Flood Risk Assessment and Forecasting Tools Brief

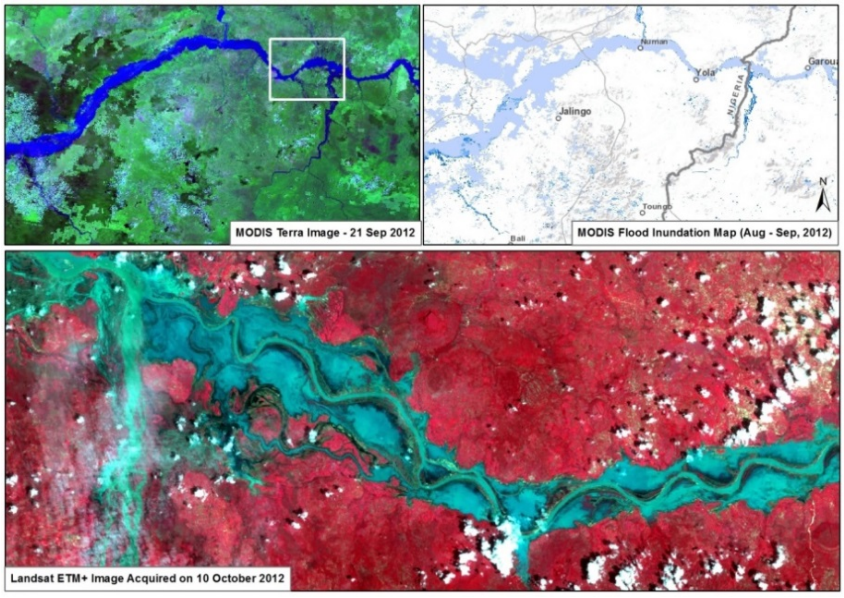
Turning tragedy into an opportunity: Water management solutions for flood-recession and dry-season agriculture in Nigeria

Extreme weather events, such as the floods witnessed in Nigeria in 2012, are becoming more frequent. The widespread devastation to lives and property and significant impairment of agricultural activities often caused by flooding can be mitigated through adequate flood planning and management.

Floodwater is used successfully for agricultural production in many parts of the world. Mostly this is done where farmers have developed methods to cope with and take advantage of flood events. Considering the large areas of land in Nigeria that experience annual flooding there appears to be huge potential to further develop effective and productive flood-based farming systems, known as flood-recession agriculture. However, the important linkages between the productive cultivation of this annually flooded land and the area's hydrology have not always been studied sufficiently in-depth.

The overall aim of this component of the project is to reduce the risks posed by flooding through accurate forecasting systems and mitigation plans, including putting floodwater to productive agricultural use. Through improved flood planning and response, the negative social, economic and environmental impacts of future flood events, particularly in the agricultural sector will be reduced. A number of interrelated activities will be conducted including:

1) Assessment and analysis of flood inundation and recession patterns over time;
2) Identification of locations and economic activities at particular risk of future flood events;
3) Development of early warning flood forecasting tools;
4) Development of flood incidence and soil moisture maps to indicate areas that are suitable for flood recession agriculture.



Flood inundation mapping along the Benue River (Nigeria) using MODIS and Landsat Satellite images (IWMI)

CGIAR RESEARCH PROGRAM ON Water, Land and Ecosystems

Led by: IWMI International Water Management Institute

Research methodology

There are three steps in the work envisaged in this component of the project.

1. **Identification of flood recession areas using the National Aeronautics and Space Administration's (NASA) Moderate Imaging Spectroradiometer (MODIS) time-series images**
2. **Development of flood forecasting tools using hydrological and hydraulic modeling systems**
3. **Radar altimetry: flood forecasting rating curves, comparing upstream to downstream in the Niger-Benue River basin**

The three activities are interrelated and complimentary. Identifying areas suitable for flood recession agriculture (step 1) will enable farmers and other decision-makers to plan and develop policies and initiatives that make the most of the opportunities for dry-season and flood recession agriculture that these bring. The flood forecasting tool based on rainfall-runoff modeling and hydraulic processes (step 2) enables flood extent prediction (depth and duration) on a daily basis enabling appropriate decisions and steps to be taken in real time. The flood forecast rating curve (FRC) tool (step 3) can be used to provide early flood warnings (flood levels) within a longer time frame (up to several days) enabling significant mobilization to avoid loss of life and mitigate significant damage to property.

Step 1: Identification of Flood Recession Areas using MODIS time-series Images

In this study, time series images of MODIS Terra/Aqua datasets (product "MOD09A1", from years 2000 - 2013), will be used to assess the historical patterns of flooding and to identify flood prone areas. These images are 8-day composite data at a 500m resolution. Compositing involves compiling daily images over an eight-day period and selecting pixels of the highest quality based on a combination of low view angle, the absence of clouds or cloud shadow, and levels of fine solid or liquid particles, often from pollution, (aerosols) present in the air. In general, this process reduces interference from cloud cover and sensor aberrations, resulting in improved image quality. However, the trade-off is the possibility of missing inundation caused by rapidly changing flood events.

To ensure accuracy of the data, the MODIS dataset will be evaluated using the Landsat Thematic Mapper (TM)/ Enhanced Thematic Mapper (ETM) (Optical) and Environmental Satellite (ENVISAT) Advanced Synthetic Aperture Radar (ASAR) or RADAR Observation Satellite (RADARSAT) (microwave) images. The Landsat TM/ETM+ images (at 30 m resolution) will be acquired from the United States Geological Survey/ Earth Resources Observation and Science (USGS/EROS) Center. The ENVISAT ASAR or RADARSAT images will be acquired from the Canadian Space Agency.

The *IWMI Flood Mapping and Analysis* (IFMAN) tool will be used to map inundation on the MODIS imagery. This tool calculates various spectral indices derived from 7 spectral bands to generate a number of indices. These indices can then be used to generate pixel level water-sensitive parameters, including flood, non-flood and water-related pixels. This approach provides a series of flood inundation maps from 2000 to 2013 for mapping flood risks areas and enables detection of areas that can be potentially used for flood recession agriculture.

Step 2: Development of flood forecasting tools using hydrological and hydraulic modeling systems

Flood forecasting involves rainfall-runoff modeling which requires various data inputs including; land cover, soil, geology and elevation data, climatic characteristics (daily rainfall, minimum/maximum temperatures, wind speed, relative humidity, sunshine hours), and stream flow data at key gauging stations and information on hydraulic structures upstream of, and within, the floodplain. The presence of hydraulic structures (such as dams, reservoirs, canals, weirs, etc.) will affect the rainfall-runoff relationship and the potential flood generated.

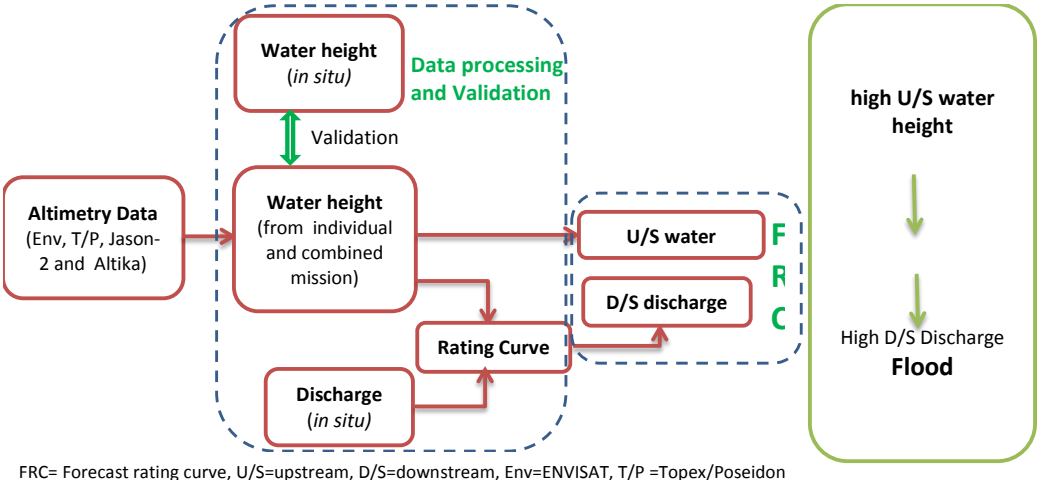
Water released from reservoirs both within Nigeria and in upstream countries (such as Cameroon) will have an impact on the flood magnitude and wave propagation. All of these aspects will be assessed as part of the development of flood forecasting tools within this project.

Observed rainfall datasets and satellite rainfall estimate products from NASA's Tropical Rainfall Measuring Mission (TRMM), Climate Prediction Centre MORPHing technique (CMORPH) or National Oceanic and Atmospheric Administration Rainfall Estimate (NOAA RFE) will be used in the development of the project's flood forecasting tools and systems. This methodology involves computing the flood hydrograph of the river basin, at the mouth of the river, and can be broadly divided into five stages; computing runoff volume (excess rainfall), modelling direct runoff, flood routing, calibration of the model, and model validation.

Step 3: Radar Altimetry: flood forecasting rating curves, comparing upstream to downstream in the Niger-Benue River basin

A forecast rating curve (FRC) indicates the ratio of measured upstream water levels in comparison to estimated downstream discharge. This enables downstream water level forecasts by assessing upstream water levels. Forecast rating curves can be used to provide timely early warning of downstream flood events and their probable severity. This early warning can be used to ensure that appropriate, timely steps are taken at the local, regional and national levels to safeguard lives, property and livelihoods.

Satellite remote sensing offers an indirect way to measure upstream flows and water levels. Correlating these indirect measurements with known forecast rating curves allows considerably more accurate prediction of downstream flows. This project will use several altimeter-derived satellites, including the JASON-2 (Ocean Surface Topography Mission) and the ARgos and ALtiKa Satellite (SARAL/AltiKa) to calculate water level heights in the Niger-Benue River, and so develop a forecasting system. This requires that rating curves be derived at various river locations in upstream Nigeria and Cameroon, which match the JASON-2 altimeter ground tracks (also known as "virtual stations"). Once the known rating curve and the altimeter-based forecasting have been correlated (or validated) the altimeter-based forecasting system (only) may be used to accurately predict downstream flood events.



FRC= Forecast rating curve, U/S=upstream, D/S=downstream, Env=ENVISAT, T/P =Topex/Poseidon

Methodology for forecasting flooding using Radar Altimetry and forecast rating curves

Innovation using ICT

As a further innovative initiative the research team is also exploring the use of ICT to provide a flood early warning system and safeguard lives and property in Nigeria by looking into developing a smart phone app that would provide real-time flood warning information to farmers and other decision makers. The app would use satellite imagery, combined with other data. It would enable decisions to be implemented more quickly, saving lives and property. It would also help to ensure that farmers have the information they need, to better plan and prepare for flooding at their fingertips.

Key outputs from these project activities:

- Provision of near real-time flood inundation maps during the rainy season, using multi-resolution satellite data at basin and state scales
- Development of flood forecasting tools along the Niger and Benue rivers providing information on flood heights, the extent of flooding and potential impacts
- Development of an altimeter-based river flood forecasting system within Nigeria (including transboundary flows) and shared via a Smart Phone app
- Flood vulnerability maps, at the national and basin scales
- Identification of flood capture and storage options and related AWM solutions for flood recession agriculture
- Creation of soil moisture maps and spatial and non-spatial databases of Nigeria's land and water resources to support the flood mapping activities as well as the identification and targeting of appropriate AWM solutions
- Identification of areas suitable for flood recession farming that can contribute to increased output and incomes
- Building capacity of national partners in developing and using these flood maps, and other risk assessment and forecasting tools
- A series of maps and digitized statistical data on the impacts of flooding on communities, agricultural production, infrastructure, etc.

Project stakeholders

The project will be implemented to complement on-going initiatives and in collaboration with many national and international organizations, including:

Project partners

About IWMI

The International Water Management Institute (IWMI) is a non-profit, scientific research organization focusing on the sustainable use of water and land resources in developing countries. It is headquartered in Colombo, Sri Lanka, with regional offices across Asia and Africa. IWMI is a member of CGIAR, a global research partnership for a food secure future.

Our role

IWMI works in partnership with governments, civil society and the private sector to develop scalable agricultural water management solutions that have a real impact on poverty reduction, food security and ecosystem health. IWMI is a:

- think tank driving innovative research and ideas for solutions;
- provider of science-based products and tools; and
- facilitator of learning, strengthening capacity and achieving uptake of research findings.

We work directly with a broad spectrum of people and organizations, from rural farmers to national and Pan-African policymakers. This is because we recognize that, in order to really make a difference, our efforts are most effective when we partner with others. Careful consideration of how the outputs of IWMI's research activities can be easily communicated, understood, taken up and acted on forms a core component of our work. Our approach to impact puts people – research users and the ultimate beneficiaries – at the heart of research-for-development efforts.

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