified by analyzing the flood inundation scenario for a range of flow boundary conditions at forecasting stations for each river. Table 7, presents the threshold water levels with reference to Mean Sea Level (MSL) and stations gauge height and runoffs corresponding to warning level and danger level.

Critical level for rainfall to cause runoff and flash flood

The flood vulnerability variables were determined by; rainfall duration and intensity, drainage density and shape, slope type of soil and land cover.

Floods related to extremes in rainfall (from tropical storms, thunderstorms, aerographic rainfall, etc.). A combination of precipitation characteristics (e.g., the amount of rainfall, intensity, duration and spatial distribution) influences the flood events.

Flash floods due to the upward rains and cumulative clouds that fall at night in the Gedaref region, Dinder and Al-Rahad received a lot of attention from the communities and was considered a feature of the parts of the basins located in the border strip of Sudan from the Red Sea in the north heading south passing through the borders of Eritrea and Ethiopia with Sudan to the city of Malakalin Southern Sudan, the reason for interest is because it is an agricultural and pastoral area. Also, the frequency of flash flood losses has increased in recent years due to the population increase in cities and the lack of proper urban planning (knowledge of contour maps) in major cities such as Khartoum. The rainfall cannot immediately infiltrate as ground water or runoff. It converges to the catchment area. The heavy rainfall raises the amount of discharge from rivers and causes overflowing, according to the flood record by SMA, this case often occur inside Sudan, Table 8.

Table 7: Threshold runoff, warning level and danger level

River	Station	R. to MSL	Threshold Runoff (m3/day)			
			Normal	Alert	Critical	Flooding
B.Nile	Eddeim	481.20	< 350	350 - 519	520-608	> 608
			Threshold Water Level (m)			
			Normal	Alert	Critical	Flooding
B.Nile	Madani	380.09	10.91 -18.41	18.41-19.41	19.41-19.91	> 19.91
B.Nile	Khartoum	363.00	10.00 -15.00	15.00 -16.00	16.00-16.50	> 16.50
M.Nile	Shandi	342.40	10.60 -16.10	16.10 -17.10	17.10-17.60	> 17.60
Atbara	Atbara	332.82	9.68 -14.18	14.18 -15.18	15.18-15.78	> 15.78
M.Nile	Marwi	231.30	10.00 -12.00	12.00 -15.50	12.50-13.00	> 13.00
M.Nile	Dongola	212.03	8.97-13.47	13.47 -14.72	14.72-15.22	> 15.22

Table 8 : Rainfall classification by Sudan Meteorology Authority (SMA)

Catchment in Sudan	River	Rainfall intensity range and description				
		0-10 mm/day	10 - 25 mm/day	26 - 50 mm/day	50 - 100 mm/day	>100 mm/day
		Very light	Light	Moderate	Heavy	Very heavy
Blue Nile from Eddeim up to Wad Madani.	B.Nile		Starting causing runoff in valley	Generate runoff in valley to river	runoff in valley to river and torrential	runoff in valley to river and torrential and flash flood
Blue Nile from Wad Madani to Khartoum	B.Nile			runoff in valley to river and torrential	Runoff in valley to river and torrential and flash flood	
Dinder and Rahad	Dinder and Rahad		Starting causing runoff in valley	Generate runoff in valley to river	runoff in valley to river and torrential	runoff in valley to river and torrential and flash flood
Setit and Takazi up to El Girba Dam and gash	River Atbara And gash		Starting causing runoff in valley	Generate runoff in valley to river	runoff in valley to river and torrential	runoff in valley to river and torrential and flash flood
River Atbara to Atbara Town	River Atbara			Starting causing runoff in valley	Generate runoff in valley to river	runoff in valley to river and torrential

COMMUNICATION METHODOLOGY FOR FLOOD EARLY WARNING

Warning communication refers to users' understanding of the received message, prompting users to take appropriate actions.

Dissemination is the physical delivery of flood forecast and warning information.

Every warning system is made of two main components:

Communication infrastructure hardware that must be reliable and robust, especially during the natural disasters; and

Appropriate and effective interactions among the main actors of the early warning process such as the scientific community, stakeholder, decision makers, the public and media.

Many communication tools available for warning dissemination such as short massage(SMS), Email, Radio, TV, and web service,Newspaper,Flags, Sirens, Phone, speakerphone and door knocking. etc.

4.1 Best practices and Methodologies in Flood EW Communication Globally

The chain of communication about the risk of flooding, from key providers to the users

ICPAC Flood forecasting

ICPAC has established a Live-Web map service for flood forecasting known as "Flood-FINDER".

The Flood-FINDER system is a modeling chain that includes meteorological, hydrological and hydraulic models that accurately linked to enable the production of warnings and forecast flooding scenarios up to three weeks in advance.

Together with modeling is an automated flood forecasting using MIKE-Hydro and GEOSFM models covering all the major river basins in the GHA region.

With these flood-forecasting capabilities, an online flood risk map with 90-meter resolution and a 25-year return period has been established for the region.

Bangladesh Flood Forecasting and Warning Centre (FFWC)

FFWC issues five-day deterministic flood forecasts and ten-day probabilistic flood forecast.

Satellite altimetry-based flood forecasting technology, providing lead times of up to eight days

Flash flood forecasts, based on rainfall intensity–duration thresholds

Flood forecast information made available on the webpage of the FFWC, also disseminated viaSMS andtoll-free24-hour Interactive Voice Response (IVR).

Discharge forecasts at boundary locations use Mike 11 hydraulic model to generate water-level forecasts.

The FFWC generates flood bulletin and flood situation summary on a daily basis during the monsoon.

The FFWC carries out monitoring, forecasting, dissemination and communication of flood early warning.

The response and preparedness capacity framed through standing orders on Disaster (SOD) at the national, district (sub-national) and local government levels.

Different NGOs have done risk assessments at community level.

4.2 Current Flood Early Warning Communication Method

ENTRO conducts EWs Daily, and weekly flood forecast bulletin and reports written in English generated and disseminated to different users at different levels via ENTRO website, portal, email, and watts. (Figure 3)

MoWRE combined regional and nationalflood earlywarningsin one statement(in Arabic),and disseminated it on daily bases officially to relevant stakeholders such as federal ministries, media, response agencies and communities viatelephone,email and fax, also shared via the social media watts, twitter and face-book.

ENTRO's FEWs, and thus making communities flood resilient is a development better, there is so far, formal communication and dissemination channel of flood information fromENTRO to the government and the communities, (Figure4).

SMA bulletin EW communicated by Arabic language and disseminated twice a day by phone, Radio/TV, Newspaper, watts and website.

HAC/center bulletin EW communicated by English language and disseminated no regular bywatts and website.

ICPACbulletins EW communicated by English language and disseminated by wattsup and website,portal and dashboard.

4.3 Gaps in Existing Communication methodology

At both national and regional,lack follow-up of thereare no systems for gathering and responding to feedback from the local or district level to regional level or even national levelto improve the dissemination and communication system.

Lowapplication of Information and Communications Technology in ENTRO FEWs websites and dashboard, gapin layers ofHydro Met monitoring system data source and forecasted risk mapping information inwebsites and dashboard, these media has low uploaded of observed and forecast data, hazard and risk information, and warnings in visual form, through info-graphic, data tables, geospatial layers, maps.

At national level lack on reliability of communication channels, the communication channel mainly depend on internet access this can seriously delay dissemination (e.g. at 11:00 o'clock there is limitations to intent access).

At regional level, insufficient frequency of warning (e.g. depends on the nature, intensity, and duration of the threat but ENTRO only one per day).

At both national and regional, lack of communication skills, (e.g. water level at Eddeim station is 13.40 m, this need more elaboration (duration, magnitude, probability likelihood of the hazard happening, potential impacts and advisories).

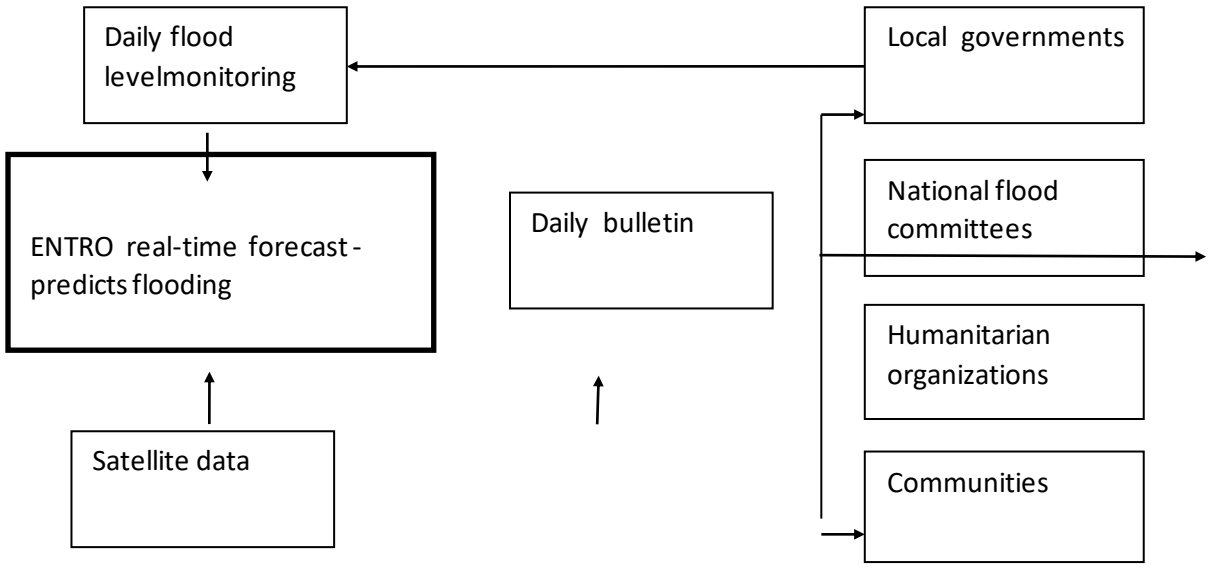


Figure 3: ENTRO forecasting disseminate of data and information

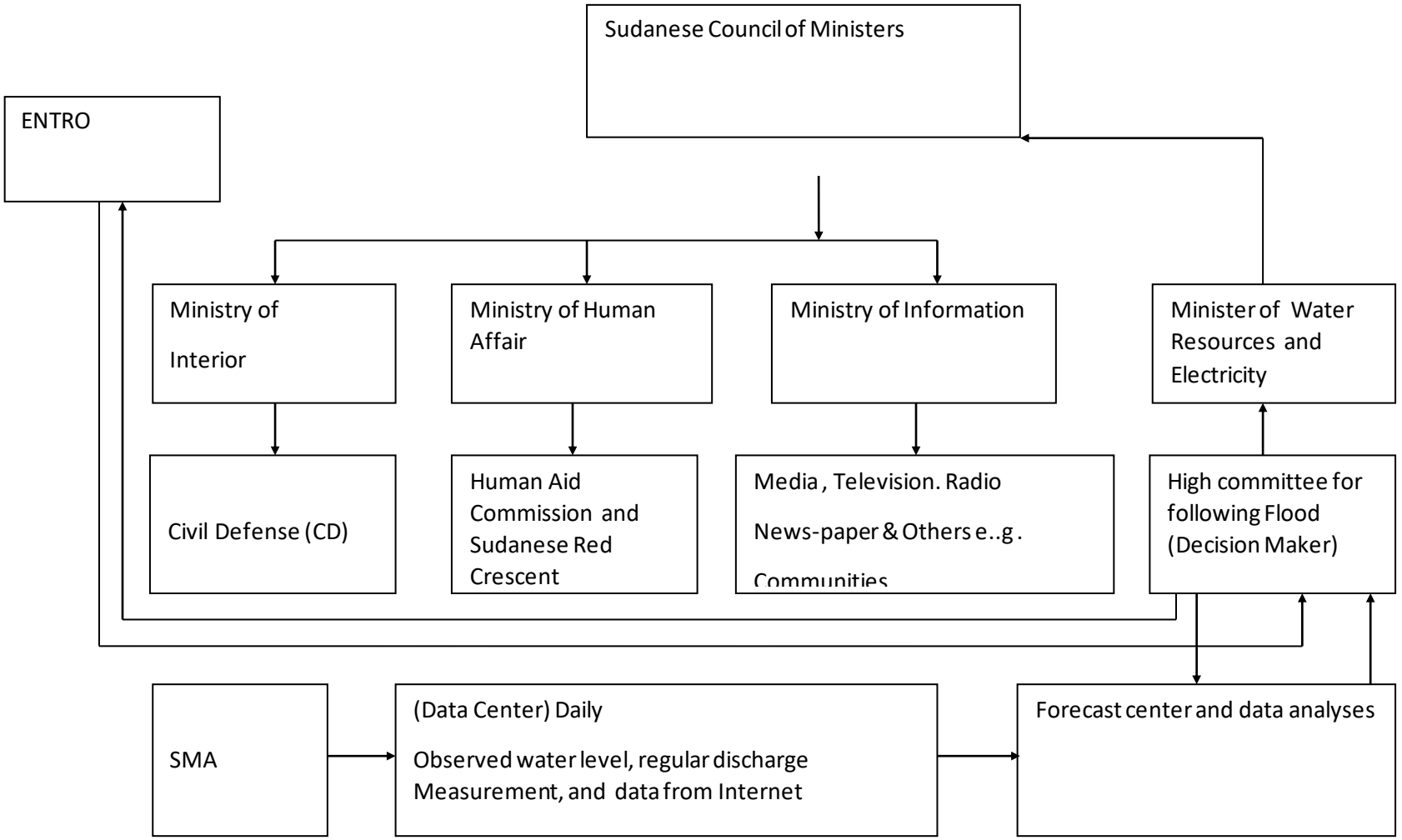

Sudanese Council of Ministers
ENTRO
Ministry of Interior
Ministry of Human Affair
Ministry of Information
Minister of Water Resources and Electricity
Civil Defense (CD)
Human Aid Commission and Sudanese Red Crescent
Media , Television. Radio
News-paper & Others e..g .
Communities
High committee for following Flood (Decision Maker)
SMA
(Data Center) Daily
Observed water level, regular discharge Measurement, and data from Internet
Forecast center and data analyses

Figure 4: Governmental structures charged within flood management and disseminate of data and information

Table 9: Access to early warnings in Pilot community areas (Total 40 person e.g. 10 per pilot)

category	question	Overall sample	Pilot flood community areas (State)			
			Tuti Island andWawsi at Khartoum State.	Sidon and AlAbaka at River Nile State.	Elsabounabi Umbaneenvillages SinnarState	Seven villages Azuhur Extension Blue Nile
Access to communications technology	Do you have access to a phone You can use?	29 (73%)	9	7	7	6
	Do you have access to a radio?	28(70%)	10	6	5	7
	Do you have access to a TV ?	23(58%)	10	6	3	4
	Do you have access to theinternet?	14(35%)	7	2	3	2
	Do you have access to the gauge reading?	10(25%)	3	2	2	3

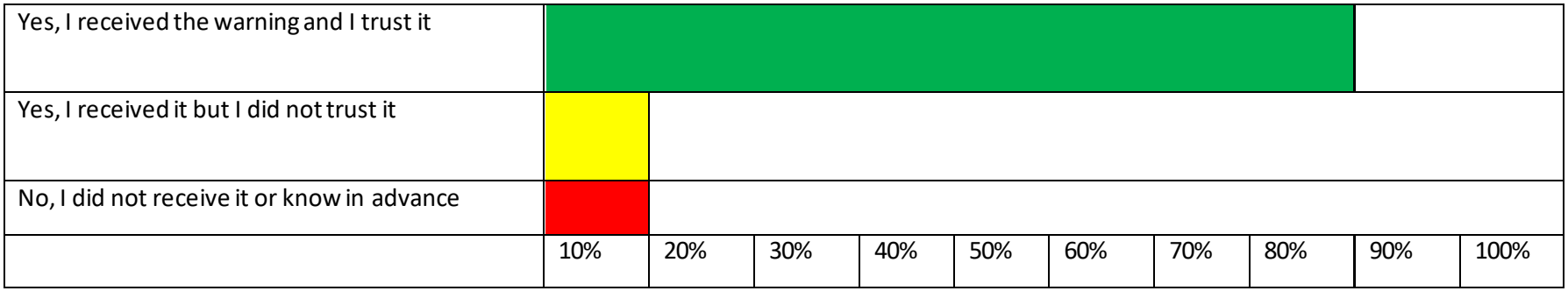


Figure 5: Timeliness of warnings in pilot flood communities floods area (overall sample)

4.4 Proposed Flood Early Warning Communication Method and Technology

From the interviews, it seems that communication tools available for warning dissemination are short massage (SMS), Email, Radio, TV, and web service, Newspaper.

Though some are not receive these messages or information because they do not have a phone, radio, TV or internet access (Table 9) and (Figure 5).For those poor communities flood areas risk,early warning can be receive bycommunity leaders (Emam Elmasgid) and disseminate the information through a speakerphone.

At national level where there flood plain settlement areas, (e.g. Wad Ramly village) just Northern Khartoum, the first information reach communities suppose come from the river bank observer (like gauge reader) but volunteer from local area, already trained on notice the color marked staff which indicate rate of river rising (how much the river rising during the day after threshold of flood level).

In Khartoum or others towns flood marks and other forms of visualization can be used to communicate past water levels of historical floods andpublic by locate flood marks on the side of bridges.

At regional level, enhance Websites and dashboard content: These media allow sharing of observed and forecast data, hazard and risk information, and warnings in visual form, through info-graphic, data tables, geospatial layers, maps, etc.

Effective websites and geo-dashboard usually includesof three layers :

First layer, data source, will composeof automatic stage gauges and rainfall station with others climatology sensors (Automated Hydro Metstations or manual). including the data downloaded from satellite, connected to a ENTRO center and the sensors will be design to collect data from the river reaches and sub-basin catchments, e.g. its stage, velocity, rainfall quantity an duration, humidity, water quality and temperature.

Second layer, service layer for fusion, as well as for transforming and sharing the data provided by the previous layer. In addition, analyses the quality of these data in terms of their accuracy.

Finally, the third layer, the visualization layer consists of the (Automated Hydro Met stations) monitoring system and forecasted risk mapping dashboard which draws on the bases of historical and real-time data provided by the service layer to create a simple and unique dashboard with performance indicators that are essential to assist decision-making of several types of official agencies.

Warning dissemination could take advantage of new information and communications technologies (ICT) is used, which includes Internet and mobile services. Use of ICT for warning dissemination is, however, context specific, with consideration of available communication infrastructure, social culture, literacy, etc.

For ENTRO's FEW, dissemination to be more effective through proposallinkages with National Council for Civil Defense (NCCD) structures charged within floods dissemination and communication information and response mechanism illustrated in (Figure 6).

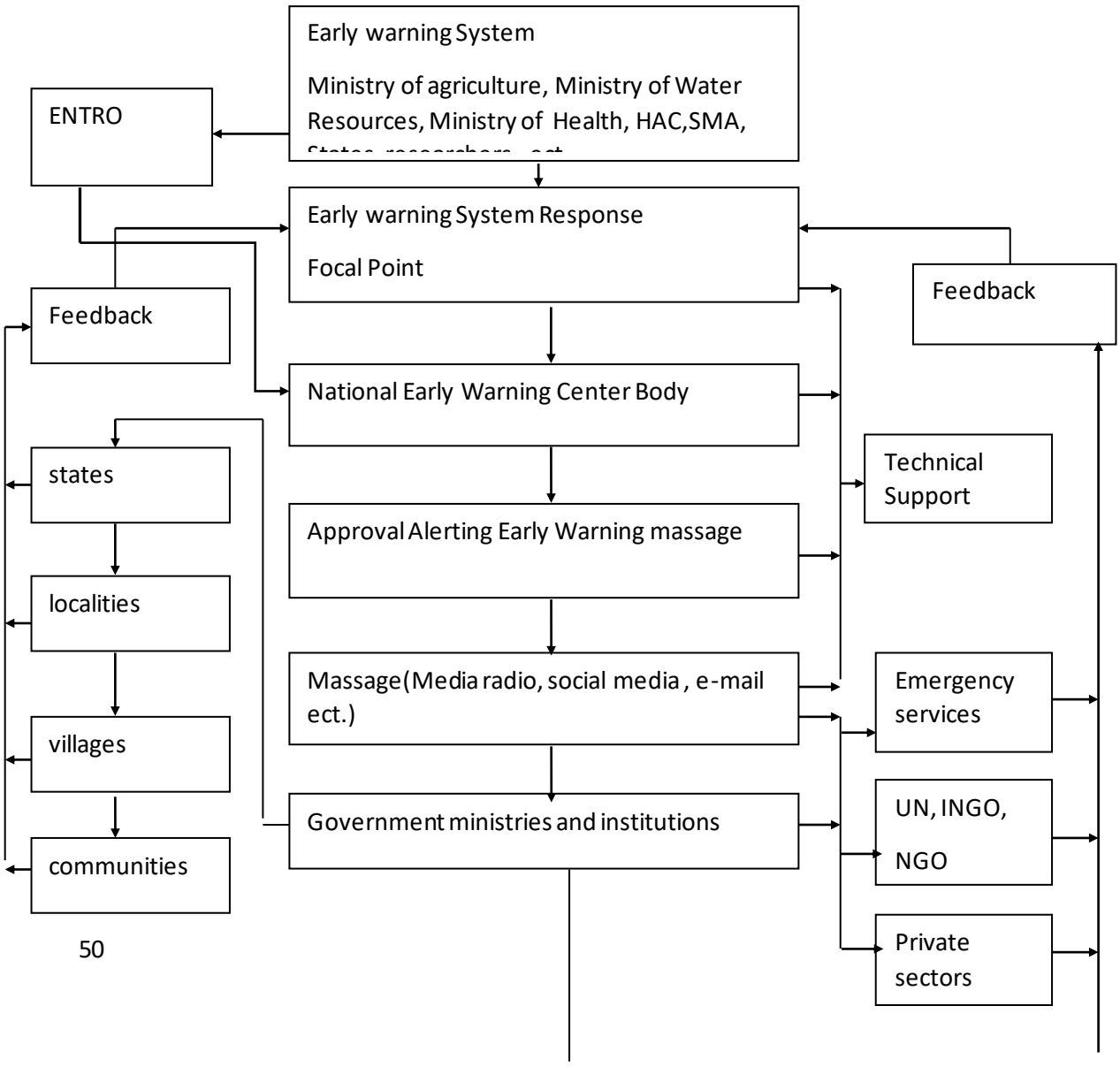
Central Body responsible for collection assimilation and dissemination of information in terms of issuing alerts when disaster is likely to occur, or when it has actually taken place, (this body exist and take action during 2019 flood).

Once information received of an imminent disaster or a disaster having occurred, Central Body generates alert massage/disaster warning to the concerned authorities.

Warning of impending, imminent or actual disaster situations may reach Central Body from various sources in a number of ways. Central Body confirms the exact position in this regard from the model officers of official sources/agencies before issuing Alert massages.

Upon receipt of weather warnings or reports of actual disasters, Central Body activates "call up actions".

Each disaster situation has different parameters in terms of severity, early warning and time available for response. Therefore, different stages for different events shall standardize for issuance of Alert massages.



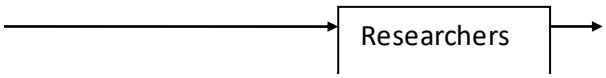


Figure 6: Proposal for ENTRO to linkages with NCCD structures charged within floods dissemination and communication information and response mechanism.

In Sudan practices related to indigenous early warning for both flash and riverinefloods are:

Flash flood

Heavy formation of clouds in the Northeast with Thunder (locally called Morbat Al Egil) during night (lielia) and during morning (Dahawia) =>forecasting heavy rain.

Low clouds moving rapidly from south-west to northeast =>forecasting flashflood.

Riverine floods

River water color turningmuddy, creation of foam in the waters=>forecasting flood.

The water in the river before the floods is very dirty and carrying timbers and trees sometimes carrying animals and the these show up its only a matter of time before the river flood this happen at River Atbara locally called (Crazy river).

Peoplecompare the label on trunks of trees labeled by pastyear floodand they can predict the new one (flood) when onset,where can extend on floodplain.

The traditional system being common to most communities “watch and warn” managed differently by adding more preparedness aspects.

Watch Component:

Large groups of frogs seen outside the mainstream of the river

Change in the color of the river water suggests the arrival of large quantities of water

Movement of insects like ants and mice with their young from one place to another.

Such traditional indicators vary from one community to another depending on the traditional inherited experiences in each community.

Warn Component:

The traditional warning in the communities varies from one area to another such as:

Traditional drums

Horn

Human voice (roray)

Depending what these sounding traditionally at the community level, the first sounding of, mean may indicate that communities should prepare, while a second one meant that they should evacuate.

CURRENT RESPONSE ACTIVITIES TO FLOOD EARLY WARNING

5.1Performance of Current Response to Flood Early Warning

From the interviews at the flood area, people seem to trust and give credence to the messages or information they receive directly from the ENTRO/MOWRE or any official warning (e.g. broadcast warnings, websites),

The statement send broadcast and direct provided to CD, HAC and SRCS as well as communities at risk (pilot areas). Once the warning reached CD and communities at risk they take action, for examples in 2019 flood CD evacuated people at flood risk areas (North Khartoum) as soon as it got the information.

The above performance did not fully cover the Nile and its tributaries, (e.g. Atbara River, Dinder and Rahad are out of the system of EWs,needto develop of inundation maps to support their rapid response of major flooding events).

5.2 Current strategies of coping with flood risks and adaptation mechanisms

Before flooding vulnerable people individually and collectively, develop their own means, resources and strategies to cope with flooding. To prevent or minimize the potential impacts from natural disaster occurrence in the future, the interviewees (Wad Ramly) were asked what preparations and plans their households were considering to counter the impacts of floods. Most of interviewee's respondents indicated that they rehabilitated flood diversion trenches around their houses. This was based on their perception that the impacts were only from flash flood from rainfall that life would return to normal after such disasters and they forget riverine flood. This finding indicates that some households in the community lacked confidence to depend on local government units for defensive strategies and actions to move them to high places, Table 10.

At individual household level people use of sandbags and tree logs; raised pit latrines and doorsteps; provision of water outlet pipes above plinth level; construction of embankments around wall, protection walls and elevation of house foundations

Immediate short-term strategies

During and after the 2019 flood, affected households received assistance from the government and friendship countries as well as NGOs like UNICEF, WHO, IOM, UNHCR and the WFP which played an important role in assisting most of the surveyed households. This assistance was mostly in the form of food and material aid. In addition, the government provided temporary shelters and tents in Wad Ramly villages, which used by most of the respondents.

In 2019 flood at Wad Ramly, while the people were staying in temporary shelters and tents, the government distributed new site residential lands in high places to people affected by the flood instead of their old site places located in the flood plain of the river.

Table 10: Planning of new places for the resettlement in 2019 flood

No	State	Number of villages to move	Number of villages moved
1	Blue Nile	8	0
2	Red Sea	1	0
3	Gadaref	67	0
4	River Nile	30	0

Long term strategies

Following the high floods of 1998, a decision taken by Sudan Federal government to resettle 190 flood prone villages that were located along the Nile and its tributaries.

The responsibility of implementing the plan left to the affected states. In each state, the Ministry of Physical Planning is the administrative body that plans the new settlements and demarcates areas for essential public services. Once plots allocated, it assumed, Ministries from the relevant sectors would construct essential service infrastructure. (Health, water, schools etc.). So far, the focus has been on settlement planning and there has not been an accompanying financial package to support costs of home construction and/or service provision. Some of the concerned communities have moved and started a new life in the designated areas but the vast majority did not leave their original areas.

Adaptation Measures/Strategies and Coping Mechanisms of Households and Community

An important question posed in this study was; "What adaptation measures/strategies were being implemented by the households, the community in general, and the local government units to address the impacts of flood risk disasters?" Household survey results (Table A2- 9) showed that majority of the respondents (70%) indicated having adaptation measures to address vulnerability, risk reduction, and coping mechanisms for flood disasters.

The top four adaptation measures/strategies implemented by many of the respondents included the following: Transfer of households to evacuation area temporarily (30%); restructuring of housing units to fit the new condition (20%), improvement of the dike system or canal near residence (20%), other respondents prepared their household needs and safety precautions (20%), changed their livelihood and sources of income (4%), and changed their land use to fit their new conditions (1%), (Table A2-10).

This finding indicates that some households in the community lacked confidence to rely on cooperative solutions or to depend on local government units for defensive strategies and actions. Another interesting finding was that the households' most preferred option of temporary relocation seemed to base on their perception that the impacts were only short-lived and that life would return to normal after such disasters.

In addition mentioned in chapter 3 in social indicator in this chapter also the households answer that in the rural floodplains, local residents have usually helped or worked together in order to mitigate flood damage to individuals and the local community. Local residents have helped each other to upgrade or build houses, flood-related means, dykes, roads or bridges this is one of good practice coping mechanism.

5.3 Proposal on how to improve the response to Early Warning

Need of capacityfor awareness on the use of ENTRO flood forecasting products, few stakeholders know how to use inundation map and forecast on digital numbers.

The Flood Early Warning System needs be extend to cover all the flood hazards (Main Nile, Atbara River, Dinder and Rahad) which will allow humanitarian agencies, individuals exposed to hazard of flood risk to take action to avoid or reduce their risk for effective response.

In order to strengthen the capacity of the community to response it is necessary to de al with Flood Task Force led by Government's Humanitarian Aid Commission (HAC), which coordinating and facilitating flood preparedness and response efforts.

The Task Force requires more response equipments such as hand mikes and medicines, life jackets, boats etc. Regular tests, training and drills undertaken to ascertain the readiness of the warning systems and response mechanisms.

Evacuation routes and shelter zones jointly identified by the Task Force and communities with help of MENRU, and subsequently equipped with first aid facilities, water and sanitation, relief materials and communication facilities needed during the flood disaster.

6. INSTITUTIONAL ARRANGEMENTS FOR EWS

Since 2010, the implementation of FPEW phase (I), important institutional changes have created new roles and responsibilities for flood early warning in Sudan. The Ministry of Water Resources and Irrigation would have oversight on flood forecasting and early warning system through the national flood center and ENTRO, Figure 7.

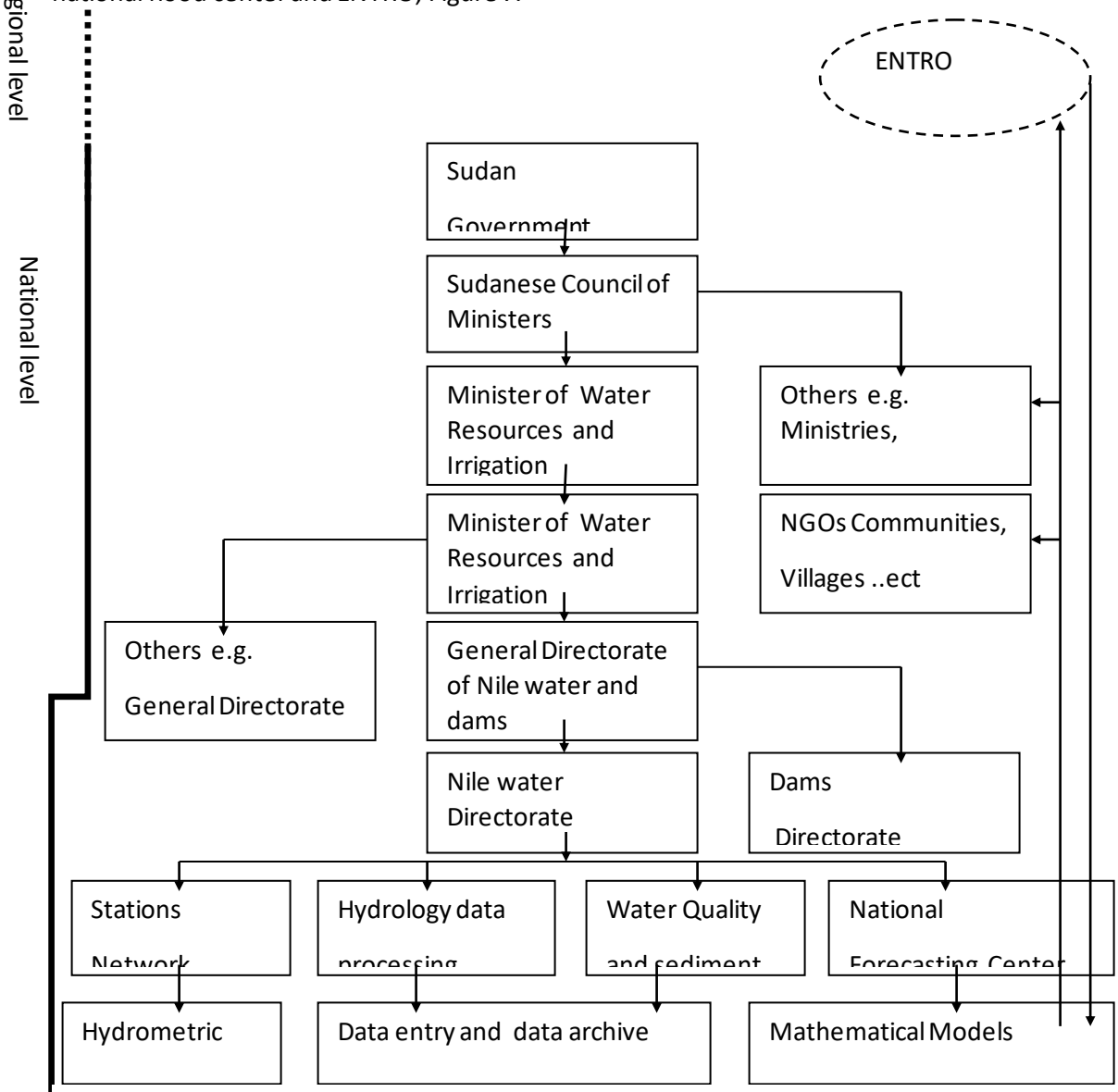


Figure 7: EWS governance arrangements

Institutions and their roles

The findings indicated that multiple institutions are involved in disaster risk reduction in Sudan but their roles, inter-relationships, coordination mechanisms, and accountability arrangements are overlapped or most organizations have multiple roles Table 11.

Table 11, provides most roles and functions of different organizations in disaster risk management in Sudan, Most of the activities in disaster risk management are being undertaken

by multiple organizations with overlapping roles and responsibilities; 10 of the 13 organizations were involved in coordination; 10 in providing technical support, and 10 in implementation, while only six were involved in formulating policy and strategy frameworks. The policy and strategy related activities mainly carried out by central level government organizations, and implementation by local NGOs and community-based organizations, supported by INGOs and national NGOs.

In fact the overlap of roles in the activities through institutions is not typical it is depend on the mandate of the institutions, e.g. research with regard to flood in ministry of water is different with research in ministry of health.

There is an ongoing regional effort through the ENTRO to improve FEWS and national efforts by National disaster risk reduction committee to strengths disaster risk reduction in Sudan, and propose institutional arrangements for effective implementation. However, at present, there is no comprehensive or systematic documentation specifically for flood early warning systems at the different levels (community, district, and national) that describes institutional roles, structures, systems, and practices, or overall architecture.

6.1 Gaps in the current institutional setup at Regional and National Level

Top-down institutional arrangements (Figure 4) generally refer to a decision-making process that starts at the constitutional-choice level (national) and goes through the collective-choice level (regional/national) to the operational level (local) the gap is one-way no feedback from FEW responses.

So need of bottom up or lateral (collaborative) is vital, local stakeholders and communities, with a focus on intervention, problem identification, strategy formulation and implementation, may lead Bottom-up arrangements.

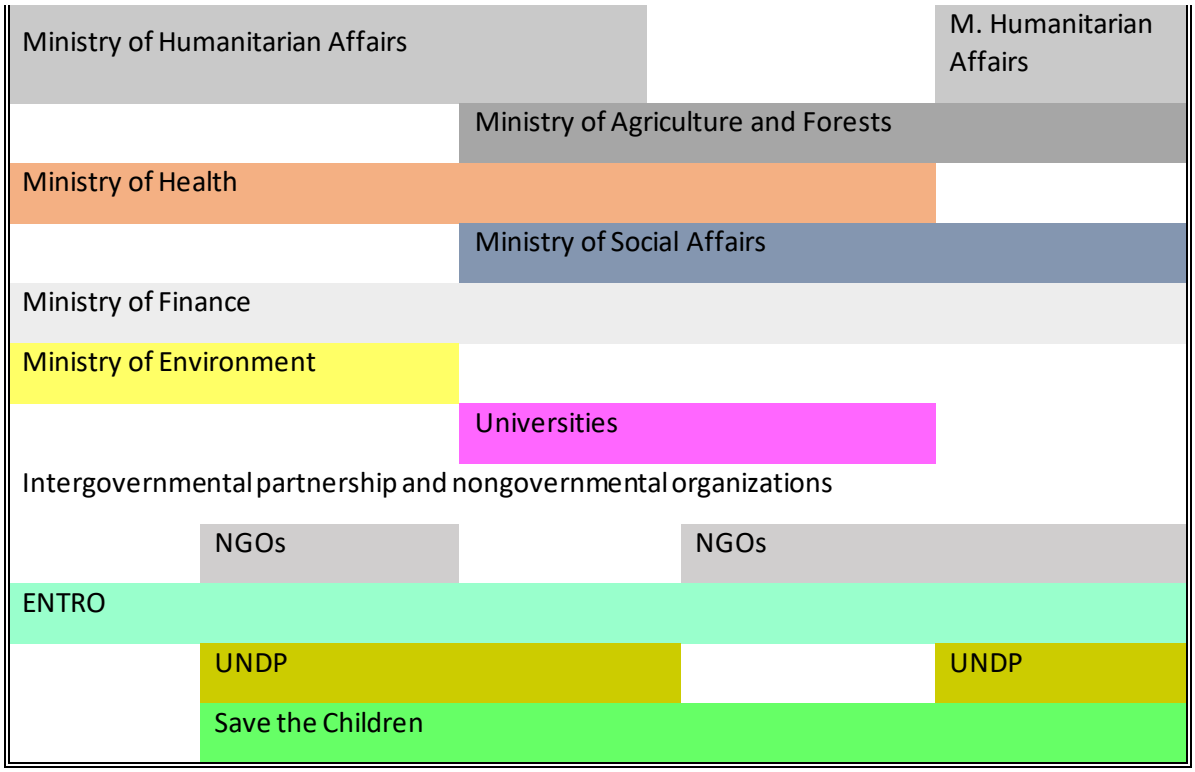
At the communities, level there is a gap in terms of capacity to respond to warning information if they receive it.

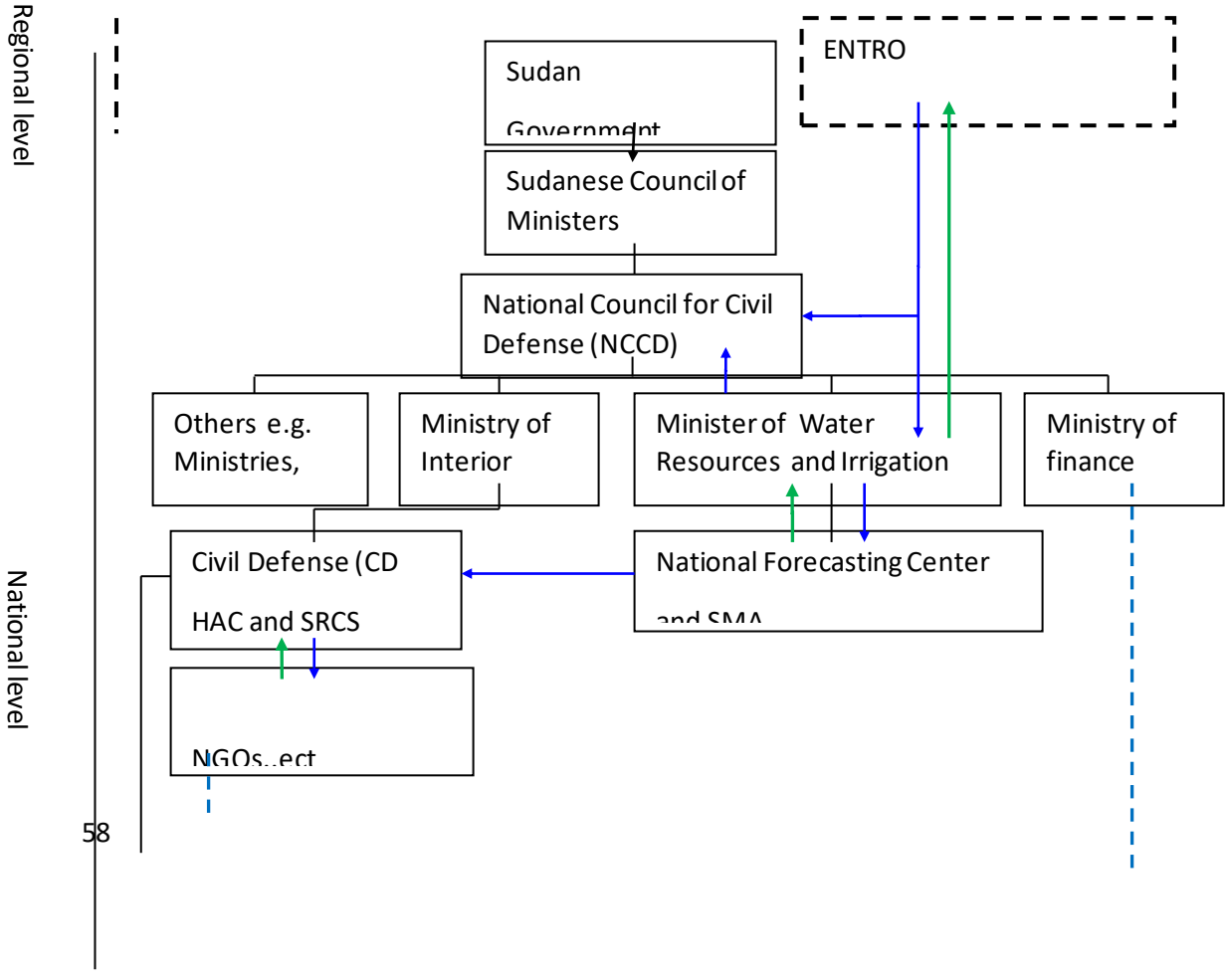
6.2 Proposed setup for an effective Flood Early Warning System Level

The new proposal structure distributes power and resources to sub-national and local levels (urban and rural municipalities), offering an opportunity to improve all components of floods EWS in Sudan. This section reviews the roles and responsibilities of, and coordination between, the government and NGOs, and offers suggestions regarding how EWS can improve under the new proposal structure. Roles and responsibilities assessed at the national, states and local levels – in the Blue, Main and Gash river basins – including the role of NGOs in developing community-based EWS. (Figure 11) and (Figure 8).

Table 11: Roles and functions of different organizations in disaster risk management

Policy	Coordination	Research	Technical support	Implementation
Ministry of Irrigation; Water Resources and Electricity				
Ministry of Interior			Ministry of Interior	


Ministry of Humanitarian Affairs
M. Humanitarian Affairs
Ministry of Agriculture and Forests
Ministry of Health
Ministry of Social Affairs
Ministry of Finance
Ministry of Environment
Universities
Intergovernmental partnership and nongovernmental organizations
NGOs
NGOs
ENTRO
UNDP
UNDP
Save the Children


Regional level
National level
ENTRO
Sudan Government
Sudanese Council of Ministers
National Council for Civil Defense (NCCD)
Others e.g. Ministries,
Ministry of Interior
Minister of Water Resources and Irrigation
Ministry of finance
Civil Defense (CD HAC and SRCS
National Forecasting Center and SMA
NGOs..ect

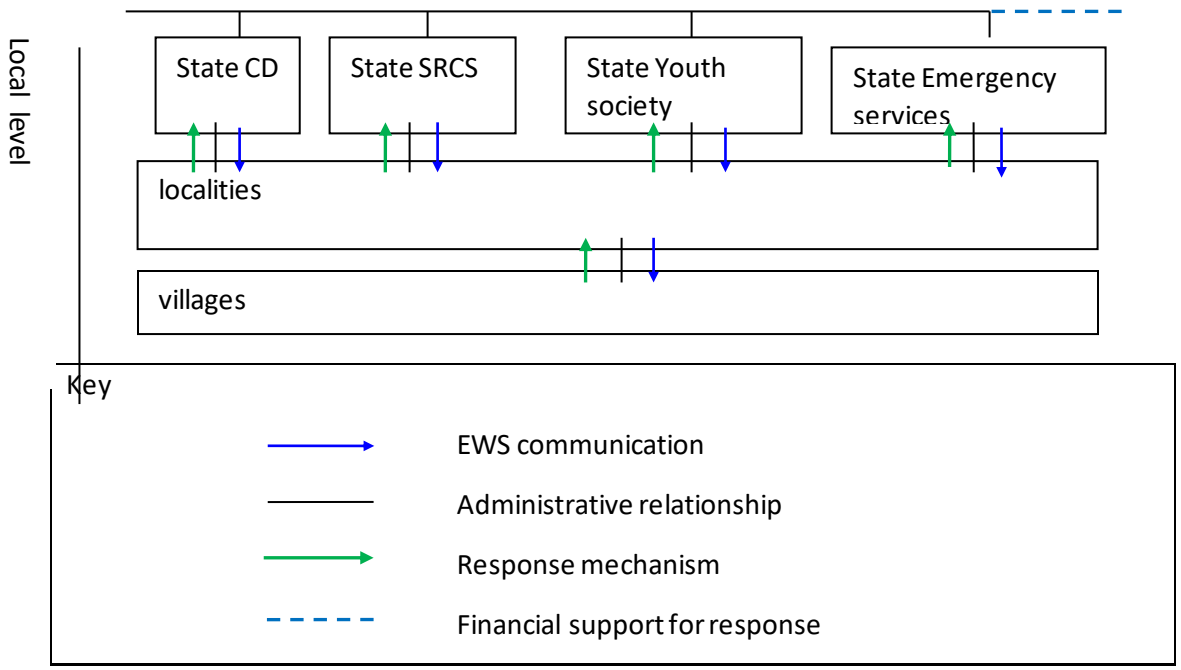


Figure 8: Proposed setup for an effective Flood Early Warning System Level

7. CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

In order to enhance ENTRO FEWS,stakeholderswere mapped through individual interviews approach to find out forecast providers and users, analyse stakeholders mandate, gaps,response activities and communication methods for flood early warning.

ENTRO,was found to be mainly involved in forecast provision in Sudan, however it doesnot cover Atbra River, Dinder and Rahad, it is also not addressing the issues of flash flood in the basins,with more than 5 million inhabitants.

ENTROFFEW products, makesMOWRIE flood forecast warning development better, nevertheless there some barriers to accessing ENTRO's warning forecasting information due to low internet access and insufficient information on its websites/dashboard, in additionto its EW frequency of warning and lack of communication skills on ENTRO models products.

ENTRO, during of FEWP phase (I) through the community action plan, the communities learnt from it and develop their own preparedness andare so far ready torespond. Still there is a challenge for those not covered by ENTRO's FEWs as they lack thecapacity.

MOWRIE, mandateis improveriver-monitoring system, also release of warning and ensuring that warning massage reached everyone in the community and shared across multiple actors, however there is no institutionalized feedback mechanisms to evaluate whether warning massage accessed, understood or used.

MOWRIE, multiple institutions are involved in disaster risk reduction in Sudan but their roles, inter-relationships, coordination mechanisms, and accountability arrangements are overlapped, or most organizations have multiple roles.

It is apparent from flood prone areas map and settlement map. There are 2900 villages within 15 km radius of the riverbank that are directly exposed to floods.

Sample of household study shows that vulnerability to urban and rural flooding or any other hazard must not treated as a single entity, but rather as a composition of social, economic, physical/infrastructural, institutional, and attitudinal factors, and proposesa multidimensional model to measure vulnerability.

Sample of household survey shows the fact that these households live in floodplains makes them more susceptible to high flood impacts. Moreover, these households highvulnerable to economic dimension and veryhigh vulnerable to physical/ infrastructural and attitudinal dimensions.

Community level surveys in Sudan revealed that at least 7 days lead time is required to save livelihood assets from flood disaster, however long lead time the less accurate.

Popular mechanisms employed by households to mitigate the impact of floodswere:

Seeking relief materials from the Government and other agencies, constructing flood diversion trenches to protect villages form torrents and moving the effected households fromflood prone areas to safer upland.

Adaptation measures and coping mechanisms of Households and Community, households in the community lacked confidence to rely on cooperative solutions or to depend on local government units and preferred option of temporary relocation than permanent.

7.2 Recommendations

MOWRIE/EN countries, need to upgrading existing manual record stations to make them automatic stations (hydro met) and increasing the spatial density of stations, to feed into national centers, as well as appropriate stations feed to regional center that can provided a good data base and consequently improve flood forecasting and early warning systems.

ENTRO is encouraged to established/enhance such models system to be like Toolkit of FFEW in trans-boundary river basins or a system or modelling chain that includes meteorological, hydrological and hydraulic models that are accurately linked to enable the production of warnings and forecast, using appropriate modelscovering all the major river basins in the EN region. This will enables to use flood-forecasting online flood hazard risk map with 90-meter resolution and a 25 up to 300-year return period to be establish for the region.

MOWRIE/ENTRO, need to provide regular, tailored training and capacity building for users, responders and community members on ENTRO FFEWs products and what to do when they receive warning information and send feedback to the centers.

ENTRO needs to improve warning dissemination and take advantage of new information and communications technologies (ICT), which includes Internet and mobile services may be solve problems of unexpected communication channel breakdown e.g. low internet access.

MOWRE, needs to strengthen the capacity of the community to response is necessary deal with Flood Task Force led by Government's Humanitarian Aid Commission (HAC), which coordinating and facilitating flood preparedness and response efforts which include NGO.

MOWRIE/ENTRO, need of bottom up approach. It needs to intensify visits to flood-affected people and adopt their ideas to solve the flood problem and cooperate with the relevant authorities to reach a plan to reduce flood damage. Feedback from bottom is important is vital, local stakeholders and communities, with a focus on intervention, problem identification, strategy formulation and implementation, may lead bottom-up arrangements.

To make the flood awareness more official and responsible its better ENTRO FFEWs products, can disseminationthrough Committee for Flood Control (decision maker) of Ministry of Irrigation and Water Resources (MoIWR),which has direct link to the National Council for Civil Defense (NCCD), This integrated flood forecasting system and dissemination system of MoIWR and NCCD also has many links to the stakeholders and communities levels.

Need to launch awareness campaigns and design risk communication strategies to enhance the flood risk perceptions of the communities and engage the local institutions with the communities to implement disaster risk reduction plan effectively.

Need of build confidence between local government units and households in the community for such solutions of defensive strategies and actions concerning floods early warning (households and community need to be involved in such process and development).

References

Abdalla, A.K. (2003). "Evaluation of the Sudanese experience in rainfall seasonal Forecast". Workshop on the use of meteorological data in disaster control. Sudan Meteorological Authority. Khartoum, Sudan.

Abdel Ati Hassan (2005); A Baseline Social Survey Report – Sudan. Khartoum and Addis Ababa: MoIWR/Sudan and Eastern Nile Technical Regional Office/ENTRO, Ethiopia.

Abdel Ati Hassan (2009), Enhancing Voluntary Resettlement in SUDAN, A Report for Flood Preparedness and Early Warning Project (FPEW-I) Nile Basin Initiative (NBI)

Civil Defense report"Flash flood impact", 2018 floods.

Consultancy Service's report"Flood early Warning Survey in Sudan", Project April NBI - FPEW, 2010.

Consultancy Service's report "Peak Season Community Surveillance in Sudan", Project NBI - FPEW, July 2010.

Deltares, (2015), Final Report: Mobile Services for Flood Early Warning in Bangladesh.

EC, 2003. EU Best Practices Document on Flood Prevention, Protection and Mitigation. Available online at: http://ec.europa.eu/environment/water/flood_risk/pdf/flooding_best practice.pdf.

ANNEXURES

Annex 1-1:List of persons and institutions met

	Name	Email	Telephone	Job / Institution
1	Dr. Balla Ahmed Abdelrhman Shaheen	ballashaheen1@yahoo.com	+249 91 269 3455	General Director of Nile Water and Dams Affairs (Nile TAC member) / MoIWR
2	Dr. Salih Hamad	Shhomer@gmail.com	+249 91 269 1468	Head of the Technical Organ for Water Resources/ MoIWR
3	Eng. Abdelrhman Sagairon	a.saghayroon@gmail.com	+249 123 494 480	Director for Nile Water/MoIWR
4	Eng. Ahmed El Tayeb Ahmed	aeltayeba58@yahoo.com	+249 123 348 972	Director for Dams /MoIWR
5	Dr.Ahmed Abdelkarim	ahmed.akarim2010@gmail.com	+249 91 292 8619	Director-General for Sudan Metrology Authority (SMA)
6	Gasim Musa	gasim1_78@yahoo.com	+249 12 140 1745	Sudan Metrology Authority (SMA)
7	Major General. Abubakar Sayed Ahmed	cdga@nccd.gov.sd	+249 91 220 5001	Secretary General of the Secretariat of Civil Defense/NCCD
8	Pilot officer. Hosham	cdeias2016@yahoo.com	+249 91 814 0652	Civil Defense/CD
9	First lieutenant. Hassam	yousrimoh3@gmail.com	+249 12 276 9013	Civil Defense/CD
10	Prof. Kamaluddin Bashar	basharke@gmail.com	+249 99 1919194	Dean of the Faculty of Engineering, Islamic University of Omdurman

11	Rahama Mohamed Ibrahim	rahamamohamed@yahoo.com, rahama@srcs.sd	+249 91 2613410	Sudanese Red Crescent Society (SRCS)
12	Yaser Hashem	sewsusu@gmail.com		Head of Early Warning center/HAC
13	Hafsa Ahmed	hafsareal@gmail.com	+249 91 2895077	Early Warning center/HAC
14	Ghada Nasreldeen	nasreldeen@un.org	+249 187 123 110	UN/Sudan
15	Hanan Mutwakil	hanan.mutwakil@undp.org	+249 187 123 110	UNDP/Sudan
16	Ms/Sawsan Khair Elsied	Sawsanatkh2yahoo.com	+249 91 255 9438	Director-General/MLF
17	Osama Abdalla	oaraby@gmail.com	+249 12 702 0301	Communities representative

Notice: A few managers mentioned above during interviews, I deal with level below them or available person in the place.

Annex 1-2:Key stakeholders contacted

	Name	Telephone	Institute
1	Al zamzmy Othman	0916818869	Wad Ramly
2	Mobark Mohammed		Wad Ramly
3	Awad Abdel Monem	0911213607	Wad Ramly
4	Khalid Mohammed Abdelgalil	0918199841	Wad Ramly
5	Altaype Mohammed Madani	0128439770	Wad Ramly
6	Ala Eldin Abdelhab Mohammed	012430020	SRCS
7	Abo Bakar Othman Mohammed	0912232525	SRCS
8	Majda Abdela Mohammed	0923400988	SRCS
9	Amna Owad Gaber	0922568946	SRCS
10	Major General. Abu-Bakr Saied Ahmed	091 220 5001	NCCD
11	Pilot officer. Hosham	091 814 0652	CD
12	First lieutenant. Hassam	012 276 9013	CD
13	Dr. Ahmed Suliman	0912243464	U of K
14	Fattma Yousuf	0122769013	Ministry of physical planning
15	Nagla Ginawi	0912220143	Ministry of Agriculture
16	Bader Adam	0912390965	NCCD
17	Mohammed Ahmed	0922253773	NCCD

Annex 2:Check list questions

Interview questions platform for expert group

Name			
Sex:		Qualifications	
Years of Experience		Job Title	
Organisation		Group	expert

Q1.	How many flood events have you encountered? And at what times? Were these events occurring ?
Q2.	What are the flood-prone areas in the Sudan? and what is the reason?
Q3.	What are the main valleys in the Sudan causing flash flood?
Q4.	Where are these valleys passing through?(i.e. residential, agricultural, economic areas). What will be doing to prevent flood water from coming to residential areas? What problems did you encounter in your bid to ensure that floods do not overwhelm households? How do you think these situations could be improved?
Q5.	These valleys constitute a major factor in flood occurrence in the local, through your experience, how do you explain that?
Q6.	Floods mainly leave casualties or damages; can you talk about these damages?
Q7.	When floods occur, preventive measures have to be taken to reduce the floods risk, what are these measures?
Q8.	What measures or tools does Ministry of water resource and irrigation adopt to mitigate flood risk?
Q9.	What measures do the people adopt at property level? Do they over rely on regional measures?
Q10.	Is there a periodic review for these measures and improvement as appropriate need? What authorities are involved in this? Are there any joined up activities between different authorities and agencies?

Q11.	Ministry of Water Resources and Irrigation plan to deal with the flood risk (that may be annually reviewed) is an important component, of disaster risk management plan, how does (should) Ministry of Water Resources and Irrigation coordinate with concerned parties (within contingency plan) to reduce flood risk, such as civil defence, Ministry of Humanitarian Affairs, Sudanese Red Crescent …etc.?
Q12.	How does Ministry of Water Resources and Irrigation and/or civil defense are assess (should assess) the damages due to flooding? What are the processes followed?
Q13.	Is there specific policies relating to floods in your organisation? What is the Flood Early Warning System (FEWS) from your point view? How soon should the early warning be received for it to be meaningful? And what are the factors important for effecting FEWS?
Q14.	What are the main components of the FEWS?
Q15.	How would a FEWS be an effective system and helps mitigating floods impacts?
Q16.	FEWS that be established in Minstry of Water Resource and Irrigation, rigional at ENTRO, to whom it should be directed? Local communities, local government(MOWRE) , different stakeholders …etc. How do they perform their function; how many warnings have they issued or transmitted in the recent past? What is the content of their warning? Is it enough and understandable? Do they issue both riverine as well as flash flood or only riverine? Which actionable information would they like to get from ENTRO to support the issuing of the (flood) early warning? What support are they comfortable giving to ENTRO to support the regional early warning?
Q17.	How could locals be aware of the actions that they have to do in case of flood?
Q18.	How do these systems (FEWS) deal with the nature of flash floods, such as suddenness, unpredictable?
Q19.	What are the current modelling methods (in Sudan) related to floods?
Q20.	What are the current early warning systems related to floods?
Q21.	What is the level of communication and interaction between your orgaisation/institute and other agencies to achieve your goals?

Interview questions platform for users group

Name		Group	Users
Education		Sex: a) M b) F	
Occupation		Age	
Village/ region		Years of experience	
		Monthly Income (Average)	

Q1.	How long have you been living (here the name of region----------)?
Q2.	How many flood events have you encountered? And at what times? Were these events occurring when in specific place?
Q3.	What are the flood-prone areas in the region? And what is the reason?
Q4.	How the flooding, according to your perspective, affected the pepole and economic activities of the area?
Q5.	What are the impacts of floods in the region (infrastructure, public and private properties …etc.)?
Q6.	Have there been any casualties in the past due to the floods? When? How many was the number of deaths in each event?
Q7.	When did you think the casualties were the highest and why?
Q8.	What type of early warning system is in place in this locality? How does it function? Who owns it? How does it sustain? Any committees to manage it? Are there clear roles and responsibilities of the committee for flood contral (MoWRIE)?

Q9.	Is there a cooperation and coordination between regional, government institutions, local community and community-based organisations to reduce flood risk? What is the nature of this cooperation and coordination?
Q10.	Are the local citizens aware of the actions to follow in case of flooding? What independent measures do they adopt?
Q11.	From whom do they seek more information? Are you happy with this information and what adjustments are needed?
Q12.	Are there any community awareness and training programmes on early warning on flooding?
Q13.	Who in your opinion should train you or make more awareness? How many times did you attend such trainings? Have you participated in any meetings related to flood management? How many times have you attended such meetings? Who (department/office) organized the meetings?
Q14.	What is the best way to inform you about a flood according to your opinion?, e.g. Radio-Television- Through mobile Phone. Why do you think that it is effective?

Annex 3: Household Vulnerability Index Analysis

The subjective weighting technique to allocate values to classes of phenomena for each indicator and formulates indices based on Eq. 1.

CI = (W1+W2+W3+…Wn)/n = $\sum_{i=1}^{n} w_i$ /n---------- (1)

Where, CI is the composite index, W1 to Wn are respective transformed values assigned to indicators, and n is the number of indicators used for computing the composite index.

Following this general principle, the Social Vulnerability Index (SI), Economic Vulnerability Index (EI), Physical/ Infrastructural Vulnerability Index (PI), Institutional Vulnerability Index (II), and Attitudinal Vulnerability Index (AI) were calculated.

The Multidimensional Vulnerability Index (MVI) for each household in the study area calculated using Eq. 2.

$$\text{Social Vulnerability Index (SI)} = \sum_{i=1}^{4} \frac{SW_i}{n} \qquad (n = 4)$$

$$\text{Economic Vulnerability Index (EI)} = \sum_{i=1}^{4} \frac{SW_i}{n} (n = 4)$$

$$\text{Physical/ Infrastructural Vulnerability Index (PI)} = \sum_{i=1}^{4} \frac{SW_i}{n} (n = 4)$$

$$\text{Institutional Vulnerability Index (II)} = \sum_{i=1}^{4} \frac{SW_i}{n} \qquad (n = 4)$$

$$\text{Attitudinal Vulnerability Index (AI)} = \sum_{i=1}^{4} \frac{SW_i}{n} \qquad (n = 4)$$

$$\text{Multidimensional Vulnerability Index (MVI)} = \frac{SI + EI + PI + II + AI}{5} \qquad (2)$$

The original values of the indicators have transformed to 0–1 based on the vulnerability level, for computing the indices. The values closer to

Zero signifies low vulnerability, whereas values closer to one denote high vulnerability. Each variable further divided into classes depending on its characteristics:

For example, nature of response divided into two classes (yes or no response), three classes, four classes, and five classes, as required. With literature support, these classes framed to demonstrate the degree of variation, as much as possible, in that particular variable. In dual classes, the values were zero and one. The indicators with three classes assigned the values 0.33, 0.67, and 1; for four classes, the values were 0.25, 0.50, 0.75, and 1; and for five classes, the values were 0.2, 0.4, 0.6, 0.8, and 1. Thus, the composite index for each component fell between zero and one. Table A3-1 lists the indicators used for the different dimensions, the classes and values, and the empirical studies that have used these indicator

Table A3-1 Social vulnerability indicators and transformed values for dimensions of vulnerability.

S.No	Indicators	Classes	Transformed values	Frequency	Percentage(%	Explanation
1	Family type	Extended	0.33	34	68	The extended family type will have morestrength in number, and have moreaccess to societal resources
		Middle	0.67	11	22	
		Single	1	5	10	
2	Household that includes family members with chronic illness/pregnancy or disability	0	0	43	86	Household with special needs will belimited in its mobility in case ofemergency.
		1	0.33	7	14	
		2	0.67	0	0	
		> 2	1	0	0	
3	Household living incommunity (in years)	>40	0.2	29	58	Household residing for shorter time maynot be aware of evacuation routes andemergency protocols.
		30-40	0.4	10	20	
		20-30	0.6	6	12	
		10-20	0.8	4	8	
		<10	1	1	2	
4	Household having past experiences with floods	Yes	0	42	84	People with previous encounters withfloods can foresee issues and problemsthat could faced.
		No	1	8	16	

Table A3-2 Economic vulnerability indicators and transformed values for dimensions of vulnerability.

S.No.	Indicators	Classes	Transformed values	Frequency	Percentage (%)	Explanation
1	Dependency ratio(dependents to totalhousehold size)	< 0.25	0.2	4	8	Infants, children, and the elderly will bemore vulnerable than young personsand adults, because of limited mobilityand dependency
		0.25-0.5	0.4	6	12	
		0.5-0.75	0.6	16	32	
		0.75-1	0.8	15	30	
		>1	1	5	10	
2	Livelihood options of thehousehold	0	1	15	30	Multiple sources of livelihood will Decrease vulnerability.
		1	0.67	30	60	
		>1	0.33	5	10	
3	Average monthly household's income (SDG)	<1,500	1	20	40	Lower income results in higher vulnerability
		1,500- 4,999	0.8	15	30	
		5,000-9,999	0.6	7	14	
		10,000-19,999	0.4	5	10	
		>20,0000	0.2	3	6	
4	Household residing in rentedhouses	Yes	1	10	20	Tenants on rent cannot repair, fortify their buildings against floods
		No	0	40	80	

Table A3-3 Physical/infrastructural vulnerability indicators and transformed values for dimensions of vulnerability.

S.No	Indicators	Classes	Transformed values	Frequency	Percentage (%)	Explanation
1	Location of the house	Between trench andriverbank	1	34	68	Low elevation and proximity to floodhazard source will increasevulnerability
		Floodplain	0.67	10	20	
		Upland	0.33	6	12	
2	Building type	Galosse (constructed from mud)	1	24	48	Type of materials used for constructionwould affect structure. Galosse and Agad laybylocalterminologies fordescribing strength of buildingmaterials used
		Agad layby (mud, brick)	0.67	16	32	
		Great beam (Brick,Cement)	0.33	10	20	
3	Building age (in years)	<10	0.2	5	10	Old houses will be structurally weaker and make household more vulnerable
		10-20	0.4	13	26	
		20-30	0.6	22	44	
		30-40	0.8	5	10	
		>40	1	5	10	
4	Household means of communication	Yes	0	40	80	Household with no access to means ofcommunication will be morevulnerable
		no	1	10	20	

Table A3-4 Institutional vulnerability indicators and transformed values for dimensions of vulnerability.

S.No	Indicators	Classes	Transformed values	Frequency	Percentage (%)	Explanation
1	Warning about last floods received by the household	Yes	0	36	72	Household that did not receive warningin last flood, indicates institution'sinefficiency
		No	1	14	28	
2	Household's level of understanding national warning system	Very high	0.2	12	24	Household that does not understand national warning system, represents enable of institution to convey properearly warning.
		High	0.4	18	36	
		Moderate	0.6	10	20	
		Low	0.8	5	10	
		Very low	1	5	10	
3	Household's awareness regarding emergencyshelter	Yes	0	40	80	Lack of awareness of household showsincapacity of institutions
		No	1	10	20	
4	Availability and circulation of emergency plans.	Yes	0	35	70	No circulation ofemergency plans by institutions mayincrease household vulnerability
		No	1	15	30	
5	Household's knowledge ofemergency protocols regarding floods	Very poor	1	5	10	Household not understanding local authority's emergency procedures will be more vulnerable
		Poor	0.75	10	20	
		Average	0.5	25	50	
		Good	0.25	10	20	

Table A3-5 Attitudinal vulnerability indicators and transformed values for dimensions of vulnerability.

S.No	Indicators	Classes	Transformed values	Frequency	Percentage (%)	Explanation
1	Community cooperation indisaster response	Very poor	1	2	4	Cooperation strength represents community attitudes and social networking towards helping each other and coping with floods
		Poor	0.8	5	10	
		Average	0.6	23	46	
		Good	0.4	10	20	
		Very good	0.2	10	20	
2	Household believing in possibility of future occurrence of floods	Low	1	35	70	Household not believing in flood likelihood might be more vulnerable
		Moderate	0.67	10	20	
		High	0.33	5	10	
3	Household feeling afraid offlood	Not afraid	1	10	20	Household not feeling afraid of flood willnot seek preparedness measuresagainst future flooding, and might bemore vulnerable
		Neutral	0.67	25	50	
		Afraid	0.33	15	30	
4	Community having land use/zoning laws and household following them.	Yes	0	40	80	Household not following urban planningregulations will be more vulnerable
		No	1	10	20	

Table A3- 6 Multidimensional vulnerability to floods prone areas in Wad Ramly community, (HHs = Households; n = 50)

Dimension vulnerability	Vulnerability increase from Very low to very high	Descriptive statistics

	Class	Very low	Low	Moderate	High	Very high	Total	
	Range	<0.25	0.25-0.49	0.50- 0.74	0.75-0.99	> 1		Min = 0.05
Social	No. of HHS	28	13	4	1	4	50	Max = 1.00
	%	56	26	8	2	8	100	Mean = 0.4
	No. of HHS	12	4	13	8	13	50	Min = 0.10
Economic	%	24	8	26	16	26	100	Max = 1.00 Mean = 0.45
	No. of HHS	11	7	12	1	19	50	Min = 0.05
Physical/ infrastructural	%	22	14	24	2	38	100	Max = 1.00 Mean = 0.4
	No. of HHS	24	6	7	3	10	50	Min = 0.04
Institutional	%	48	12	14	6	20	100	Max = 1.00 Mean = 0.34
	No. of HHS	13	8	15	1	14	50	Min = 0.05
Attitudinal	%	26	16	30	2	28	100	Max = 1.00

							Mean = 0.4
Total	8	18	10	3	12	50	

Table A3-9 Adaptation measures/strategies implemented by households to minimize the impacts of flood risk, Wad Ramly, 2019

Household with Adaptation Measures	Frequency	Percentage (%)
Yes	35	70
No	15	30
Total	50	100

Table A3-10: Adaptation Measure/Strategy

Adaptation Measure/Strategy	Frequency	Percentage (%)
Relocate residence to a safe place permanently	2	4
Transfer to an evacuation area temporarily	15	30
Restructure housing unit	10	20
Improve dike system or canal near residence	10	20
Change land use to fit new condition	1	2
Change livelihood and sources of income	2	4
Prepare household needs and safety precautions	10	20
Total	50	100